TECHNOLOGICAL AND NUTRITIONAL EVALUATION OF *SEL-ROTI*

Dissertation Submitted to the Central Department of Food Technology, Institute of Science and Technology, Tribhuvan University, Nepal for the Award of Doctor of Philosophy (PhD) Degree in Food Technology.

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Recommendation

This is to certify that **Mr. Surendra Bahadur Katawal** has completed dissertation entitled **Technological and Nutritional Evaluation of *Sel-roti*** for the award of Doctor of Philosophy in Food Technology under my supervision. To my knowledge this work has not been submitted for any other degree.

Date: 16th April.2012.

…………………….

Prof. Dr. Dilip Subba
Supervisor

Declaration

I hereby declare that the work presented in this dissertation has been done by myself and has not been submitted for the award of any degree. All the sources of information have been acknowledged by reference to the authors or institution.

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Abstract

Sel-roti is a popular and delicious rice-based, sweet, puffed, spongy, deep-fat fried, ring-shaped doughnut like Nepalese indigenous food product prepared from the batter of rice flour, ghee and sugar. *Sel-roti* making technology is an indigenous technology of Nepal. A survey study of 126 respondents comprising different casts, ethnicity, religion, age, sex from different district of Eastern and Central Development Regions of Nepal was conducted to gather the information on ingredients, recipe, equipments and processing methods of *Sel-roti* by using questionnaires. The factors affecting quality, storage and shelf life and also production, marketing, socioeconomic and cultural aspects were gathered and documented. It showed that the variety and age of rice, type of ingredients, method of preparation, and storage condition influence the quality and self-life of *Sel-roti*.

To study the effect of particle size of rice flour on the physical properties, sensory quality and textural attributes of *Sel-roti*, the soaked rice was ground into flour with the help of iron mortar and pestle, analyzed for particle size distribution by using standard sieves and separated into three particle size categories i.e. coarse (>890 μm), medium (450-225 μm) and fine (<120 μm). They were mixed in different proportions; analyzed their distribution and calculated mean particle diameter; prepared *Sel-roti*, and analyzed for bulk density & fat uptake; and sensory and texture attributes were evaluated by trained panelists. The experiments were conducted in triplicate. The results obtained showed good positive correlation between mean particle size and the bulk density ($r = 0.97$, $p \leq 0.05$) and a good negative correlation between mean particle size and fat-uptake ($r = -0.90$, $p \leq 0.05$). Also, good correlations of mean particle size with sensory texture attributes like smoothness ($r = -0.97$, $p \leq 0.05$), hardness ($r = 0.99$, $p \leq 0.05$), fracturability ($r = 0.96$, $p \leq 0.05$), cohesiveness ($r = -0.92$, $p \leq 0.05$), Stickiness ($r = -0.76$, $p \leq 0.05$) and oily mouth feel ($r = -0.85$, $p \leq 0.05$), but fair relation with chewiness ($r = 0.65$, $p > 0.05$) were found. The ANOVA and LSD of panel scores for each sensory attribute like appearance, taste, texture, flavor and overall acceptance showed significantly difference ($p \leq 0.05$) among treatments. From the same experiment the optimum particle size of flour i.e., 520±6μm was selected for good *Sel-roti* preparation.

Processing parameters like soaking of rice, kneading of ingredients, ageing of batter, consistency of batter, frying temperature and time had significant effect ($p \leq 0.05$) on some physical properties and sensory quality of *Sel-roti*. From the same study the optimum processing parameters investigated were 2h(minimum) soaking time of rice; 10mim kneading time of ingredients for 250 g flour; 1.935DS/L corresponding velocity flow rate, 2.302cm/s or 25 ml water per 100g fresh flour; minimum 1h ageing time of batter; and 210°C(initial) frying temperature and 33S frying time.

The frying medium had also effect on the quality of *Sel-roti*. Among the used ghee and oils refined soybean oil was selected. The result of the study of the effect of age of rice and '*daun* ' on the quality of *Sel-roti* revealed that *daun* is must for good *Sel-roti* preparation whereas age of rice had not significant effect($p > 0.05$).

There were significant effect ($p \leq 0.05$) of ageing temperature and ageing time of batter on the biochemical parameters such as pH, acidity, reducing sugar and total sugar.

On the comparision Sel-*roti* prepared from optimized process and recipe were found to be superior to *Sel-roti* prepared from traditional process.

The physical properties of Sel-roti determined were 542kg/m^3, 10.78±0.55cm, and 1.93±0.16cm for bulk density, ring diameter and cross section diameter of *Sel-roti* respectively. The sensory properties of *Sel-roti* were ringed shape, light to reddish brown colour and grainy surface, moderate sweet taste, soft and little crunchy texture and sweetish and burnt sugar flavor characteristics to *Sel-roti*; and the proximate composition of *Sel-roti* were found to be as 4.68±0.10, 26.46±1.35, 0.30±.01, 0.16±0.02 and 68.41±1.44 on dry weight basis for crude protein, crude fat, ash, crude fibre and carbohydrate respectively and calorific value of *Sel-roti* was found to be 533kcal on dry weight basis.

The texture attributes of *Sel-roti* were found to be 8.20±1.6, 6.01±1.4, 8.53±1.6, 7.33±1.5, 5.70±1.5, 9.47±1.6 and 15.00±3.0 for smoothness , hardness, fracturability, cohesiveness , stickiness, oily mouth feel and chewiness respectively.

Key words: *Sel-roti*, indigenous, texture, sensory, quality

Abbreviations

AAS	=	Atomoc Absorption Spectrometer
ANOVA	=	Analysis of Variance
AOAC	=	Association of official Analytical Chemists
AV	=	Acid Value
CLA	=	Conjugated linoleic fatty acid
DFTQC	=	Department of Food Technology and Quality Control
DG	=	Diglyceride
FFA	=	Free fatty acid
HDL	=	High density lipoprotein
HPLC	=	High Performance Liquid Chromatography
LDL	=	Low density lipoprotein
LSD	=	Least Square Difference
MG	=	Monoglyceride
PC	=	Polar compound
RDS	=	Rapidly digestible starch
RI	=	Refractive Index
RM	=	Reichert Messel
RS	=	Resistance starch
SDS	=	Slowly digestible starch
SV	=	Saponification value
TG	=	Triglyceride

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1. Introduction

1.1 General introduction

Nepal is a country of different culture, religions and races. The country is divided into three different geographic regions e.g., Mountain, Hill and Tarai. The different castes are *Brahmin, Chhetria, Newar, Limbu, Rai, Gurung, Sherpa, Damai, Kami, Sharki* etc. who are the habitat of mountain and hilly region. The different ethnic groups such as *Dhimal, Tharu, Satar, Rajbansi* etc are the Adhibasi (Tribes) of Tarai. Now many people have been migrating from Mountain and Hill to Tarai and so almost all races are found in Tarai. The different races and ethnic groups have their own culture. They have their own food habits oriented from their ancestors since immemorial time. They have their own food selection and preparation. There are many traditional food products found in different parts of the country. Some of them are cultural and ethnic group specific; some are common to all. They have their own traditional method of food preparation and preservation. The traditional methods have been transferring from generation to generation. Many of these are not documented completely and properly.

Traditional foods with some exception are indigenous to Nepal. They are called indigenous foods of Nepal. Some of them are nutritious; some are used as appetizer; some have medicinal value, etc. Some foods are used as snack. Some food stands for special occasion such as *Sel-roti* for *Tihar* and *Furoula* for *Maghe Sakranti* and is equally popular in *Holi* and *Siruwa* among *Tharu* culture. Some foods are necessary to the specific ritual processes or feasts.

The indigenous foods of Nepal based on main raw materials are as follows:

a. Vegetable based: Gundruk, Sinki, Mesu (Tama). Khalpi, Pickles(Gajurel and Baidya,.1979), Dried vegetables products
b. Milk based: *Dahi, Mohi* ,*Chhurpi*(Gajurel, and Baidya,.1979)*, Kurauni*
c. Legume based: Kinema, Furaoula,
d. Cereal based: *Jand, Raksi, Chhyang* (Gajurel. and Baidya,.1979), *Cheura* (beaten rice) *Mura*i(puffed rice), *Sel-roti, Bhakka*,(Anon,2063B.S.) etc.
e. Fruit based : *Melko amilo, Bhakkimlo/ lemon amilo or chuk, Titoura,*
f. Meat based : *Sukuti , Chhoyala, Kachila(Shrestha,,et al.1999)*,
g. Fish based: *Sidra* (small dried fish)

h. Pulse and vegetable/ tuber based: *Maseura*(Gajurel and Baidya,.1979),

Some of above indigenous foods are location (region) specific eg, *chhurpi* in Mountain or Hilly areas; some are community specific eg , *chhoyala* and *kachila* in Newar; *kinema* in Limbu,Rai; *jand* and *raksi* in lower caste communities; *bhakka* in tarain tribes whereas some food products eg , *gundruk , sinki, Sel-roti,dahi etc.*are common to all geographic regions, all tribes and cultures These indigenous foods have been prepared by traditional methods specific to the products .These traditional technologies have been following generation to generation.

One of the most important indigenous products of Nepal is *Sel-roti*. *Sel-roti* is a circular ring shaped product prepared from rice flour making batter of proper consistency and frying in oil/ghee at high temperature (Brihat Shabdakosh 2040B.S.). The batter is prepared from rice flour , cream or ghee, sugar and water .The frying medium may be different cooking oils (e.g. , mustard oil, refined oils), ghee or may be lard or mutton tallow.

Sel-roti is popular in almost all geographic regions; in almost all tribes and communities of the country. It is popular and essential item in many festivals e.g. *Tihar* (Dipawali), *Maghe Sakranti* and ritual works e.g., *Pooja* (worship of god called *Satyanarayan*) as well. It is also a necessary food items in wedding ceremony and *Bratabandha*; and as *Kosheli (*Katawal, 2062B.S.). The importance of *Sel-roti* is also found to be mentioned in *Swasthani Brata Katha* (Anon, 2003), and Puran. It is very delicious and energy rich food item liked by many people of all ages. It is prepared and sold in local food shops, restaurant and open market as well.

Sel-roti is also very popular food item in Sikkim, Hills of Darjeeling of India, and in some parts of many other counties where Nepali or the people originated from them reside there. They prepare *Sel-roti* in many occasion and festivals, eat and enjoy their happiness with family, neighbors and friends (Yonzan and Tamang, 2010).

Quality is the degree of excellence. The quality is the composite of characteristics that have significance and make for acceptability. Food quality detectable by our senses can be divided into three main categories such as appearance factors (shape and size, wholeness, color), textural factors (hand feel, mouth feel of firmness, softness, grittiness stickiness and chewiness), and flavor factors (taste and odor: sweet, salty, sour, bitter, burnt etc.) (Potter, 1978).

According to Katawal and Subba (2008) *Sel-roti* should be ring shaped, puffed, reddish brown color, spongy and having grainy appearance; sweet and delicious in taste. Neither hard nor too soft, crisp or crumbly, somewhat fried flavor and oily or fatty mouth-feel are its other eating quality. By a survey study conducted information has been gathered as which the factors are influencing the quality of *Sel-roti* (Katawal and Subba, 2008). It was found that the particle size of rice flour influences the quality characteristics such as puffing, bulk density, fat-uptake, sensory attributes like appearance, taste, and texture of *Sel-roti* (Subba and Katawal, 2011).

1.2 Justification

There are not found written documents about *Sel-roti* except about traditional processing of *Sel-roti* in Sikkim, Darjeeling of India and some microbiological aspect of batter of *Sel-roti* written by Yonzan and Tamang(2010), and two articles –survey of *Sel-roti* in 2008 and effect of particle size on physical and sensory quality of *Sel-roti* in 2011 by Katawal and Subba in journals and some information about *Sel-roti* in net and some information about processing of *Sel-roti* by Kharel et al,(2010) in their published book – traditional food of Nepal.

The people of almost all households of Nepalese prepare *Sel-roti* but the products quality varies because the product quality depends on many factors which could be optimized. As mentioned earlier there are also variations in processing conditions, ingredients used and skills, this need to be studied.

It is interesting to note that there is no proper documentation of traditional technology of *Sel-roti*. Scientific information as regards the production, nutritive value, quality etc also is lacking. Proper documentation is important to authenticate its origin, preserve its culture and improve and standardize its technological parameters and eventually successfully commercialize the product.

Being *Sel-roti* a popular, delicious and essential food item in many occasion, festival and ritual process as well as worships its different aspects such as consumption, production, traditional method of preparation ingredient used and cultural aspect should also be studied and documented. There is a need to explore and familiarize *Sel-roti* about its quality and nutritional value to the people of country and abroad, so that the *Sel-roti* can be commercialized and can be export as indigenous food of Nepal. Therefore, this work was undertaken. In this study first of all a survey study of *Sel-roti* whose objective is to collect the information and related data that could be the basis for further evaluation and disseminate the information to the people was carried out and on the basis of the available information the further works were carried out.

2. Objective of the study

The Objectives of the research work about *Sel-roti* were as follow:

2.1. General objective

The general objective of the study was to evaluate the technological and nutritional aspect of the *Sel-roti*, so that the very important information about technological parameters, cultural and nutritional aspect were identified and documented.

2.2 Specific objectives

Specifically the objectives were to

a. gather the information about cultural, traditional processing, ingredients, factor influencing the quality, uses, consumption and marketing aspect of the *Sel-roti*,
b. optimize the recipe for good *Sel-roti* preparation, study the effect of particle size of rice flour on physical and sensory quality of *Sel- roti*, and determine the optimum mean particle size of flour from the same work,
c. Study the effect of processing parameters such as soaking time of rice, kneading time, ageing time, consistency of batter, frying temperature and time, and frying medium as well,
d. Study the effect of age of rice and *daun* on the quality of the *Sel-roti*,
e. Compare the Sel-roti prepared from traditional process and recipe and optimized process and recipe,
f. Study the biochemical changes of batter during ageing at different temperature and different time,
g. Determine the physicochemical and sensory characteristics as well as energy value of *Sel-roti*.

2.3 Importance of the study

This study helps disseminate the important information about *Sel-roti*. The optimized technological parameter and the sensory characteristics help prepare uniform products which is very useful to commercialize the products. The *Sel-roti* traders will take more advantage from these research findings.

The findings of this research will be the basis for further research about *Sel-roti*.

2.4 Limitations of the study

The study covered only Eastern Development Region, Kathmandu and Rupandehi for survey and experimental study was limited to only one variety of rice i.e., *Kanchchi mansuli*.

Though the following works were necessary could not be carried out due mainly to unavailability of required facilities;

Shelf life study

Amino acid profile

Fatty acid profile

3. Literature Review

3.1 *Sel-roti*

Sel-roti is a popular fermented rice-based ring shaped, spongy, pretzel like, deep fried food item commonly consumed in Sikkim, Dargeeling hills in India, Nepal and Bhutan. It is prepared during religious festivals and special occasions. *Sel-roti* is a Nepali word for ring shaped rice based bread (Yonzan and Tamang, 2009). *Sel-roti* is a unique fermented cereal food of the Nepali people in the Himalayas (Yonzan and Tamang, 2010). *Sel-roti* is a circular ring shaped deep-fat fried product prepared from the batter of rice flour, ghee, sugar and water (Nepali Brihat Shabdakosh 2040 B.S.). Sel-roti is a home-made circular-shaped bread prepared during *Tihar*, a widely celebrated Hindu festival in Nepal. It is something like a doughnut, but less fluffy. They're deep-fried rings of sweet bread made from rice. Nepali traditional bread is *Sel-roti* and is also called crispy rice donut, a traditional food of Nepal. *Sel-roti* is connected with *Tihar*, a great festival and because of this at this time the roti is called *Tihar ko Sel-roti* (Wikipedia, 2008). *Sel-roti* or Sel closely resembles Doughnuts. Instead of regular flour, Sel is made from rice flour. Sel is a very unique Nepali treat for everyone with sweet tooth (Anonymous, 2010).

Among the products (e.g.,*Yomari*, Chatamari*, Lochamahi, Mada, Dhakne roti/Dhukdhuke roti, Bhakka, Kasar, Babar*) prepared from rice flour *Sel-roti* is a very popular food product all over the country in Nepal as well as in places where Nepalese are living e.g, India, Bhutan and others. *Sel-roti* is specially prepared during *Tihar* and other festivals, pooja occasions and as gift to take bride home by married daughters (Anonymous, 2063 B.S.). It is doughnut like-shaped deep-fried rice confection indigenous to Nepal and is normally prepared in festive occasions and rituals like *Tihar, Pooja, Bratavanda and Kajkriya*, but now a days it is available almost all the time at hat-bazaars(local markets) and cities(Kharel et al, 2010).

Making *Sel-roti* is a traditional practice, especially during *Tihar*, and is also sometimes prepared and served during certain ceremonies. It is very popular with young and old alike and is also distributed to young people after playing the customary *deusi*, a song-and-dance routine where these youngsters wish prosperity on households as they tour around the neighborhood (Shakya, 2010).

3.1.1 Nomenclature of *Sel-roti*

Sel-roti is pretzel like bread. The name *Sel-roti* is given to the ring shaped deep fried rice bread from the word saela which means any thing lifted with suiro because *Sel-roti* is lifted by suiro turning during frying and taking out from hot oil after complete frying. There are other hypothesis on the nomenclature of *Sel-roti* that the *Sel-roti* is prepared from a variety of rice called *seli* which is cultivated in foot hills of Nepal and probably the roti prepared from that rice is called *Sel-roti*. Some people believe that the word *Sel-roti* is originated from the word 'Saal' whose meaning confectionary bread prepared during festivcal i.e., *Tihar*, once a year (Yonzan and Tamang, 2009 and Yonzan and Tamang, 2010). Different ethnic groups call it by various names: selsoplay by the Mukhia, selgaeng by the Tamang, selpempak by the Rai, etc. (Tamang, 2010).

Yonzan and Tamang (2009) reported in traditional knowledge of processing of *Sel-roti* – a rice base fermented food that the Ethnic fermented food is distinct food culture of the Nepalis living in the Himalyan regions of India, Nepal and Bhutan. Traditional processing and product characterization of *Sel-roti* has not been documented. They conducted a survey in village households located in Sikkim, representing the major ethnic Nepali and other tribes Butia and Lepcha on the traditional processing of *Sel-roti* and collected the information about traditional processing, consumption and documented. The relevant information about *Sel-roti* from their report included here.

3.1.2 Origin of *Sel-roti*:

The antiquity of *Sel-roti* remains a myth; no historical documents were available (Yonzan and Tamang, 2009). The *Sel-roti* is mentioned in Swosthani Bratakatha ((Anonymous, 2003) and *Puran*. In older days, *Sel-roti* prepared did not include the use of spices or condiments but now-a-days, because of the developments of diversified taste, people prefer to add spices during preparation (Yonzan and Tamang, 2009 and Yonzan and Tamang, 2010).

Sel-roti has ethnic importance. Since the time immomerial *Sel-roti* is known as a ceremonial food in Sikkim, Darleeling hills, North East hills, Nepal and Bhutan. It marks a special occasion of the Nepalis such as marriage, religious and cultural festivals. It is served during marriage ceremony of various castes of Nepali/Gorkha along with other traditional food items. Traditionally, newly married Nepali/Gorkha bride visits her parents once a year. When she returns back to her husband's house she should carry a *thumsay* (local name for bamboo basket) containing freshely fried *Sel-roti*. This tradition is known as *Pani Roti* in Nepali. *Sel-r*oti is also served during the occasions like *Tihar, Bara Dasain, Chaite Dasain, Maghe Sakranti* etc.Carrying fried *Sel-roti* is a traditional practice among Nepalis/Gorkha while traveling for long distance (Yonzan and Tamang, 2009 and Yonzan and Tamang, 2010).

3.1.3 Recipe of *Sel-roti*

Sel-roti is made of rice flour with adding customized flavors. A semi liquid rice flour dough is usually prepared by adding milk, water, sugar, butter, cardamom, clove and other flavors of personal choice. The ingredients are mixed well by stirring. Once the semi liquid dough is ready, it is poured by hand on home-made shortening or oil in circular shape and cooked on low heat until it turns light brown on both sides. Plain rice flour, sugar, ghee, and oil are the main ingredients (Wekipedia). There is litle variation on recipe of *Sel-roti*. One recipe consisted 1kg rice, 250g wheat flour, 500 ml milk and 200g of sugar and 100g ghee and fried in edible oil (Recipe-*Selroti*, 2008 and Sikkiminfo, 2008).

Two cups long grain rice,1 ripe banana,1½ cup sugar,2 tablespoon butter, pinch of baking powder and oil for deep frying (Anonymous, 2010).

According to Regmi (2009) *Sel-roti* is a donut-like preparation made from ground rice and nuts. This is mainly served in Gorkhali festivals. He has given the ingredients as: 3 cups basmati rice, soaked for a few hours, 3 cups soft butter, 1 cup sugar, 1 teaspoon vanilla extract, 1 tablespoon ground cardamom, 1/4 cup almond nuts, 1/4 cup cashew nuts, 2 tablespoons grated coconut, 3 cups chilled whole milk, 1 teaspoon salt, 1 liter cooking oil, and powdered sugar, for dusting. He has given direction for the preparation of *Sel-roti*. The major steps of method resembles with the methods given in processing section.

The main ingredients used for *Sel-roti* preparation are rice flour, sugar, ghee and refined oil. The process of manufacture and the ingredients used depend on the availability of raw materials and difer from place to place and household to household. In some places some people use ripe banana, *dahi* and cream as an improver. The flour should be neither too fine nor too coarse. The rice flour can be made by grinding in machine but such flour produces inferior quality *Sel-roti* because excessive damage of the starch granules (Kharel et al, 2010).

3.1.4 Traditional processing of *Sel-roti*:

According to Yonzan and Tamang (2009) for *Sel-roti* preparation, local variety of rice (Oryza sativa, L) *attey* is sorted, washed and soaked in cold water for overnight or 4 to 8h at ambient temperature, water is then drained with the help of bamboo made sieve called *chalni* and spread over a woven tray made up of bamboo locally called *nanglo* and dried for one hour. The soaked rice is pounded into coarse powder in a wooded mortar and pestle known as *okhali* and *mushli*, respectively. Larger particle of pounded rice flour are separated from the rest by winnowing using bamboo tray i.e., *nanglo*. Then rice flour is mixed with nearly 25% refined wheat flour, 25% sugar, and 10% butter or fresh cream and 2.5% of spices/condiments containing large cardamom (*Amomum subulatum* Roxb.), cloves (*Syzygium granatium* Marr.), coconut (*Cocos nucifesh* L.), fenel (*Foeniculum vulgare* Mill.), nutmeg (*Myristica fragrans* Houtt), cinnamon (*Cinnamonum zeycaricum* Bl.), and small cardamom (*Elletaria cardamomum* Maton) and mixed thoroughly. Some prople add table spoon full of honey or unripe banana or baking powder (Sod.bicarbonate) to the mixture, depending on quantity of the mixture. Milk (boiled/unboiled) or water is added, kneaded into soft dough and into batter with easy flow. Batter is left to ferment naturally at ambient temperature (20 – 28°C) for 1 to 4h during summer and 10 – 18°C for 6 – 8 h during winter. The fermented batter is squeezed by hand or *daaru* (metallic serving spoon) deposited as contionuous ring onto hot edible oil and fried until golden brown and is drained out from hot oil by poker locally called *jhreer* or *suiro* or by spatula locally called *jharna*. Deep fried *Sel-roti* is served as confectionary. Some flow charts for *Sel-roti* preparation traditionally are shown in fig 3.1, 3.2, 3.3 & 3.4.

Rice
↓
Washed with cold water
↓
Soake in cold water for one hour
↓
Drained water
↓
Pounded in Okhli and Mushli to coarse powder
↓

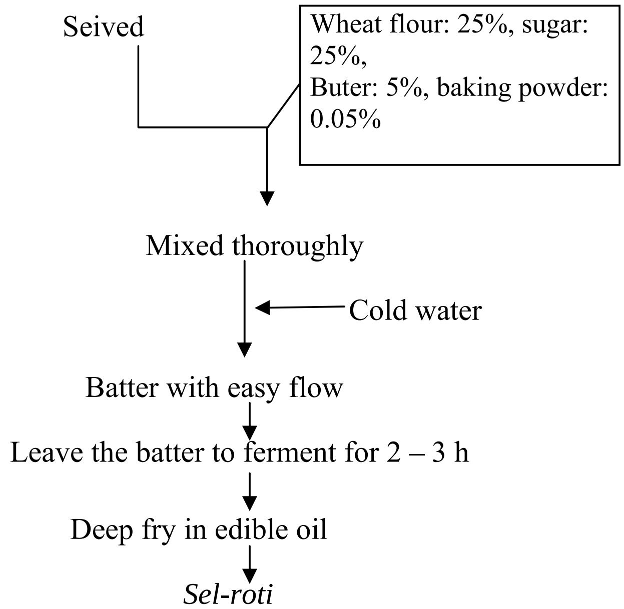


Fig.3.1. *Sel-roti* Preparation in South Sikkim and Nepal (Yonzan and Tamang, 2009)

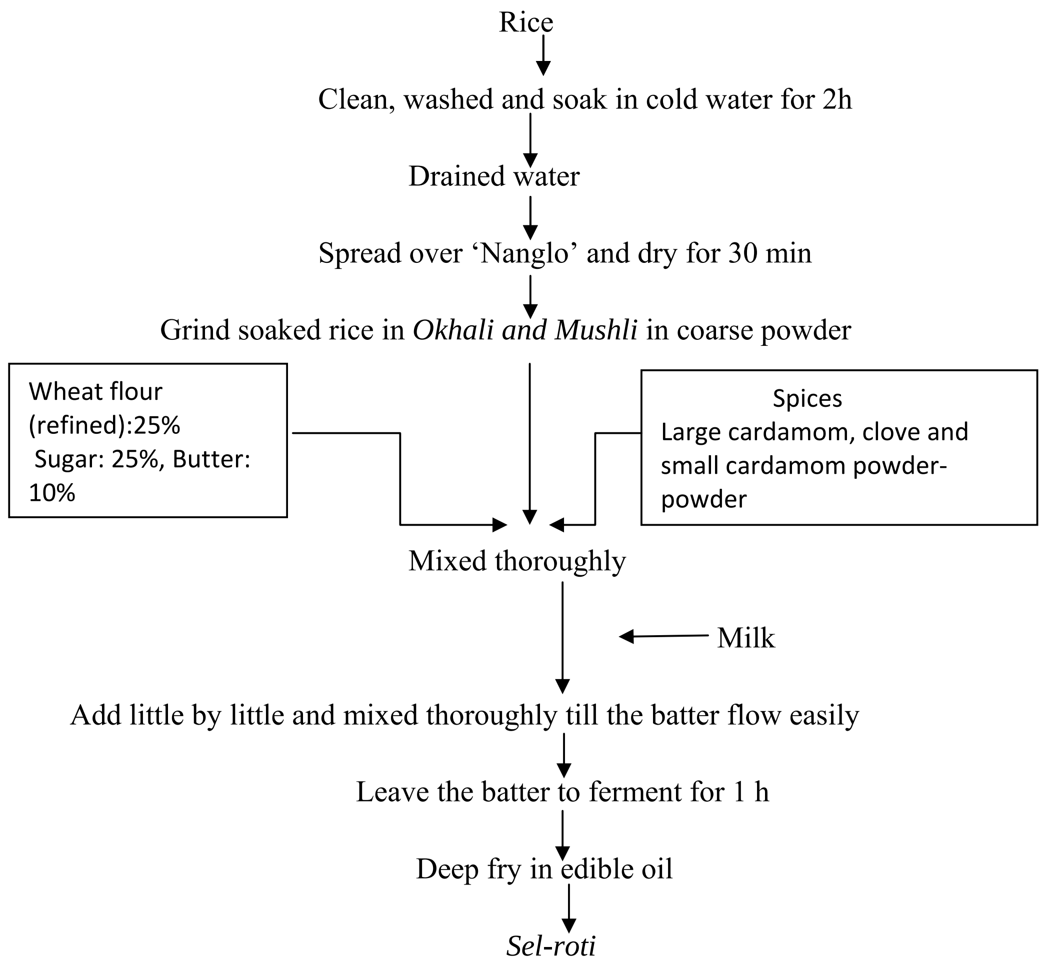


Fig.3.2. *Sel-roti* preparation in East Sikkim (Yonzan and Tamang, 2009)

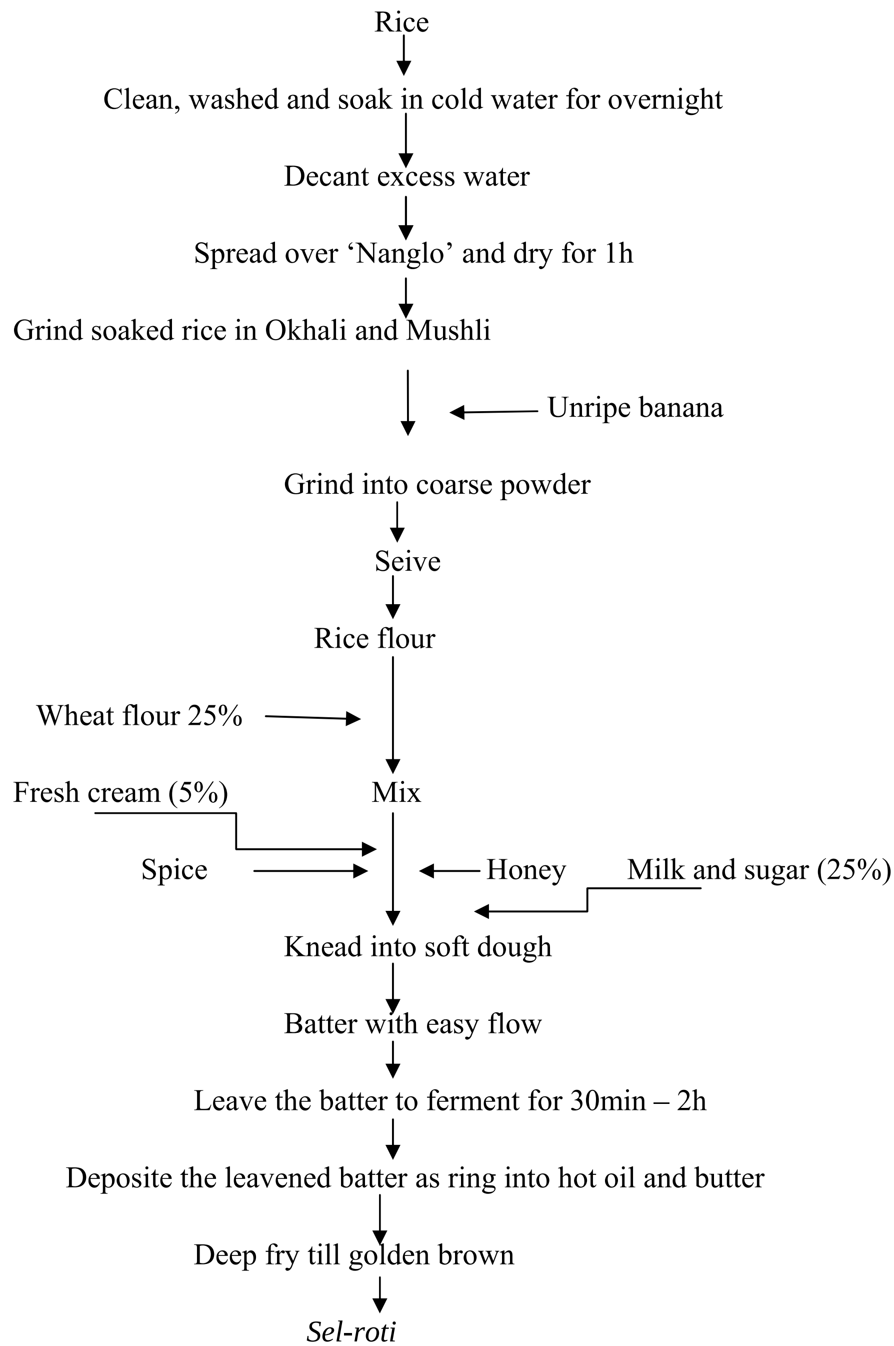
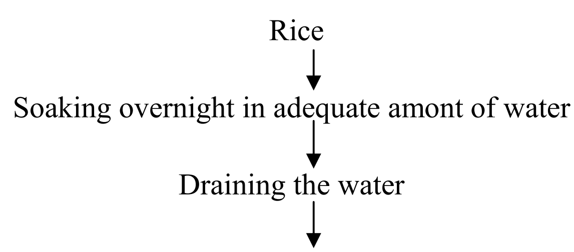


Fig.3.3. *Sel-roti* preparation in Darjeeling hills (Yonzan and Tamang, 2009)



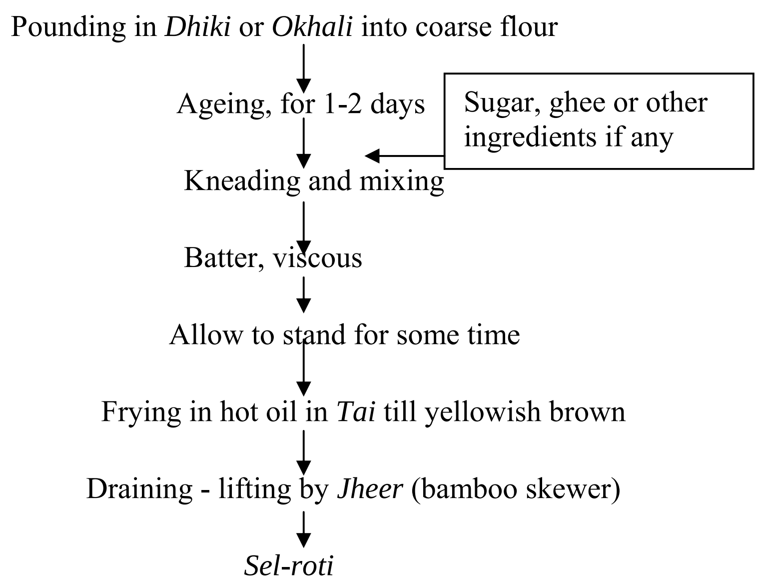


Fig.3.4. Improved method of *Sel-roti* preparation (Kharel et al, 2010).

The steps in the preparation of *Sel-roti* (Anonymous, 2008, and Anonymous, 2010) are given as follows:

1. First, the rice is soaked in normal tap water for around 2h or preferably overnight. This makes it really easy to blend and at the same time, makes the bread soft.

2. Once the rice has been soaked, drained the water,

3. Then, the soaked rice is blended little by little in blender. The batter with optimum consistency is prepared.

4. Suitable amount of ghee and sugar are added in plain rice flour.

5. Once everything is added, then all are mixed by adding water until the mixture when poured makes a good circle.

6. Then it is left for another hour. This allows the mixture to settle down when you cook it later, it'll become better. Or if the rice is soaked for longer than 2 hours, may be 3 or 4, or overnight then cooking can be start immediately.

7. Deep frying pan is set on the stove and poured in oil, may be to half of the pan and let the oil heat on medium heat or a little more as that helps the bread to 'fill' out nicely.

8. Once the oil has heated, the mixture is poured onto hot oil making circle by using funnel.

9. After cooking some time it is turned upside down by using stick and cooked until it turns brown. The *Sel-roti* is lifted up with stick, drained oil and took out and put onto container.

10. Serve hot or cold.

Sel-roti is prepared from rice flour, sugar, ghee and oil. The method of preparation is as follows: The cleaned rice is soaked overnight, drained, dried on *Nanglo* by air, and pounded with *dhiki* or *janto*. The required amount of sugar and ghee are mixed with flour and kneaded well with hand and made batter of optimum consistency with water and allowed to stand for about 4h in sumer/hot place and about 24h in winter/cold places and then the batter is deposited onto hot oil in ring shaped with hand or other means fried till reddish brown color on both sides in intermittent turning and drained oil and take out. Thus, prepared sel-roti can be consumed for 4 to 5 days (Anonymous, 2063 B.S.).

3.1.5 Equipments used for *Sel-roti* preparation

As reported by Yonzan and Tamang (2009) on the basis of their syrvey the following equipments are used for *Sel-roti* preparation:

Okhali and Mushli: a pair of wooded mortar and pestle respectively used to pound soaked rice.

Nanglo: bamboo tripes woven tray used to dry soaked rice.

Chalni: a sieve either made up of metal wire or bamboo stripes, used to sieve pounded rice flour.

Suiro: pointed bamboo stick used to turn up *Sel-roti* upside down, lift and drain oil and to take out the fried *Sel-roti*.

Daaru: a metallic serving spoon used to pour batter onto the hot edible oil.

Tawa: a cast iron frying pan used to fry *Sel-roti*.

Jharna: a metal spatula and wide flat blade with holes.

Thumse: a bamboo made basket use to store freshly fried *Sel-roti*.

3.1.6 Preparation and consumption of *Sel-roti*

Sel-roti was mostly prepared at home (76.5%), and market purchased amount to 14%. Among the ethnic group, 89% of Nepali prepared *Sel-roti* followed by Lepcha 6.6% and Bhotia 4.4%. The per capita consumption of sel-roti in Sikkim was calculated as 8g/cap/day. The average annual production of *Sel-roti* per household in Sikkim was 18.5kg. The *Sel-roti* was served as confectionary bread with *aalu dam* (boiled potato curry), *simi ko achar* (pickle prepared from string bean) and meat. It can be consumed hot or cold. It can be stored at room temperature for 2 weeks (Yonzan and Tamang, 2009). Widely prepared during Nepali festivals, Saelroti is normally eaten with potato curry or non-vegetarian dish. Normally not available in restaurants but *Saelroti* is prepared from well-mixed fermented rice batter which is deep fried, ring-shaped, spongy, pretzel-like product commonly consumed as confectionery bread in festival and special occasions. *Sel-roti* is served as staple confectionery bread with *simi ko achar* and mutton curry. The batter is fermented by spp. of yeasts and lactic acid bacteria (Tamang and Tamang, 2007).

3.1.7 Socio-economy

The preparation of *Sel-roti* is an art of Technology and is a family secret passed from mother to daughter. Women prepare it and men help them in pounding the soaked rice. *Sel-roti* is mostly prepared at home; also in canteen, local food stalls and resteurants. In local food stalls in Sikkim and Dargeeling hills, it is sold at average rate of Rs.10/- per plate containing 4 pieces (Yonzan and Tamang, 2009).

3.2 Principles of Good doughnut and similar product production

According to Lawson, (1997) some of the important factors in making good doughnut or similar product are (i). Good prepared mixes, (ii). Correct water level, (iii). Proper dough handling and mixing, (iv). Proper make up before frying, (v). Proper frying, (vi). Proper care of shortening, and (vii).Proper finishing. The discussion on the factors is given as:

(i).Good mixes: Good product depends on the correct proportion of required ingredients, correct amount of water, proper mixing time, proper dough or batter temperaure.

(ii).Correct water level: The proper quantity of water is of utmost importance in obtaining proper batter consistency. If the too much water is used the products have (a) a distorted appearance, (b) excessive absorption, (c) poor expansion, (d) improper ‘break”, (e) large hole i.e., hollow inside.

If less water is used, the products have (a) a rough broken surface on one side, (b) excessive absorption (in cracks, etc), (c) thick crust, (d) cracks developing during frying, (e) poor expansion, (f) improper “break”.

(iii).Proper dough handling and mixing: Mixing time varies depending on such factors as the following:

The richnes of the dough: lean mixes require less miximg time,

The type of flour: large particle size flour require longer mixing time,

The temperature of dough: cold dough requires more mixing than warm one. The room temperature is optimum.

Undermixed dough will produce the products with excessive absorption, coarse texture and irregular shape, whereas overmixed dough will produce the products with large hole, tight grain and texture, excessive absorption (due to cracking of dough during frying), and a knobby, irregular surface.

(iv) Proper make-up before frying: After the correct water addition and the correct mixing the dough is often given a certain rest period (e.g., 10 or 15 mins for doughnut) before frying. For doughnut a short rest period promotes the best tolerance for the desired expansion and optimum grain and texture. The rest period vary with the products.

(v) Proper frying: The proper frying time vary with the products e.g., cake doughnut (about 45s on each side at 193 – 199°C). Frying at lower temperature does not seal the surface rapidly enough, and excessive absorption results. The product takes longer time to cook or fry or the products remain in oil longer. The rich doughnuts are more susceptible to excessive absorption at low temperature than are lean doughnuts. The above or high temperature prevents proper expansion and may produce soggy interiors and also burnt the surface give dark color. During frying the product simultaneously dried up and absorbs fat.

(vi) Proper care of shorteining: The filtration should be done minimum once per shift. Because the particles accumulating in fryer can rerult in excessive visual smoking of frying fat and also promote excessive color darkening, excessive oxidation and the development of free fatty acids. The fat cannot be thrown away, it is preferred that the frying fat be kept in as good condition as possible to maximize both frying life and doughnut/ products quality.

Principal desired characteristics of doughnut- frying shortening should be of

(a). Long shelf life,

(b). Proper solids content at temperatures of 50 – 105°F (10-41°C): for excellent sugar adherence and glaze adherence for both packaged and unpackaged doughnuts.

(c). Bland flavor: From 20 to 25% of the finished product weight is the absorbed fat. The absorbed fat bcomes an important part of the product; it must be bland in flavor.

(vii) Proper finishing: The extra finishing depends on the product. Some products need extra finishing i.e., sugaring or glazing, flavoring etc. and some do not. If the products need proper finishing should be done properly.

3.3 Ingredients for *Sel-roti*

The description of the major ingredients of *Sel-roti* is given as follows:

3.3.1 Rice

Rice (*Oryza sativa L.*) is the second largest crop in the world, and feeds nearly ½ of the entire population (WHO, 2009; Chen and Zeng, 2007). Rice is also one of the leading food crops of the world and is a staple food of over approximately one-half of the world population (Singh et al. 2005).

Rice is the main crop of Nepal as well as of the world. The main diet of the Nepalese is also rice. Fifty-five percent of the cultivated land of Nepal is covered with rice. Rice is also cultivated in the diverse eco-climatic ranges of Nepal at differing altitudes, topography and climate. More than half of the human population depends on rice for food. Ninety percents of the rice grown in the world is produced and consumed in Asia. The importance of rice will increase as the population in rice growing areas increases compared to other crop growing countries (Mallick, 1981). Rice is as important to the cultures of South Asia as is it in China and other parts of Southeast Asia (Anonymous, 2009).

3.3.1.1 History of rice:

Rice is cultivated since before the *Vedic* time in Nepal. The description of rice is found in the Veda written 1500 B. C. and in other Nepalese literature. Even in the ancient literature of 2800B.C. rice cultivation were mentioned. Even during those days, they were aware of the importance of maturity days, temperature, water management, eating quality and nutritive value. According to the *Rig Veda*, rice has been divided into five divisions (Mallick, 1981), such as (i) *Sali dhanya*, (ii) *Vrihi dhanya*, (iii) *Suk dhanya*, (iv) *Shimi dhanya*, and (v) *Chudra dhanya*(Mallick, 1981).

Alexander the great and Medagaskar contributed in spreading rice to Europe and the U.S.A. (Mallick, 1981).

Descended from wild grasses, rice is a staple food in South Asia. Historians believe that it was first domesticated in the area covering the foot-hills of the Eastern Himalayas (North-Eastern India), and stretching through Burma, Thailand, Laos, Vietnam and Southern China. Remains of early cultivated rice have been found in the Yangtze valley dating to about 8500 BC. From this region, it spreaded in all directions and human selection created numerous varieties. Different rices cross-breed easily and there are now thousands of varieties including wild rice. The earliest remains of cultivated rice in the sub-continent have been found in the north and west and date from around 2000 BC. Perennial wild rice still grows in Assam and Nepal. It seems to have appeared around 1400 BC in southern India after its domestication in the northern plains. It then spread to all the fertile alluvial plains watered by rivers. Rice is first mentioned in the Yajur Veda (c. 1500-8000 BC) and then is frequently referred to in Sanskrit texts, which distinguished summer varieties from rainy season and winter varieties. Shali or winter varieties were most highly regarded. About 2000 years ago, rice was well-established as the main cereal of the sub-continent, with barley second and wheat a barely mentioned winter food (Mallick, 1981).

Greek visitors noted the popularity of rice amongst Indians. The Greek emissary Megasthenes, visiting Pataliputra (modern Patna) in 315 BC, wrote that they ate it ceremonially, boiled, placed in a bowl and then various other dishes added to it. Hundreds of years later, the Portuguese in the 15th century observed cooked rice being eaten in much the same way. The 17th century traveller Francois Bernier described fields of rice in Kashmir and Bengal, irrigated by endless channels. The Muslim rulers of India created famous rice and meat dishes such as pilafs and biriyanis. The number of dishes made with rice was by this time legion (Plant culture-Rice history.htm net available on 18th Jan. 2009).

3.3.1.2 Origin of Rice

There are different views about the origin of rice by different scientists. As early as 1930 Vavilov pointed out that the origin of the present rice is in the South- East Himalayan region. Vabilov(1930) and Ramiah (1935) also have the same views that any particular plant which has origin in certain area has so many different types, variety, different quality of plants are found there. Therefore, according to them the origin place of rice is in the South –East Asia, India, China and Indochina where different types of rice are found. Copeland (1924) adds linguistic evidence to prove that rice originated in South-East Asia. He points out that in Chinese and many languages in South-East Asia, agriculture and rice or food and rice are synonymous, indicating that rice was first cultivated in this part of world (Grist, 1986). If we consider their views the Himalayan range is also in Nepal. Different types of rice varieties are found throughout the Tarai plain to the top Hills of Nepal (Mallick, 1981). According to the study conducted by Morinaga et al.1967 on the rice of Himalayas mountain's foot region and the views of origin of rice described by Yoshida (1978), they found Japonica and the cross varieties of Japonica and Indica were found in Nepal, Bhutan, Burma, Laos, Vietnam and Yamuna Province of China. Kihara (1953) found Japonica rice in high hills, Javonica rice in mid hills and Indica rice in Tarai plain of Nepal. So these rices might have spread to Japan, Java and other places. *Oryza perennis* is still found as wild rice in Nepal. Rice samples of 5000 years ago are found at Simraungarh of Bara district of Nepal, this rice is of the time of king Shiv Singh.These also give evidences that one of the origin places of rice is also Nepal (Mallick, 1981).

Rice is one of the oldest and most important food crops. Rice probably originated in South-East Asia, where it has been grown for many centuries. The earliest record of rice production in China dates back to about 2800 BC (Ghose et al, 1956) and in India to 1,000 BC. Later, rice culture spread westward to the Middle East, Africa, and Europe. It was cultivated in the Euphrates valley in 400 BC, was mentioned by the Greek poet Sophocles in his Tragedies in 495 BC, and was brought to Southern Europe in Medieval times by the Saracens. It has long been an important food crop in Spain, Italy, and

Portugal. Rice cuture in the United States began about1685 in South Carolina and later spread to North Carolina, Georgia, Alabama, Mississippi, and Florida. (Matz, 1996)

Rice cultivation is well suited to countries with low labor costs and rainfall, as it is very labor intensive to cultivate and requires plenty of water for irrigation. However, it can be grown practically anywhere, even on steep hill sides. Rice is the world's third largest crop, after maize (corn) and wheat. Although its species are native to South Asia and certain parts of Africa, centuries of trade and exportation has made it common place in many cultures. The modern English word rice originates from ancient Greek word "arizi" which in turn was borrowed from the Tamil word of the same pronunciation, strongly indicating trade relationship between ancient Greeks and Tamils (Nationmaster.com 2008).

The cultivation of rice certainly dates to the earliest age of man, and long before the era of which we have historical evidence rice were probably the staple food and the first cultivated crop in Asia (Grist, 1986). Hogan (1970) reported that, according to the Archaeological survey of India, four terraces for rice cultivation on the banks of the Ravi River in South-West Kashmir dated to the Pleistocene or ice Age. If this be so, it would appear that rice is an older cereal grain than is generally recorded by historians.

The ancient name for rice, *Dhanya,* meaning 'sustainer of the human race', indicates its age-old importance. The names of some of the ancient kings of India were derived from or associated with the word rice; thus, about the sixth century BC, the king of Nepal, father of Gautam Buddha, was known as Suddhodhana, which means 'pure rice'. All Hindu scriptures mention rice and all offerings to God were given as rice, denoting the antiquity of rice (Ramiah and Rao 1953).

Rice has been one of the most commonly used grains produced since ancient times. No historian can be accurate about the first appearance of rice because rice cultivation is older than recorded events. Though a lack of historical records prevents accurate determination, botanical evidence suggests strongly that rice originated in South-East continental Asia (Jonson and Peterson, 1974).

3.3.1.3 Variety of rice

Rice cultivation has been done since the beginning of the civilization, so there are thousands of varieties available in the world. In Nepal 930 local varieties from 54 districts of Nepal have been collected and evaluated. Some of the varieties found in Nepal are *Sanga marshi, pahelo Marshi, Thapachiniya, Tauli, Attay, Rate dhan, Jerneli, Kalo marshi, Sabitri, janaki, Durga, Laxmi, Jaya, Taichung, Masuli*, IR8, IR20, (Mallick,1981, and Shrestha, 1975). Varieties available at present in Eastern Nepal are *Jethi masuli, Kanchi Masuli, B40, Rangit, Biramphul, Taichung, Bans dhan, Tauli, Atte, Dudhraj, Anadi, Pokhara, Kalo Nuniya* etc (Personal Communiction,2005).

Over the centuries, three main types of rice had developed in Asia, depending on the amylose content of the grain. They were called indica (high in amylose and cooking to fluffy grains to be eaten with the fingers), japonica (low in amylase and cooking to sticky masses suitable for eating as clumps with chopsticks), and javanica (intermediate amylose content and stickiness). Rice is further divided into long, medium and short-grained varieties, and in the sub-continent different regions grows and consumes different varieties. Basmati rice is probably the best-known variety of rice from the sub-continent (Plant culture-Rice history.htm 2009). According to Juliano (1985a) O. sativa can be separated into three important races Indica, Japonica, and Javonica. He also pointed out the term long, medium, and short varieties; and the above classification is of the Sativa rice. Indica rice is generally cultivated in Tarai of Nepal. The high yielding variety of the Kathmandu Valley and hills is Japonica. The local variety of Nepal is Indica. Masuli is the first popular Japonica and indica cross variety. The parent is Mayang Ebos 80/2 x Taichung 65. This matures in 145 -165 days. Its plant height is 135-140 cms (Mallick, 1981). The rice is characterized by the size of grain, the color of the bran, type of starch and aroma.

The amount of amylose, a starch present in rice will determine how sticky & fluffy the rice grains will turn out after being cooked. Long grain rice is 4 to 5 times as long as the width. It is slender & whitish. When long grain rice is cooked, grains remain separate & fluffy. It is a good choice for main dish, side dish or salad recipes. Medium grain rice means grain fits just in between the long & short grains. It is about 2 or 3 times as long as the width. Short grain rice is almost round & plump and it has the highest amylose content among the 3 types of grains (Tripsofallsorts, 2005).

The different varieties of rice differ greatly in their composition of starch (amylose and amylopection). All of these various types and forms of flours provide different functionality. Long grain rice flour (22 % amylose) commonly known as standard rice flour used in coating applications and many of the clear coatings currently found on French fries. Medium grain rice flour (18 % amylose) can be used in the same applications as long grain flour, but provides a lighter texture and a little more expansion when puffed. Waxy rice flour (0 % amylase, 100 % amylopectin) can be used in many of the same applications as long grain flour, but provides an even lighter texture and much more expansion when puffed (Sagefoods, 2004).

Variety of rice for the preparation of *Sel-roti*

Now a days Kanchhi mansuli is the variety of rice used for the *Sel-roti* preparation. The other coarse varieties such as *attay, anadi, tauli*, B40 of rice are also used depending on the availability for its preparation. Year aged old rice is preferred to obtain the good quality of *Sel-roti.* The aged rice gives soft and well puffed *Sel-roti* (Personal communication, 2005).

3.3.1.4 Chemical composition of rice:

3.3.1.4.1 Rice composition

The chemical composition of rice grains varies widely, depending on environment, soil and variety. Values for starch, lipid and protein also vary with the method of analysis, which means that comparisons can be misleading. Nevertheless, brown rice is generally regarded as having the lowest protein content among the common grains and is also low in fibre content and lipid content (Table No3.1). However, the net protein utilization and digestible energy in rice are the highest amongst the common cereal grains. The rice grain (Fig.3.5) comprises the hull (16–28% dry mass basis) and the caryopsis (Juliano, 1985c). The mass distribution of the rice caryopsis (Hinton & Shaw, 1954) is pericarp, 1–2%; aleurone plus seed coat and nucellus, 4–6%; embryo, 2–3%; and starchy endosperm, 89–94%. The aleurone layer varies from one to five cell layers and is thicker at the dorsal than at the ventral side and is also thicker in short-grain than in long-grain rice (del Rosario et al., 1968). Further milling to remove the pericarp, seed coat, testa, aleurone layer and embryo to yield milled or white rice results in a disproportionate loss of lipid, protein, fibre, reducing sugars and total sugars, ash and minor components including vitamins, free amino acids and free fatty acids (Singh et al., 1998; Park et al., 2001). Diastatic, proteolytic and lipolytic activities were also reduced by milling. On the other hand, available carbohydrates, mainly starch, were higher in milled rice than in brown rice. Starch is the major constituent of milled rice (Table No3.2) at about 90% of the dry matter.Protein and lipid contents are also significant (Azhakanandam et al., 2000).

Table No 3.1. Composition and energy balance data of selected whole-grain cereals* (Juliano, 1985a)

Property	Brown rice	Wheat	Corn	Barley	Millet	Sorghum	Rye	Oat
Protein (N · 6.25) (%)	7.3	10.6	9.8	11.0	11.5	8.3	8.7	9.3
Fat (%)	2.2	1.9	4.9	3.4	4.7	3.9	1.5	5.9
Available carbohydrate (%)	64.3	69.7	63.6	55.8	63.4	58.0	71.8	62.9
Fibre (%)	0.8	1.0	2.0	3.7	1.5	4.1	2.2	5.6
Ash (%)	1.4	1.4	1.4	1.9	1.5	2.6	1.8	2.3
Net protein utilization (%) †	73.8	53.0	58.0	62.0	56.0	50.0	59.0	59.1
Digestible energy (kJ (100 g)	1550	1360	1450	1320	1440	1290	1330	1160

*Data quoted at 14% moisture, †Of intake nitrogen.

The composition of rice differs with the variety, the nature of the soil, environmental conditions and the fertilizers applied .The average composition of both husked and polished rice is given in Table No 3.2(Grist, 1975).

The fat content of rice is low and most of it is removed in the process of milling and is contained in the bran (Grist, 1975). The rice bran contains about 20% oil which is the cause of quick rancid of bran (http://www.indiacurry.com/rice/r001aboutrice.htm).

The total fat content of milled rice remained constant in either ordinary or hermetically storage under a wide range of moisture and temperature conditions (Pillaiyar, 1998).

Rice flour is a finely granulated powder made by grinding and sifting a long grain variety of rice, unless otherwise specified, which is hard milled and electronically sorted to insure Whiteness(Table No 3.4 and 3.5).

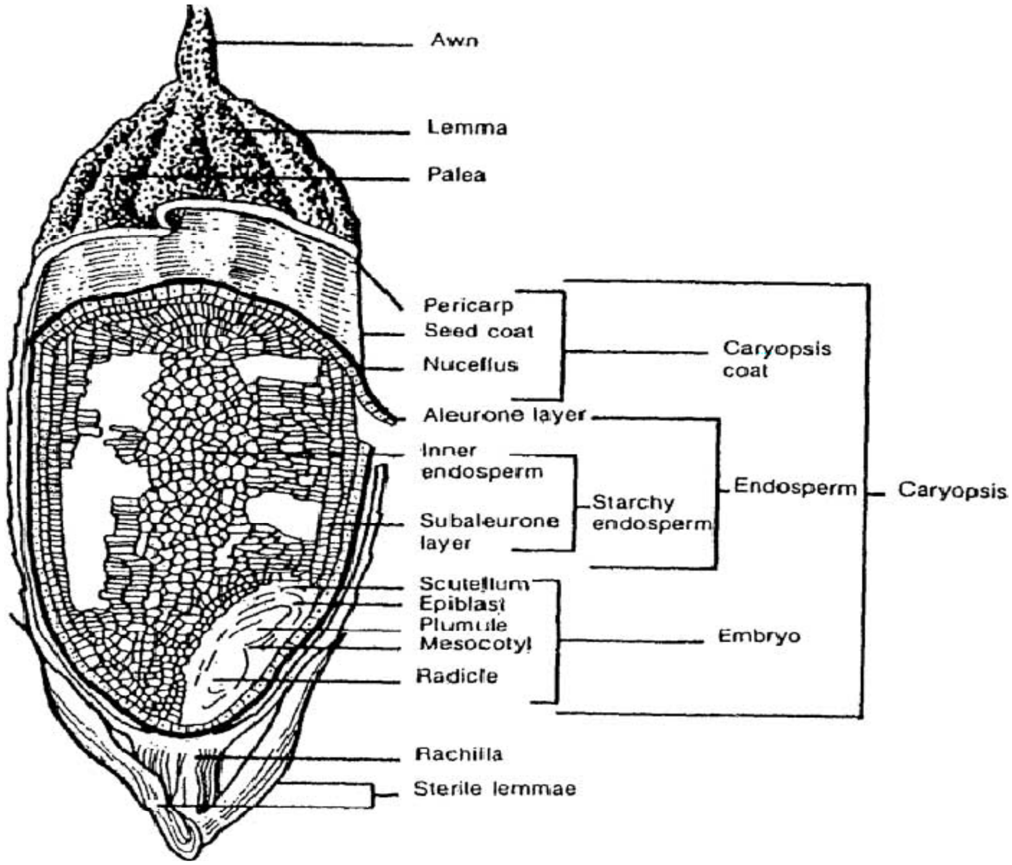


Fig. 3.5 A detailed structure of the rice grain (Blakeney, 1984).

Table No 3.2 Average composition of rice (% dry weight basis)

Component	Husked	Milled(Polished)
Carbohydrate	87.67	90.97
Protein	8.67	8.15
Fat	2.45	0.37
Crude Fibre	0.88	0.16
Ash	1.22	0.36

Source: (Grist, 1975)

Table No 3.3. Nutrients content per 100g of polished rice

Energy	1461 Kj(344 kcall)	Amino acids	
Water	12.9g	Arginine	570mg
Protein	6.9g	Histidine	170mg
Lipids	0.6g	Isoleucine	340mg
Carbohydrates	77.8g	Leucine	660mg
Fiber	1.4g	Lysine	290mg
Minerals	0.5g	Methionine	170mg
		Phenylalanine	390mg
Carbohydrates		Threonine	280mg
Sucrose	150mg	Tryptophan	90mg
Lipids		Valine	490mg
Palmitic acid	110mg		
Stearic acid	12mg	Minerals	
Oleic acid	220mg	Sodium	6mg
Linolic acid	220mg	Potassium	105mg
Linoleic acid	12mg	Magnesium	65mg
		Calcium	6mg
Vitamins		Manganese	2mg
Vitamins E	70µg	Iron	600µg
Vitamins B1	60µg	Copper	130µg
Vitamins B2	30µg	Zinc	500 µg
Nicotinamide	1300µg	Phosphorus	120 µg
Pantothenic acid	630µg	Fluoride	50 µg
Vitamins B6	150µg	Iodine	2 µg
Biotin	3µg	Selenium	10-70 µg
Folic acid	30µg		

Source: (Matthias, 1999)

Table No 3.4 Chemical composition of rice flour

Component	Range	Average
Moisture	8.5 – 13.0%	11.0%
Protein	6.0 - 9.0%	7.5%
Fat	0.4 – 1.0%	0.8%
Crude fibre	0.3 – 1.0%	0.6%
Ash	0.6 – 0.8%	0.7%

Source: http://www.sagefoods.com/Mainpages/products/RiceFlour. htm 09/6/11

Table No 3.5 Physical Characteristics of rice flour

Appearance:	white to creamy white powder, and relatively free from specks.
Aroma:	typical rice aroma, free from sour, musty or other objectionable odors.
Flavor:	bland, typical rice flavor with no rancid or off flavors.
Particle size:	Thru a 80 sieve 80.0 – 85.0 %; Thru a 100 sieve 40.0 – 45.0 %

Source: http://www.sagefoods.com/Mainpages/products/RiceFlour. htm 09/6/11

3.3.1.4.2 Carbohydrates

(a) Chemistry

Carbohydrates are polyhydroxy aldehydes and ketones, their derivatives or substances that yield one of these compounds on hydrolysis (Jain, 1998). They are classified according to their degree of polymerization into three principal groups, namely sugars, oligosaccharides and polysaccharides as shown in table no 3.6 (FAO, 1998; Jain, 1998; Swaminathan, 1999).

Table No 3.6 Classification of carbohydrate

Class (DP*)	Sub-Group	Components
Sugars (1-2)	Monosaccharide	Glucose, galactose, fructose
	Disaccharide	Sucrose, lactose, trehalose
	Polyol	Sorbitol, mannitol
Oligosaccharides(3-10)	Malto-oligosaccharide	Malto-oligosaccharides
	Other oligosaccharide	Raffinose, stachyose, fructo-oligosaccharide
Polysaccharides (>10)	Starch	Amylose, amylopectin, modified starch
	Non-starch-polysaccharide (NSP)	Cellulose, hemicellulose, pectin, hydrocolloid

DP * = Degree of polymerization, (Source: FAO, 1998)

(b) Carbohydrates in maintenance of health:

Though, amount of carbohydrate required for normal human avoiding ketosis is very small (about 50 g/day), carbohydrate provides the majority of energy in diets of most people. In addition to providing easily available energy for oxidative metabolism, carbohydrate containing foods are vehicles for important micronutrients and phyto-chemicals. Dietary carbohydrates are important to maintain glycemic homeostasis and for gastrointestinal integrity and function. They have the sparing action on protein. They are transaminated to amino acids, serves as metabolic intermediates and components of nucleotides, and plays roles in lubrication, cellular inter-communications and immunity. Unlike fat and protein, high levels of dietary carbohydrate, provided it is obtained from a variety of sources, is not associated with adverse health effects. Finally, diets high in carbohydrate as compared to those high in fat, reduce the likelihood of developing obesity and its co-morbid conditions (Jain, 1998; Swaminathan, 1999).

An optimum diet should consist of at least 40 % of total energy coming from carbohydrate obtained from a variety of food sources. When carbohydrate consumption levels are at or above 75% of total energy there could be significant adverse effects on nutritional status by the exclusion of adequate quantities of protein, fat and other essential nutrients (FAO, 1998; Jain, 1998; Swaminathan, 1999).

© Available and unavailable carbohydrate:

McCance and Lawrence in 1929 divided dietary carbohydrate into available and unavailable. Available carbohydrate was defined as starch and soluble sugars and unavailable as mainly hemicellulose and fibre (cellulose). This concept proved useful, not the least because it drew attention to the fact that some carbohydrate is not digested and absorbed in the small intestine but rather reaches the large bowel where it is fermented. It suggests that the site of digestion or fermentation, in the gut, of carbohydrate is of overriding importance. (FAO, 1998).

(d) Starch:

(i) Chemistry of starch

Chemically, starches are polysaccharides, composed of a number of glucose molecules linked to-gether with α-D-(1-4) and/or α -D-(1-6) linkages. The starch consists of 2 main structural components, the amylose, which is essentially a linear polymer in which glucose residues are α-D-(1-4) linked typically constituting 15% to 20% of starch, and amylopectin, which is a larger branched molecule with α-D-(1-4) and α-D-(1-6) linkages and is a major component of starch (Parker and Ring, 2001). Linear regions of the amylose chain form a dark blue complex with polyiodide ions in aqueous solution at room temperature. This interaction is a basis for defining amylose as that starch polysaccharide which, under standardised conditions, binds 20% of its weight of iodine while under the same conditions amylopectin generally binds <1% w/w. This iodine binding allows a distinction between amylose and amylopectin and permits the determination of the amylose content of native starch (Parker and Ring, 2001).

Amylose is linear or slightly branched, has a degree of polymerization (DP) up to 6000, and molecular mass of 10^5 to 10^6 g/mol. Chains can easily form single or double helices (Takeda *et al*. 1989). On the basis of X-ray diffraction studies on oriented amylase fibres, the presence of type A and type B amylose is indicated (figure 3.6 and 3.7; Galliard 1987). The structural elements of type B are double helices, which are packed in an antiparallel, hexagonal mode. The central channel surrounded by 6 double helices is filled with water (36 H_2O/unit cell). Type A is very similar to type B, except that the central channel is occupied by another double helix, making the packing closer. In this type, only 8 molecules of water per unit cell are inserted between the double helices.

Amylose content varies greatly between varieties, from a low of 0–2% in waxy rice (milled rice, dry mass basis) to a high of greater than 25% in non-waxy rice (Juliano, 1979, and Parker and Ring, 2001). Cooking characteristics, texture, water absorption ability, stickiness, volume expansion, hardness and even the whiteness and gloss of the cooked milled rice are affected by the amylose content (Juliano, 1985b).

The main variation in composition of rice starch is caused by the relative proportions of the two fractions in the starch granules and this, together with the chain length distribution and the frequency and spacing of branch points within the amylopectin molecule (Lu et al., 1997), has a profound influence on the physicochemical properties of starch (Jane et al., 1999).

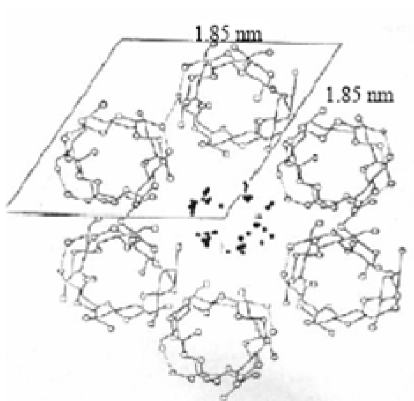


Fig. 3.7 Unit cells and arrangement of double helices cross section in B-amylose

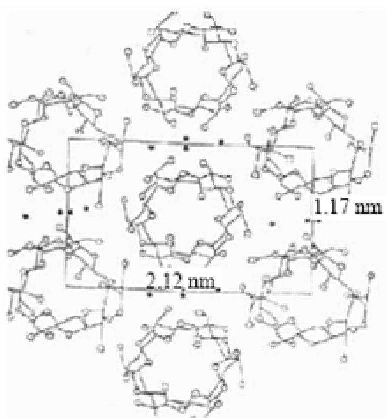
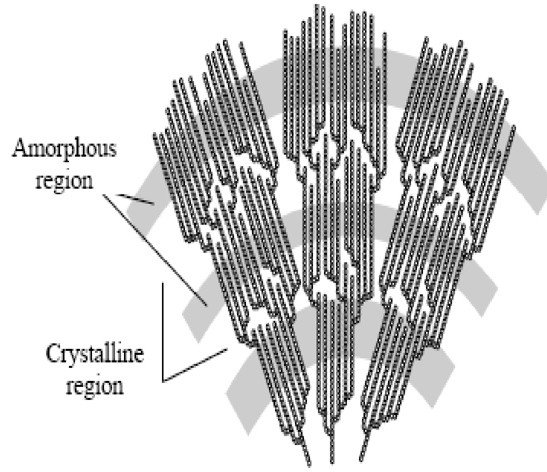


Fig. 3.6 Unit cells and arrangement of double helices cross section in A-amylose

Waxy varieties produce only amylopectin and these starches are non-gelling because of the lack of amylose. Both the amylose contents and amylopectin branch chain-length distributions affected starch pasting properties (Jane et al., 1999). Rice starches that had short average amylopectin branch chain lengths displayed low gelatinization temperatures. Cereal amylopectins retrograded more slowly than those from pea, potato and canna amylopectin, and these differences were attributed to shorter average chain length in cereal amylopectins (Kalichevsky et al., 1990).

Rice amylopectin (10^7 to 10^9 g/mol) are highly branched molecules in which a (1,6) links form the branch point and has an average DP of 2 million, making it one of the largest molecules in nature. Chain lengths of 20 to 25 glucose units between branch points are typical which are similar for both waxy and non-waxy amylopectin. Its structure is often described by a cluster model (figure3.7; www.Isbu.ac.uk, 2007;Hizukuri et al., 1983a; 1983b; and Hizukuri et al., 1989). The chain length is highly negatively correlated (r ¼, 0.91) with DPn values; the higher the DPn, the shorter the chain length (Lu et al., 1997). Three types of amylopectin, designated as type A, type B, and type C have been identified based on X-ray diffraction patternsThese depend partly on the chain lengths, making up the amylopectin lattice, the density of packing within the granules, and the presence of water. Although type A and type B are real crystalline modifications, type C is a mixed form 'A' type starches are found in cereals, while 'B' type starches are found in tubers and amylose-rich starches and ‘C type’ is found in legumes (Wu and Sarko, 1978; Galliard, 1987; Topping and Clifton, 2001). The type A structure has amylopectin of chain lengths of 23 to 29 glucose units. The hydrogen bonding between the hydroxyl groups of the chains of amylopectin molecules results in the formation of outer double helical structure. In between these micelles, linear chains of amylose moieties are packed by forming hydrogen bonds with outer linear chains of amylopectin. This pattern is very common in cereals. The type B structure consists of amylopectin of chain lengths of 30 to 44 glucose molecules with water interspread. This is the usual pattern of starches in raw potato and banana. The type C structure is made up of amylopectin of chain lengths of 26 to 29 glucose molecules, a combination of type A and type B, which is typical of peas and beans. An additional form, called type V, occurs in swollen granules. X-ray diffraction diagrams of these starches are shown in figure 3.8 and 3.9 (www.isbu.ac.uk, 2007).



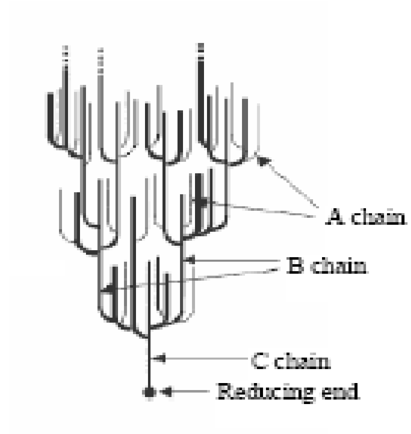


Fig. 3.8 Organization of the amorphous and crystalline regions (or domains) of the structure generating the concentric layers that contribute to the "growth rings" that are visibleby light microscopy

Fig. 3.9 Essential features of amylopectin

Starch granules are said to have a semi-crystalline character, which indicates a high degree of orientation of the glucan molecules. About 70% of the mass of starch granule is regarded as amorphous and about 30% as crystalline. The amorphous regions contain the main amount of amylose but also a considerable part of the amylopectin. The crystalline region consists primarily of the amylopectin (Sajilata *et al*., 2006).

Rice granules (Fig. 3.10) are the smallest of the grains of starch produced by plants; they average 3–8 lm in size (Ellis et al., 1998) and are polygonal but irregular in shape (Hayakawa et al., 1980). Compound granules having diameters up to 150 lm form as clusters containing between 20 and 60 individual granules (Juliano, 1985d) and fill most of the central space within the endosperm cells. However, in waxy varieties the endospermis opaque because of air spaces between the starch granules.

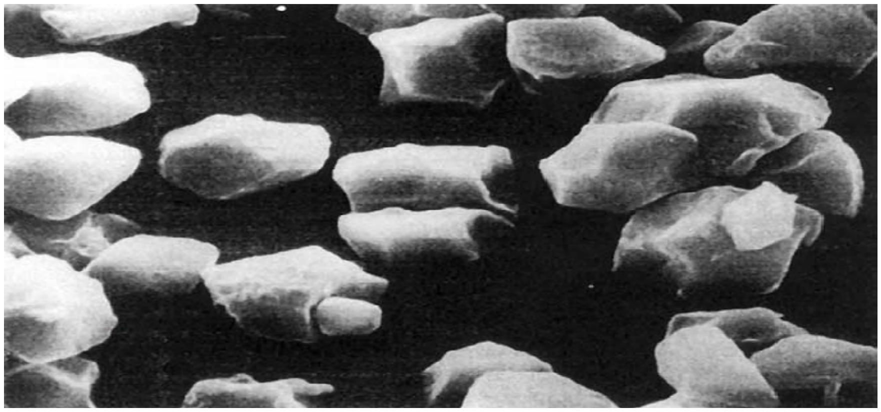


Fig. 3.10 Scanning electron micrograph of rice starch granules, 5000· (Sivak & Preiss, 1998).

Amylose and amylopectin are assembled in a cluster structure, in which the granules are composed of starch molecules laid down in concentric rings (Fig.3.11). The molecules that comprise a layer are deposited in a radial fashion with some sections in highly ordered crystalline regions. These radially ordered crystallites are linked by less structured amorphous regions. Hydrogen bonding is likely to be a significant force in both regions. Linear portions of amylopectin constitute the crystalline regions, whereas the branch points and amylose are the main components of the amorphous portion (Blanshard, 1987).

(ii) Digestibility of starch: Starch is the most important, abundant, polysaccharide having varying degree of digestibility in human. For nutritional purposes, food starches may be classified as either glycemic or resistant. Glycemic starches are those that are degraded to glucose by enzymes in the digestive tract and can be further categorized as either rapidly digestible starch (RDS) or slowly digestible starch (SDS). RDS is digested quickly in the small intestine (Englyst *et al*., 1992). In in vitro testing, it is hydrolyzed to glucose within 20 min. RDS are amorphous in nature, and is best exemplified by freshly cooked starchy foods, such as mashed potatoes. In this case, starch granules have been gelatinized and are more accessible to enzymatic digestion.SDS is degraded more slowly than RDS, but digestion is still complete. During in vitro

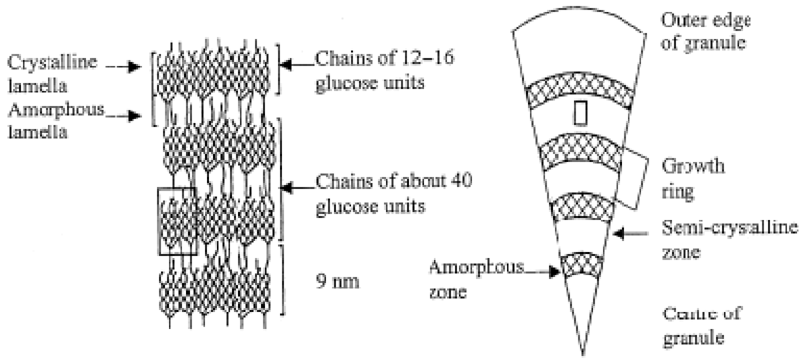


Fig. 3.11 Semi-crystalline and amorphous regions in the starch Granule (Smith et al., 1997).

hydrolysis, SDS is converted to glucose between 20 and 110 min. SDS are crystalline in nature or physically inaccessible due to granule form like raw starch from a cereal grain, such as wheat. Finally, resistant starches (RS) are those that escape digestion in the small intestine but are fermented in the large intestine by bacterial microflora (Sajilata *et al.*, 2006). A significant proportion of starch in the normal diet escapes degradation in the stomach and small intestine and is labeled 'resistant starch' but this portion is difficult to measure and depends on a number of factors including the form of starch and the method of cooking prior to consumption. Nevertheless resistant starch serves as a primary source of substrate for colonic microflora, and may have several important physiological roles. Resistant starch has been categorized as physically inaccessible (RS<sub>1), (raw) ungelatinized starch (for example, in banana; RS<sub>2), thermally stable retrograded starch (for example, as found in bread, especially stale bread, mainly amylose; RS<sub>3) and chemically modified starch (RS<sub>4). Resistant starch should be considered a dietary fiber.

(iii) Structures and functionality relation of starch: Starch is the leading component of staple foods, such as bread, rice, potato, pasta, and noodles, as well as an important ingredient of many processed foods. Starch is a versatile and cheap, and has many uses as thickener, water binder, emulsion stabilizer and gelling agent.Starch is often used as an inherent natural ingredient but it is also added for its function.

It is naturally found tightly and radially packed into dehydrated granules (about one water per glucose) with origin-specific shape and size (maize, 2-30 μm; wheat, 1-45 μm; potato, 5-100 μm). The size distribution determines its swelling functionality with granules being generally both larger and lenticular (lens-like), with less swelling power. Granules contain 'blocklets' of amylopectin containing both crystalline (~30%) and amorphous areas. As they absorb water, they swell, lose crystallinity and leach amylose. The higher the amylose content, the lower is the swelling power and the smaller is the gel strength for the same starch concentration.

Starch is generally regarded as the most important constituent of rice in terms of pasting behavior and functionality. For instance, Lii et al. (1996) concluded that the major factors influencing the rheological properties of heated indica rice starch gels were the granular structure and component, plus the amount of leached amylose. The texture of cooked rice was largely determined by the gelatinization properties of its starch granule (Juliano, 1985b). Although amylose content was considered the most important determinant of cooked rice texture, this constituent fell short as a predictor of texture (Champagne et al., 1999) and cultivars with similar amylose contents differed in textural properties.

Of the two components of starch, amylose has the most useful functions as a hydrocolloid. Amylose forms useful gels and films. Its association and crystallization (retrogradation) on cooling and storage decreases storage stability causing shrinkage and the release of water (syneresis). Increasing amylose concentration decreases gel stickiness but increases gel firmness. Amylopectin interferes with the interaction between amylose chains (and retrogradation) and its solution can lead to an initial loss in viscosity and followed by a more slimy consistency. Mixing with κ-carrageenan, alginate, xanthan gum and low molecular weight sugars can also reduce retrogradation. Structural changes of starch during processing and storage are critical to food quality and stability. Gelatinization and swelling of starch provide desired functionality to foods, but leaching and fragmentation often result in undesirable changes in quality and stability.

Retrogradation describes the process in which a heated starch paste cools, and the exuded amylose molecules reassociate and unite the swollen starch grains in an ordered structure that results in viscosity increase. This phenomenon is generally regarded as a crystallization or recrystallization (i.e. formation and subsequent aggregation of double helices) process of amylopectin and amylose (Seow et al., 1996). However, the rapid initial rate of retrogradation was related to the loss of networked amylose (Orford et al., 1987; Chang & Liu, 1991), the development of amylose aggregates, and binding of granule remnants into assemblies by amylose and amylose aggregates (Jacobson et al., 1997).

From studies on other cereals (Miles et al., 1985; Goodfellow & Wilson, 1990; Leloup et al., 1992; Gudmundsson, 1994; Liu et al., 1997), it is reasonable to conclude that amylose may form double-helical associations of 40–70 glucose units, whilst amylopectin forms shorter double helices. The latter can be attributed to restrictions imposed by the branching structure of the amylopectin molecules and the chain lengths of the branches. Thus, amylose is responsible for short-term (less than 1 day) changes while amylopectin is responsible for the longer term rheological and structural changes of starch gels.

(v) Modification of starch via chemical, physical, and enzymatic reactions: Most commercial starches employed in either food or industrial applications have been chemically modified to improve their functionality. At the present time, modification via chemical routes is the most widely used method to produce starch derivatives and chemical modification is indispensable in the continued and increased use of starch to provide thickening, gelling, binding, adhesive, and film-forming properties. Nevertheless, modification by physical and enzymatic means present great potentials to provide unique products, such as nano starch particles, when combined with chemical modifications. By understanding starch granule architecture, it is then possible to produce nano starch particles for food, pharmaceutical, and industrial applications. (http://www.uark.edu/depts/foodsci/pdf_files/WangWeb-Research%20Program.pdf)

(vi) Utilization of starch and interactions of carbohydrates with other food constituents during processing and storage: Starch is the major component of many staple foods and also one of the most versatile ingredients in the food industry. Cooking is to gelatinize and/or free starch molecules for specific functions, e.g. thickening or allowing enzymes to break these large molecules into sugars and dextrin.

(vii) Development of value-added products: The application of high intensity ultrasound and enzyme treatment in starch recovery is explored. Ultrasound may selectively degrade the protein component by disrupting or breaking the tertiary or secondary structures of protein without damaging starch and enzyme treatment will further reduce the residual protein content. Protease has been shown to effectively remove protein from rice flour and corn flour at a neutral pH. Work continues in combining ultrasound and protease treatment to further improve starch isolation efficiency.(http://www.uark.edu/depts.

/foodsci/pdf_files/WangWebResearch%20Program.pdf).

(viii) Oligosaccharides from rice bran or other sources as nutraceuticals: Non-digestible oligosaccharides have been claimed to benefit the colon by selectively stimulating the growth of bifidobacteria and by decreasing the toxicity of the colon contents. Oligosaccharides are short-chain saccharides and usually composed of 2-10 glycosidically linked monosaccharides. Human can not digest oligosaccharides because our bodies do not produce the enzymes necessary for their digestion. Instead, they are fermented and consumed by the beneficial intestinal bacteria, bifidobacteria, in the colon. Generally, oligosaccharides are classified as "prebiotics" because they are preferentially chosen by beneficial bacteria, which are termed probiotics, to promote intestinal health, i.e., a balance between the beneficial and harmful microbes. Currently, the criteria used for classification of a food component as a prebiotic include: resistance to digestion, hydrolysis and fermentation by colonic microflora, and selective stimulation of growth of one or a limited number of bacteria in the feces. In addition, a prebiotic may repress the growth of pathogens for overall beneficial health.

Recent studies have shown many health benefits of proteins and oils from rice bran, but little research has been conducted to understand the composition of rice bran is used for rice oligosaccharides and their contribution to human health. Therefore, oligosaccharides from rice bran present a tremendous potential to offer unique health benefits that are not present in current commercial products (http://www.uark.edu/depts/foodsci/pdf_files/ WangWeb-Research%20Program.pdf).

3.3.1.4.3 Rice protein

Protein is the second most abundant constituent of rice grain and is unique among the cereal protein because it contains at least 80% glutelin (alkali-soluble protein). Glutelin has the similar amino acid composition to milled rice protein, probably because it is the major protein fraction. The protein content of rice of any variety can vary considerably even when grown at the same location. The effect of differences in protein contents of milled rice on their nutritive quality shows that protein quality tended to decrease as protein contents increased (Whitaker and Tannenbaum, 1977).

Recent data for protein contents (Basak et al., 2002) ranged from 6.6 to 7.3% for brown rice (Singh et al., 1998), from 6.2 to 6.9% for milled rice (Singh et al., 1998), and for basmati rice 8.2– 8.4% (Deka et al., 2000). Values for Chinese white rice fell within these ranges but were much lower than data for Chinese and North American wild rice (12.0–15.2%) (Zhai et al., 2001). The protein (and fat) contents decreased linearly with increase in the degree of polish, as these constituents were mainly concentrated in the peripheral layers of the kernel (Pal et al., 1999). Protein content of rice starch depends on the method of isolation (Singh et al., 2000) but should not exceed 0.5%. Solubility fractions of rice proteins consisted of 9.7– 14.2% albumin (water soluble), 13.5–18.9% globulin (salt soluble), 3.0–5.4% prolamin (alcohol soluble) and 63.8–73.4% glutelin (alkali soluble) for non-basmati aromatic, basmati aromatic and non-aromatic rice samples (Basak et al., 2002). Data for brown rice showed a similar cultivar dependence and consisted of 18.8–20.8% albumin + globulin, 12.5–14.5% prolamin and 66.0– 67.7% glutelin (Asano et al., 2000).

Protein is most abundant in the subaleurone layers but is also present in aleurone cells (Azhakanandam et al., 2000). Endosperm protein comprises 7–18% albumin plus globulin, 5–12% prolamin and the rest is glutelin (Padhye & Salunkhe, 1979; Huebner et al., 1990). The endosperm protein is localized mainly in the form of large spherical protein bodies, 0.5–4 μm in size, that are rich in prolamin (Padhye & Salunkhe, 1979) and crystalline protein bodies rich in glutelin (Bechtel & Pomeranz, 1978).

The starch granule amylose bound up to 0.7% protein that was identified as mainly the waxy gene protein or granule-bound starchy synthase (Villareal & Juliano, 1989). The waxy gene protein was rich in disulphide linkages, and was found in higher amounts in high-amylose compared with low-amylose rices (Villareal & Juliano, 1986). This protein correlated with amylose content (r ¼, 0.95) and cooked rice stickiness (r ¼, 0.85) (Hamaker et al., 1991). Protein with intact disulphide bonds makes the swollen granules less susceptible to breakdown. When protein disulfide bonds were disrupted, rice starch granules apparently swelled to a large size, thereby increasing the degree of gelatinization and gel strength (Hamaker& Griffin, 1993).

Table No 3.7 Rice protein fractions

Protein / Glycoproteins	Amount of total protein
Soluble fractions	
Albumines (water soluble)	10.8%
Globulines (salt-soluble)	9.7%
Prolamines (70%-ethanol soluble)	2.2%
16 kDa Allergen (PBS-soluble fraction)	about 1.5% in seeds (300 g/ 20 mg)
Insoluble fraction	
Glutelins	77.3%

Source: (Matthias, 1999)

Protein of rice occurs mainly in protein bodies of the endosperm. Whole milled rice protein has almost the same composition as the protein bodies. About 80% of the protein in milled rice is the alkali soluble protein, glutein. Among the cereal grains, rice is unique since it contains high levels of glutelins and low prolamine contents (5%). The lysine content of the rice protein is relatively high (3.5-4.0) % due to the low level of prolamine. The latter is a nutritionally poor quality fraction (Anglemier and Montogomery, 1976).

The main protein is Oryzenin. The protein content of milled rice is low in comparison with other cereals, although the whole rice grain contains about the same. The amino acid content of milled rice is given below in table 3.8.

(a) Crude protein. For the determination of nitrogen, first the protein content of materials may be calculated. Proteins are complex organic substances consisting of chains of amino acids. They are the major constituents of all living cells, both plant and animal. The nitrogen content of different proteins is nearly alike and is approximately 16%, hence multiplying the nitrogen estimated by the factor 6.25 yields the amount of protein. In certain cases as, for example, casein, a higher factor, namely 6.38 is used for this conversion and more nearly represents the true proportion of nitrogen in this cases. The estimation of nitrogen is generally done by a modified Kjeldahl digestion method. This digestion should be done only in a hood with a good draught. This method depends upon

Table No 3.8 Level of essential amino acids of milled rice

Essential amino acids	% of Protein*	Standard pattern (% of protein) **
Isoleucine	4.13	4.0
Leucine	8.24	7.0
Lysine	3.80	5.5
Methionine	3.37	-
Methionine+ Cystine	4.97	3.5
Phenylalanine	6.02	6.0
Threonine	4.34	4.0
Tryptophan	1.21	1.0
Valine	7.21	5.0

Source: *(Whitaker and Tannenbaum, 1977), ** provisional amino acid pattern FAO (1973)

the decomposition of organic nitrogen compounds by boiling with sulphuric acid. The carbon and hydrogen of the organic material are oxidized to carbon dioxide and water. A part of the sulphuric acid is simultaneously reduced to sulphur dioxide, which in turn, reduces the nitrogenous material to ammonia. The ammonia combines with the sulphuric acid and remains as ammonium sulphate, a substance with a high boiling point. The ammonia is subsequently liberated by the addition of sodium hydroxide is distilled into a known amount of standard acid and the excess acid is estimated by titration with standard alkali (Jaccobs, 1958).

3.3.1.4.4 Lipid in rice

Cereal lipids are chemically diverse groups that were separated by Mano et al. (1999) into neutral lipids, glycolipids and phospholipids. The ratio of these lipid classes did not differ between japonica and indica rices (Mano et al., 1999), but their distribution within the grain was not uniform and the endosperm lipids contained a higher proportion of polar lipids (Fujino & Mano, 1972; Choudhury & Juliano, 1980b). The lipid or oil content of rice is concentrated in the bran fraction where it can contribute up to 20% by mass (dry basis), specifically as lipid bodies or spherosomes about 0.1–1 ηm size (Bechtel & Pomeranz, 1977, 1978) in the aleurone layer and bran. Resurreccion et al. (1979) reported 2.9% crude oil in brown rice, of which 51% was found in the germ, 32% in the polish, and only 17% in the endosperm. Within the endosperm, lipids were unevenly distributed, with the highest amount in the outer layer and decreasing progressively towards the centre of the kernel (Normand et al., 1966; Houston, 1967; Hogan et al., 1968).

The lipid contents of six varieties of brown rice and milled rice (Singh et al., 1998) ranged from 2.1 to 3.2% and 0.61–0.95%, respectively. Data for Chinese and North American wild rice (milled) were higher at 0.94–1.2% (Zhai et al., 2001). However, ranges from 1 to 4% for brown rice, and from 0.2 to 2% for milled rice have been reported (Juliano, 1985d) depending on the variety and growing conditions. The lipid content of brown rice also ranges from 2 to 4 per cent with high concentration in the outer layers. During milling 50 – 70 percent lipid is removed (Pillaiyar, 1988).

Based on cellular distribution and its association, rice lipids are generally classed as starch lipids, which are associated with starch granules (Choudhury & Juliano, 1980a, b; Juliano, 1983) and non-starch lipids that are distributed throughout the grain (Choudhury & Juliano, 1980b) but concentrated in the bran. Starch lipids typically comprise 0.5–1.0% of milled rice and are generally present in greater amounts than non-starch lipids, although this is not universal and there are differences between waxy and non-waxy varieties (Choudhury & Juliano, 1980b; Kawashima & Kiribuchi, 1980).

Starch lipids were mainly monoacyl lipids (fatty acids and phospholipids) complexed with Amylose (Ito et al., 1979; Choudhury & Juliano, 1980b). The predominant bound free fatty acids in rice starch were palmitic (C16: 0) and linoleic (C18: 2) acids (Table 3.9) (Kitahara et al., 1997). The contents of bound free fatty acids and bound phospholipid in rice starch were intermediate between those in corn and wheat. The sum of the five most abundant free fatty acids, as determined by high performance liquid chromatography (HPLC), comprised 92% of the total free fatty acids measured colorimetrically. Following hydrolysis by glucoamylase, the bound lipids remaining in the residual starches were free fatty acids and phospholipids that decreased during the initial stage of hydrolysis. During the later stages, the free fatty acids continued to gradually decrease, while the phospholipids appeared to be completely released from the hydrolysed starch granules (Kitahara et al., 1997). The chain length distribution of the debranched starch showed an increase in the relative amount of amylose following hydrolysis and the extent of the increase was greater in native than in defatted starch. Thus, the increase was attributed to the bound lipids in the starch granules.

The function of the monoacyl lipids is usually attributed to be the formation of the helical inclusion complex between the amylose and the hydrocarbon chain of the lipids (Vasanathan & Hoover, 1992). Table 3.9 shows Fatty acid composition of non-starch lipids of brown and milled rices. The effect of solvent is shown for the latter (Lasztity, 1999).

It was concluded that solubility had a significant effect on the extent of complexation. Yamada et al. (1998) also found in maize starch that saturated fatty acids were preferentially complexed with amylose as the double bond in unsaturated fatty acids hindered complexation. Rice flour heated in the presence of myristic, palmitic and stearic acid exhibited increased amylose–lipid complex formation (Kaur & Singh, 2000).

Table No 3.9. Fatty acid composition of non-starch lipids of brown and milled rices. The effect of solvent is shown for the latter (Lasztity, 1999).

	Fatty acid (% of total)				
Sample	C16 : 0	C18 : 0	C18 : 1	C18 : 2	Other
Brown rice	15–28	31–47	25–47	4	<7
Milled rice					
Petroleum ether	17–29	29–41	21–41	<3	4–6
Methanol-chloroform	27–29	27–31	35–46	<1	<4

The existence of starch–lipid complexes has several consequences. For example, complexation impacted on the formation of resistant starch (Kitahara et al., 1996; Kitahara et al., 1997) and yields of resistant starch (Mangala et al., 1999) were increased significantly by the removal of lipids from rice starch. Complexes with long chain, saturated monoglycerides were generally more resistant to in-vitro digestion than complexes with shorter chains or more unsaturated monoglycerides (Guraya et al., 1997). This was attributed to the increase in stability of the complexes with the degree of fatty acid saturation and chain length. Amylose–lipid complexation also impacts on pasting behaviour. Thus, addition of fatty acids decreased water-solubility in rice paste cooked for 30–90 min (Kaur & Singh, 2000) but increased the pasting temperature, peak viscosity, and viscosity at 95°C, viscosity of rice paste at 50°C and the consistency coefficient determined using a Brookfield viscometer.

3.3.1.4.5 Minerals and Vitamins in rice

Rice is an important source of minerals. It was reported that in 1992 in China, about 77% of the dietary iron came from wheat, rice and fruit and only 9% of iron came from meat, poultry and fishery. The ash distribution in brown rice is not homogeneous: 51% is found in bran, 10% in germ, 11% in polish and 28% in milled rice.

However, a large number of people subsisting on rice diets suffer from nutrition deficiency in terms of micronutrients such as iron, vitamin A, vitamin C and zinc. The

World Health Organization (WHO) has recognized that anemia has catastrophic effects

Table No 3.10 Vitamin content of raw, white and parboiled rice

	B-vitamins (mg/kg)		
	Thiamine	**Riboflavin**	**Niacin**
Raw rice	3.40	0.55	54.1
White rice	0.50	0.19	16.4
Parboiled rice	2.50	0.38	32.2

Source: Belitz et.al, (2009)

on the health and quality of life of at least 2 billion people, 90% of which are caused by iron deficiency (WHO, 2009; Chen and Zeng, 2007, and Hu, Li, Piao, Yang, 2010). Rice also contains phytate, an inhibitor of mineral absorption (especially iron and zinc). The content of phytate is at a high level (120 mg/100 g) even in milled rice. So, although the populations average minerals intake was at a high level, there is much disease due to minerals deficiency.

Vitamins and minerals content of polished rice are given in table 3.3 earlier. White rice, in comparison to rough or brown rice, is low in vitamin content (Table 3.10) and in minerals. A nutritionally improved product may be obtained by a parboiling process, originally developed to facilitate seed coat removal (Belitz et.al, 2009).

3.3.1.5 Rice products and their Uses

In an average the following products are obtained by milling and polishing of paddy; 50 percent head rice, 17percent broken rice, 20 percent hulls (husk), 10 percent bran, and 3 percent meal. The milling yield from paddy in different countries is given below in table No 3.11.

(a).Broken rice: The amount of broken grain resulting from milling rice depends mainly on the variety of paddy, its condition – especially its handling after harvest and the amount of milling to which it is subjected. There are several grade of broken rice in trade.

Table No 3.11. Milling Yield of Paddy.

Component	Average USA*	Brazil*	Burma#
Head rice	57	52.0	71.61
First head	3.5	10.0	0.50
Second heads	6.0	4.0	--
Brewer's rice	2.0	3.0	--
Total	68.5	69.0	72.11
Rice polish	2.0	8.0	----
Rice bran	8.5	---	2.45
Hulls	20.0	23.0	25.44
Waste(trash, etc)	1.0	---	--

*Efferson (1952), #State Agricultural Marketing Board, Rangoon.

(b).Rice meal and rice bran: The rice bran is of two types: (i) Cow-bran which is coarse meal of low food value is produced in hulling of paddy. (ii) Bran or meal produced in pearling process comprises the pericarp, aleurone layer, embryo and some of endosperm, and contains most of vitamins and minerals of grain. It has high food value – mostly as a stock feed. It has two grade i.e., No.1 Bran or white mal produced from white rice milling and No.2 bran produced from milling parboiled rice(Grist, 1986). According to ICAR(1964) compositon of rice bran is as follows(percentage): Water 8.9 to 12.5, protein 10.6 to 13.4, fat 10.1 to 22.4, N.free extract 38.7 to 44.3, fibre 9.6 to 14.1, ash 9.3 to 14.3, pentosans 8.7 to 11.4, B.vitamins 544mg. The food value is as follows (percentage): Digestible nutrients 67.7, digestible protein 8.8, calcium 0.08, phosphorus 1.36, dry matter 92.2, and fibre 13.0.

(c) Rice flour: Rice flour has been growing dramatically in the United States in recent years. Rice flour has historically been used in baby foods and extruded rice crispier. In recent years, more rice flour is being used in cereals, crackers, chips, snacks and coating applications to provide different textures. Textures can be altered dramatically depending on the type of flour used. It is widely used in the preparation of sauces and gravies for the preparation of Soya rice to make fried rice, frozen cooked rice (Sagefoods, 2005).

(d) Other uses of rice are (i). Rice flour, (ii).Rice milk, (iii). Rice pudding, (iv). Rice vinegar, (v).Rice wine, and (vi). Red yeast rice (Tripsofallsorts, 2005).

The different traditional products such as *Chuira, sel-roti, bhuja, Bhakka, Khatte, Kasaar, yomari, chatamari, lochamahi, syabaji,* and *dhakne roti/dhukdhuke roti* (Anonymous, 2005, and Kharel et al, 2010) are prepared from whole rice and rice flour in Nepal.

Only a few cereals are traditionally fermented into the products that are special foods in the cuisines of the Himalayan people. These include *Sel-roti* in Nepal, Darjeeling hills, and Sikkim; Nan in the western Himalayas; jalebi throughout the entire Himalayas; and siddu, bhatarua, and seera in Himachal Pradesh and Uttarakhand (Tamang, 2010).

3.3.1.6 Nutritional Benefits of Rice

Rice is an excellent food to help in keeping our body healthy. Rice has the following nutritional benefits:

a) Excellent source of carbohydrate and energy: Rice is an excellent source of carbohydrates. Carbohydrates provide energy. Carbohydrates are broken down to glucose, most of which is used as energy for exercise and as essential fuel for the brain (Kondidin, 2005).

Crude fiber means the combustible residue that is left after the other carbohydrates and the proteins have been removed by successive treatment with boiling acid and alkali. This residue is largely cellulose and consists of carbohydrates not assimilable by humans (AOAC, 2005). Crude fibre acts as rouphge in human body and help aliaviate constipation.

b) Low in fat, salt and no cholesterol: The Australian Dietary Guidelines recommend eating plenty of breads and cereal. Rice is an excellent food to include in a balanced diet. It is low in total fat and saturated fat, and cholesterol, and contains negligible amounts of rice bran oil (Kondidin, 2005).

c) Gluten free: Some people are unable to tolerate the proteins found in wheat, barley, rye and oats. People choose foods that are gluten free. All rice is gluten free, making rice the essential choice for people with gluten free dietary requirements (Kondidin, 2005).

d) Contains no additives or preservatives: Rice contains no additives or preservatives, making it an excellent inclusion in a healthy and balanced diet. Rice also contains resistant starch, which is the starch that reaches the bowel undigested. This encourages the growth of beneficial bacteria, keeping the bowel healthy (Kondidin, 2005).

e) Low Glycaemic Index. Aged rice and paraboiled rice has comparatively low glycemic index and has health benefit (Kondidin, 2005).

3.3.2 Fats and Oils

3.3.2.1 Importance of fats and oils

Fats and oils are recognized as essential nutrients in both human and animal diets. They provide the most concentrated source of energy. They supply essential fatty acids, fat soluble vitamins A, D, E& K, contribute greatly to the feeling of satiety after eating, are carriers for fat soluble vitamins, and serve to make foods more palatable. They also contribute to food flavor and mouth-feel as well as to the sensation of product richness. They are used as frying fats or cooking oils where their role is to provide a controlled heat exchange medium as well as to contribute to color and flavor. They are also used in many other commercial applications, including soaps, detergents, and emulsifiers, printing inks, protective coatings, and feeds for domesticated animals (Institute of Shortening and Edible Oils,1999; Lands, 1986).

3.3.2.2 What is fat?

Fats and oils are chemical units commonly called "triglycerides" resulting from the combination of one unit of glycerol with three units of fatty acids. They are insoluble in water but soluble in most organic solvents. They have lower densities than water and at normal room temperatures range in consistency from liquids to solids. When solid appearing they are referred to as "fats" and when liquid they are called "oils." (Institute of Shortening and Edible Oils, 1999).

The term "lipids" embraces a variety of chemical substances. In addition to triglycerides, it also includes mono- and diglycerides, phosphatides, cerebrosides, sterols, terpenes, fatty alcohols, fatty acids, fat-soluble vitamins, and other substances (Institute of Shortening and Edible Oils, 1999).

The oils and fats most frequently used for salad and cooking oils, shortenings, margarines, salad dressings and food ingredients include soybean, corn, cottonseed, palm, peanut, olive, safflower, sunflower, canola, coconut, palm kernel, lard, and beef tallow and specialized vegetable oils of lesser availability include rice bran, shea nut, illipe, and sal (Institute of Shortening and Edible Oils, 1999).

3.3.2.3 Chemical composition of fats

Triglycerides are the predominant component of most food fats and oils. The minor components include mono- and diglycerides, free fatty acids, phosphatides, sterols, fatty alcohols, fat-soluble vitamins, and other substances (Institute of Shortening and Edible Oils, 1999). These are as follows:

A. The Major Component – Triglycerides

A triglyceride is composed of glycerol and three fatty acids. When all of the fatty acids in a triglyceride are identical, it is termed a "simple" triglyceride or symmetrical triglyceride. The more common forms, however, are the "mixed" triglycerides in which two or three kinds of fatty acids are present in the molecule. Illustrations of typical simple and mixed triglyceride molecular structures are shown below:

Simple triglyceride	Mixed Triglyceride
$H_2COO\text{-}C\text{-}R_1$	$H_2COO\text{-}C\text{-}R_1$
$HCOO\text{-}C\text{-}R_1$	$HCOO\text{-}C\text{-}R_2$
$H_2COO\text{-}C\text{-}R_1$	$H_2COO\text{-}C\text{-}R_3$

Where R_1, R2 and R_3 = fatty acids

B. The Minor Components

1. Mono- and Diglycerides: Mono- and diglycerides are mono- and diesters of fatty acids and glycerol. They are used frequently in foods as emulsifiers. Mono- and diglycerides are formed in the intestinal tract as a result of the normal digestion of triglycerides. They also occur naturally in very minor amounts in both animal fats and vegetable oils.

2. Free Fatty Acids: They are the unattached fatty acids present in a fat. Some unrefined oils may contain as much as several percent free fatty acids. Refined fats and oils ready for use as foods usually have a free fatty acid content of only a few hundredths of one percent.

3. Phosphatides: Phosphatides consist of alcohols (usually glycerol), combined with fatty acids, phosphoric acid, and a nitrogen-containing compound. Lecithin and cephalin are common phosphatides found in edible fats.

4. Sterols: Sterols, also referred to as steroid alcohols, are a class of substances that contain the common steroid nucleus plus an 8 to 10 carbon side chain and an alcohol group. Although sterols are found in both animal fats and vegetable oils, there is a substantial difference biologically between those occurring in animal fats and those present in vegetable oils. Cholesterol is the primary animal fat sterol and is only found in vegetable oils in trace amounts. Vegetable oil sterols collectively are termed "phytosterols."

5. Fatty Alcohols: They are long chain alcohols and have little importance in most edible fats.

6. Tocopherols: Tocopherols are important minor constituents of most vegetable fats. They serve as antioxidants to retard rancidity and as sources of the essential nutrient

vitamin E. These or other antioxidants may be added after processing to improve oxidative stability in finished products.

7. Carotenoids and Chlorophyll: Carotenoids are ange from yellow to deep red color materials occurring naturally in fats and oils. Chlorophyll is the green coloring matter of plants which plays an essential part in the photosynthetic process.

8. Vitamins: Generally speaking, most fats and oils are not good sources of vitamins other than vitamin E.

(a) Fatty Acids

The carboxylic acids obtained from the hydrolysis of fat or oil are called fatty acids. They are the building blocks of the triglycerides and the fats and oils are often named as derivatives of these fatty acids. For example, the tristearate of glycerol is named tristearin and the tripalmitate of glycerol is named tripalmitin. Normal saturated fatty acids have a long, unbranched hydrocarbon chain having a general formula CH_3 (CH_2) nCOOH, where n is usually even and varies from 2 to 24. The predominant fatty acids are saturated and unsaturated carbon chains with an even number of carbon atoms and a single carboxyl group. The unsaturated fatty acids may have one double bond (monosaturated) or have more than one cis-methylene interrupted double bond (polyunsaturated).(Gunstone 2004; Gunstone 1999; Markey 1960; and Anonimous,1999).

Fatty acids are responsible for the different properties of the triglycerides; the glycerol component is identical for every triglyceride. Several aspects can differentiate the fatty acid components: (1) the carbon chain length, (2) the number of double bonds, (3) the location of the double bonds, (4) the configuration of the hydrogen atoms attached to the carbon atoms joined by the double bond, *cis* or *trans*, and (5) the position of the fatty acids regarding the glycerol (Markey 1960).

Aside from their nutritional role in the diet, the various fatty acids are purported to have different roles in regard to their health effects (Gunstone 1997). Fatty acids occurring in edible oils are broadly classified as saturated or unsaturated.

(i).Saturated Fatty Acids: The fatty acids with no double bonds between carbons in the chain are saturated. Saturated fatty acids generally vary in chain length from 4 to 24 carbons atoms. Saturated fatty acids, with some exceptions, have straight, even numbered carbon chains. They are the least reactive and have a higher melting point than unsaturated fatty acids of the same chain length due to the dense packing of the unbranched chain structure in the crystal lattice. The melting point of a lipid is dependent on both the degree of unsaturation and the chain length. Vegetable oils' saturated fatty acids are predominately even numbered carbon atoms ranging from 4 to 24. Animal fats and marine oils also contain predominately even numbered carbon chains with the addition of uneven chains containing 15 and 17 carbon atoms. This characteristic can be an identification aid for the presence of these fats and oils in a blend. Saturated fatty acids can raise the low-density lipoprotein (LDL) cholesterol level. The 2005 Dietary Guidelines for Americans recommended that saturated fatty acids should be limited to 10% of total calories for healthy individuals and a further reduction to 7% of total calories for individuals at risk for heart disease. However, most dietitians agree that not all saturated fatty acids are unhealthy. The saturated fatty acids are not a single family, but are comprised of three subgroups: short (4-6 carbon atom), medium (8-12carbon atom), and long-chain (14 – 24 carbon atom) fatty acids (Wainwright, 2000).

(ii) Unsaturated Fatty Acids: The fatty acids that contain double bonds between the carbon atoms are termed unsaturated. As many as seven double bonds have been reported; fatty acids with an excess of three double bonds are most likely of aquatic origin. Those containing 1, 2, and 3 double bonds and 18 carbon atoms are the most important unsaturated fatty acids of vegetable and land animal origin. Those with 4 or more double bonds and 20 to 24 carbon atoms are found principally in marine oils. Normal double bonds in the *cis* form cause a bend in the carbon chain, which restricts the freedom of the fatty acid. This bend becomes more pronounced as the number of double bonds increase. The kinks in the unsaturated carbon chains prevent them from packing well into the crystal lattice. This limits the ability of the fatty acids to closely pack and, therefore, the density and melting characteristics. The unsaturated fatty acid melting points decrease as the double bonds increase. The presence of double bonds also makes the unsaturated fatty acids more chemically reactive than the saturated fatty acids and this activity increases as the number of double bonds increase. The notable reactions are oxidation, polymerization, and hydrogenation (O'Brien, 2009).

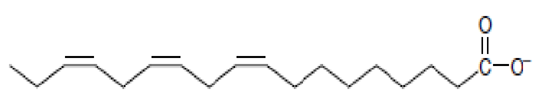
The subgroups for the unsaturated fatty acids are monounsaturated, omega-6 polyunsaturated, and omega-3 polyunsaturated. The terms monounsaturated and polyunsaturated indicate the number of double bonds.

Monounsaturated fatty acids are least reactive. Of the monounsaturated fatty acids, oleic and palmitoleic are the most widely distributed and oleic is considered the most important. High-oleic oils normally have positive health aspects because of their low saturated fatty acid levels, minimal *trans*-isomer contents, and the potential to decrease blood triglycerides, LDL and total cholesterol values, and a high oxidative stability. Olive oil is very flavor-stable oil because of the high oleic fatty acid content (~80%), other examples are high oleic acid sunflower oil, high oleic acid safflower oil. Liquid oils with high-oleic fatty acid contents have exhibited good oxidative and frying stabilities; however, it has been reported that oils with more than 65% oleic fatty acid lose some of the characteristic fried-food flavor (Neff, 1998).

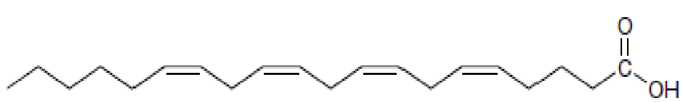
Polyunsaturated fatty acids have two or more double bonds. Chemically reactivity increases as the number of double bonds increase. Polyunsaturated fatty acids with two to six double bonds are of considerable interest nutritionally. Vegetable oils are the principal source of the two essential fatty acids: linoleic and linolenic. Arachidonic fatty acid is found in small amounts in lard, which also contains ~10% linoleic fatty acid. Marine oils contain large quantities of a variety of long-chain unsaturated fatty acids with three or more double bonds. Human life is dependent on the essential fatty acids at every stage, even before birth. They are found in the membrane of every cell in the body and help to regulate all biological functions, including those of the cardiovascular, reproductive,

(a)Oleic acid (18:1)

(b)Linoleic acid (18:2, ω6)



(c)Linolenic acid (18:3, ω3)



(d)Arachidonic acid (20:4, ω6)

Fig .3.12 : Unsaturated fatty acid (a) oleic acid, monounsaturated acid; (b) Linoleic acid and (c) linolenic acid, and (d) Arachidonic, polyunsaturated acids (Caballero,et al.,2005) .

immune, and nervous systems. They were found necessary for stimulating skin and hair growth, maintaining bone health, regulating metabolism, and maintaining reproductive capability. Further research indicated that these fatty acids can also help prevent heart disease and arthritis and appear to be important for awareness and behavior functions of the brain (Anonimous, 2006).

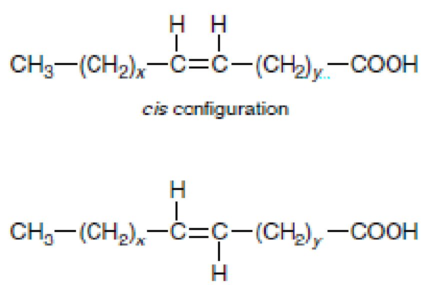
The essential fatty acids are linoleic, $C_{18}H_{32}O_2$, and linolenic, $C_{18}H_{30}O_2$. These essential fatty acids must be obtained from food because the human body lacks the enzymes required for their production. However, our bodies do possess the enzymes necessary to convert linoleic (C-18:2) and linolenic (C-18:3) fatty acids to longer chain and more unsaturated fatty acids. Therefore, these two fatty acids form the starting point for the creation of two physiological families: omega-3 and omega- 6(Anon, 2006).

There are only minor differences in the molecular structure of the omega-3 and omega-6 fatty acid families; however, they act very differently in the human body. The metabolic products of the omega-6 fatty acids promote inflammation, blood clotting, and tumor growth, while the omega-3 fatty acids are generally viewed as anti-inflammatory. Therefore, it is important to maintain a balance of omega-3 and omega-6 fatty acids in the diet as these two substances work together to promote health. When one omega family predominates, either more pro- or anti-inflammatory responses are formed. That means there is less potential for self-regulation because the omega-3 and omega-6 families tend to self regulate when they are in balance. An excess or imbalance of omega-6 fatty acids can affect the onset or progression of many diseases, such as heart disease, cancer, asthma, arthritis, and depression (Hisch and Evans, 2005).

Nutritional study results suggest that increased consumption of long-chain omega-3 fatty acids, which would decrease the omega-6 to omega-3 ratio, is beneficial for individuals suffering from coronary heart disease, type 2 diabetes, hypertension, immune response disorders, and mental illness (Djordjevicet al.2005). The 2005 Dietary Guidelines Advisory Committee Report encouraged consumers to keep their total fat intake between 20 to 35% of calories with polyunsaturated fatty acids as high as 10% of total calories. A low intake of fats and oils, less than 20% of calories, increases the risk of inadequate vitamin E and the essential fatty acids and may contribute to unfavorable changes in high-density lipoprotein (HDL) blood cholesterol and triglycerides (O'Brien, 2009).

(iii) Other fatty acids: The fatty acids which are minor and some are natural some are formed during processing but have nutritional implications are discussed below:

(a)Trans Fatty Acids: The three main origins of trans fatty acids in our diet are bacteria, deodorized oils, and partially hydrogenated oils. The preponderance of trans fatty acids in our diets is derived from the hydrogenation process (O'keefe, 2008). *Trans* fatty acids are found in meat and milk from ruminant animals, marine oils, hydrogenated and deodorized oils.Vaccenic fatty acid, C-18:1, *trans*11, is the predominate *trans* fatty acid in ruminant fats and elaidic fatty acid, C-18:1, *trans* 9, in hydrogenated and deodorized oils (Leth et al, 1998). *Trans* fatty acids are unsaturated fatty acids that contain at least one double bond in the *trans* configuration as a result of geometric isomerism. In nature, most unsaturated fatty acids have the hydrogen atoms attached to the carbons on the same side of the molecule in the *cis* form. Hydrogen atoms attached to the carbon at a double bond on opposite sides of molecule are *trans*-isomers. A tighter stacking of the molecules Nutritionally, *trans* fatty acids are regarded like saturated fatty acids in that both can



Trans configuration

Fig.3.13: The *cis* and *trans* configurations of unsaturated bonds (Sadler et al., 2005).

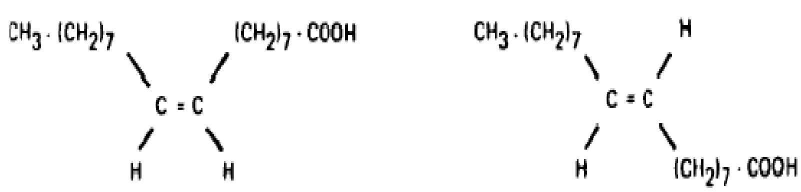


Fig.3.14: Structures of Octadec-cis-9-Enoic Acid (Oleic Acid) and Octadec-trans-9-Enoic Acid (Elaidic Acid) (deMan, 1999)

cause an increase in plasma LDL cholesterol. However, saturated fatty acids increase HDL cholesterol modestly while *trans* fatty acids decrease it.

A majority of the *trans* fatty acids are manmade, i.e., they are formed principally during hydrogenation and to a lesser extent during deodorization, frying, and baking.

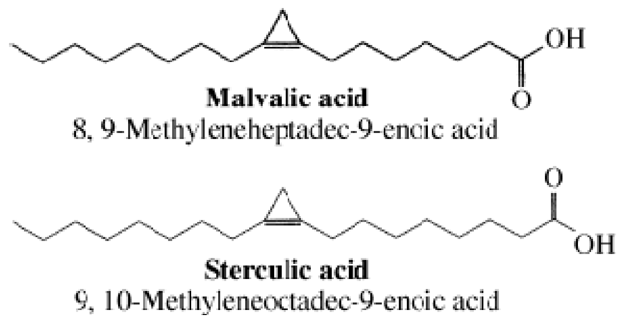
Depending on the processing conditions, 3 to 24% of linolenic fatty acid and a maximum of 2% of linoleic fatty acid will be converted to *trans*-isomers (Harper, 2001). The intake of *trans* fatty acids from ruminant and other animal fats results less harmful than the acids produced during processing.

(b)Conjugated Linoleic Fatty Acid (CLA): Conjugated linoleic fatty acids are a mixture of geometric isomers of linoleic fatty acid. Technically, conjugated fatty acids are *trans* fatty acids, but without the negative effects. Conjugated linoleic fatty acids have a number of different sources. Some plants and marine organisms produce high concentrations of conjugated fatty acids Dairy fats are a major source of conjugated linolenic fatty acids. The content of CLA in ruminant fat can range from 0.5 to 2.0% depending on the diet fed to the animals (Mossoba, et al 2005). Unintentional conjugation reactions occur during partial hydrogenation of polyunsaturated fatty acids with nickel and platinum catalysts (Kapoor, 2002 and Kapoor, 2003).

These CLA isomers may have several health-promoting properties, including cancer protection, heart disease defense, enhanced immunity, increased bone mineralization, and reduction in body fat (Crandall, 2006 and Hunter, 2002). Rumenic fatty acid, C-18:2 (*cis*-9, *trans*11), also appears to reduce cancer risks. The *trans*-10, *cis*-12 CLA isomer helps burn fat, enhance muscle tone, increase nutrient absorption and improve the body's efficiency at extracting energy from food. One study showed that consumption of at least 3 grams a day of dietary CLA led to a 3.9% decrease in body fat in human (Crandall, 2006).

©. Branched chain and cyclic acids: A large number of branched fatty acids have been identified (Gunstone, 1994).Typical acids with branched chains or containing carbocyclic systems include iso acids and anteiso acids present in wool wax and other animal fats, acids such as tuberculostearic acid (10-methylstearic acid, present in the lipids of the tubercle bacillus) with mid-chain branching, phytanic and pristanic acids with several branched methyl groups present at low levels in fish oils resulting from metabolism of phytol .

Typical examples of acids with a carbocyclic system include: Cyclopropane acids (present in bacteria.); malvalic and sterculic acids which contain cyclopropene units (present in selected seed oils of the Malvaceae and at low levels in cottonseed oil),Cyclopentene acids (C_6-C_{20}) from seed oils of the Flacourticeae.



. **Fig. 3.15: Cyclopropane acids**

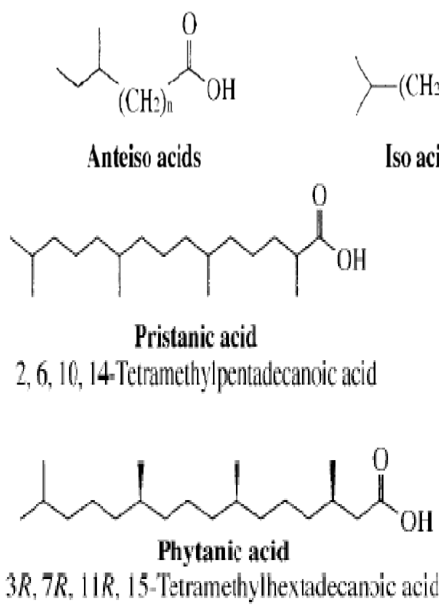


Fig.3.16 : Acids with one or more methyl branches.

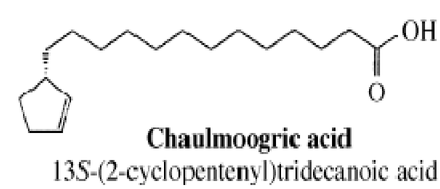
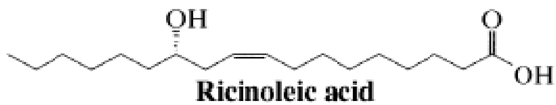


Fig.3.17: Cyclopentene acids.

(d) Hydroxy fatty acids: The fatty acids which contains hydroxyl group in their chain are called hydroxyl fatty acids. The best known natural hydroxyl acid is ricinoleic acid(12-hydroxyoleic).This is the major acid(around 90%) in castor oil and its isomers are found in strophanthus and wightia seed oils.There are also other acids of this type. Castor oil and ricinoleic acid are important materials used in cosmetics, in lubricants, and as a drying oil after dehydration (Gunstone, 1999; Gunstone 2004, & O'keefe, 2008).



Ricinoleic acid

12*R*-Hydroxy-9*Z*-octadecenoic acid

Fig.3.18 Hydroxy acid (Gunstone, 2004).

3.3.2.4 Papatability

Palatability consists of the organoleptic and physical properties that make a food product pleasurable or, at the very least, not unpleasant to eat. One of the most important palatability parameters for users of edible fats and oils is flavor. The lipids contribute undesirable as well as desirable flavors. Flavor sensation is a composite of taste, odor, and mouth feel. Fats and oils are excellent solvents for many of the good-tasting components in foods and provide the desirable flavor release and mouth feels that are lacking in foods with reduced or no fat. The major causes of off-flavors in food oils and fats are oxidation and hydrolysis. The oxidized products and the liberated fatty acids impart characteristic flavors that are objectionable even in small concentrations. Mouth feels and flavor release are organoleptic characteristics that must be controlled by the physical properties of the edible fats and oils products. These properties can be controlled by the judicious selection of the melting properties of the component base oils and the hydrogenated, fractionated, interesterified, or esterified base stocks in the formulated blends. (O'Brien, 2009)

3.3.2.5 Oxidation

All olefinic compounds are prone to reaction with oxygen and since this generally leads to the development of rancidity in fats/oils as well as fat-containing foods. Even if it is not possible to prevent these undesirable changes they can at least be inhibited through the use of appropriate antioxidants (Gunstone, 2004).

The oxygen molecule exists in two forms - in its normal ground state it is a triplet form ($^3O_2$) and in the excited state it exists in a singlet form ($^1O_2$). Both react with olefinic systems and while they share some similarities, there are some important differences between the reactions of these two forms of oxygen. Triplet oxygen is a diradical •O-O• and reacts mainly at allylic centres to give allylic hydroperoxides. In contrast, singlet oxygen is an electrophilic substance reacting with electron-rich olefinic systems, but also producing allylic hydroperoxides. It is more reactive than triplet oxygen by 22.4 kcal/mole and has a lifetime of only 50-700µs (Gunstone, 2004).

Lipid oxidation may occur through enzymic and non-enzymic processes and the latter may involve oxygen in its triplet or singlet form. Oxidation can be promoted by heat, light, metals, several initiators and can be inhibited by antioxidants acting in different ways. There are small but significant differences between the oxidation of monoenes and methylene- interrupted polyenes. The initial products are generally allylic hydroperoxides with their unsaturation still intact and these undergo further reactions that are important in the development of off-flavours and rancidity (Fig. 3.19)

Autoxidation: Reaction between olefinic esters and triplet oxygen is a radical chain process involving three stages of initiation, propagation and termination (Fig.3.19). In the initiation stage, an allylic hydrogen atom is removed and a resonance- stabilised radical is produced.Three suggestions have been made: metal-catalyzed decomposition of pre-formed hydroperoxides, formation of hydroperoxide by photo-oxidation, or thermally in

Initiation	RH → R•	resonance-stabilised alkyl radical
Propagation	R• + O_2 → RO_2•	fast reaction to a peroxy radical
	RO_2• + RH → RO_2H + R•	rate-determining step
Termination	RO_2• + RO_2• → stable products	
	RO_2• + R• → stable products	
	R• + R• → stable products	

Fig.3.19 Olefin autoxidation. RH represents an olefinic compound in which H is attached to anallylic carbon atom.

a heated fat. The initiation step and the propagation sequence depend on the ease with which a hydrogen atom can be removed from a methylene group.

In the two-step propagation sequence, given an adequate supply of oxygen, conversion of alkyl radical to peroxy radical is fast and the conversion of peroxy radical to hydroperoxide is rate-determining. This sequence will continue as long as there is a supply of reactants but, as indicated in the termination reactions, there is some loss of alkyl and peroxy radicals through dimerisation to form stable products which do not promote the reaction further. The further reaction of peroxy radicals and hydroperoxides is found in (Gunstone, 2004; Lee, 1983; deMan, 1999). Among the many factors that affect the rate of oxidation are (a) Amount of oxygen present (b) degree of unsaturation of the lipids, (c) presence of antioxidants (d) presence of prooxidants, especially copper, and some organic compounds such as heme-containing molecules and lipoxidase, (e) nature of packaging material, (f) light exposure and (g) temperature of storage (deMan, 1999).

The rate and course of autoxidation depend primarily on the composition of the fat—its degree of unsaturation and the types of unsaturated fatty acids present. The absence, or at least a low value, of peroxides does not necessarily indicate that oil is not oxidized. As Figure 3.20 indicates, peroxides are labile and may be transformed into secondary oxidation products. A combined index of primary and secondary oxidation products gives a better evaluation of the state of oxidation of oil. This is expressed as Totox value: Totox value = 2 x peroxide value + anisidine value. (Anisidine value is ameasure of secondary oxidation products).

Autoxidation can be inhibited by hindering the initiation process or by promoting the

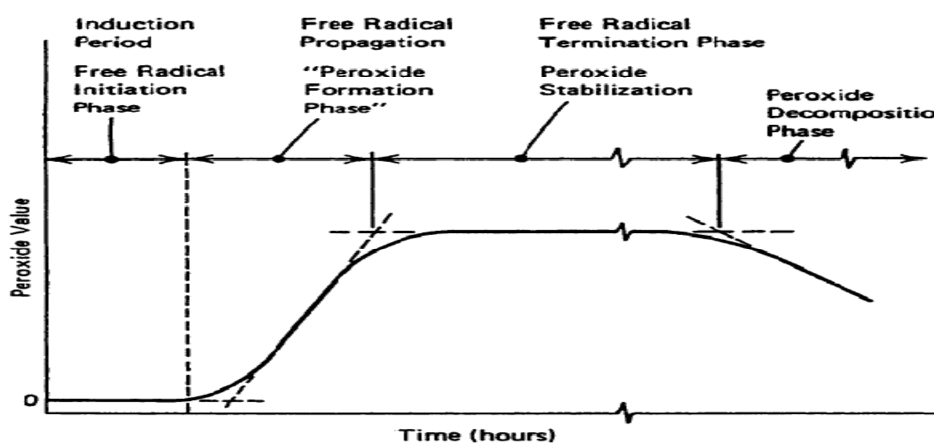


Fig.3.20 Peroxide Formation and Decomposition as a Function of Time (deMan 1999).

termination process thereby reducing the length of the propagation sequence. One purpose of antioxidants is to extend this induction period which is very slow period of reaction) (Gunstone, 2004).

Photo-oxidation: Because of the greater reactivity of singlet oxygen, photo-oxidation is a quicker process than autoxidation and there is less difference between the reactivity of monoenes and polyenes. Some typical figures are given in Table 3.12 from which it is apparent that photo-oxidation of linoleate is 1500 times quicker than autoxidation and that with oleate this ratio is 30 000.

Singlet oxygen can be formed by enzymic, chemical, and photochemical pathways. In the present context, singlet oxygen is formed from ordinary triplet oxygen and light in the

Table No 3.12. Relative rates of autoxidation and photo-oxidation of oleate, linoleate and linolenate

Reaction	Oxygen	18:1	18:2	18:3
Autoxidation	triplet	1	27	77
Photo-oxidation	Singlet	$3x10^4$	$4x10^4$	$7x10^4$
Ratio		30,000	1,500	900

presence of a sensitiser such as chlorophyll, riboflavin, myoglobin, erythrosine, rose bengal or methylene blue. The sensitiser absorbs energy from a photon and this energy is eventually passed to oxygen, converting it from the triplet to the singlet state (fig3.21a). Singlet oxygen reacts with double bonds by a reaction to give an allylic hydroperoxide and with conjugated dienes to give endoperoxides below (fig. 3.21 b & c):

$$\text{Sensitizer} \xrightarrow{h\nu} \text{Sensitizer*}$$

$$\text{Sensitizer*} + {}^3O_2 \longrightarrow \text{Sensitizer} + {}^1O_2$$

$${}^1O_2 + RH \longrightarrow ROOH$$

Fig.3.21a Conversion of triplet oxygen to singlet oxygen and reaction with unsaturated fatty acid (deMan, 1999).

$$\textit{cis}\ \ RCH{=}CHCH_2R' + {}^1O_2 \rightarrow \textit{trans}\ RCH(OOH)CH{=}CHR'$$

Fig. 3.21b: Reaction of olefin with singlet oxygen to give allylic hydroperoxides with double bonds in different position and of changed configuration.

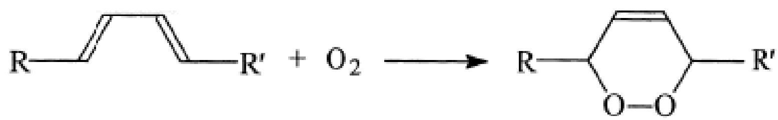


Fig.3.21c: 1,4-Cycloaddition reaction of conjugated diene with singlet oxygen to give an endoperoxide (1,4-cycloadition).

Despite some similarities, photo-oxidation and autoxidation show some important differences (Gunstone, 2004). Photo-oxidation is an ene reaction between electrophilic singlet oxygen and an electron-rich double bond whereas autoxidation is a radical chain reaction,displays no induction period in contrast to autoxidation, is unaffected by the antioxidants used to inhibit autoxidation but is inhibited by singlet oxygen quenchers such as carotene, is a reaction occurring at olefinic carbon atoms accompanied by double bond migration so that the product is an allylic hydroperoxide with trans configuration, gives reaction products that are similar to, but not identical with, those resulting from autoxidation. The distinct hydroperoxides can furnish short- chain aldeydes with their own characteristic flavours and odours,is a quicker reaction than autoxidation, especially for monoene esters , and is related to the number of olefinic centres rather than to the number of 1,4-pentadiene units, gives hydroperoxides, which once formed, promote the alternative autoxidation route.

Photooxidation has no induction period, but the reaction can be quenched by carotenoids that effectively compete for the singlet oxygen and bring it back to the ground state. Phenolic antioxidants do not protect fats from oxidation by singlet oxidation (Yasaei et al. 1996). However, the antioxidant ascorbyl palmitate is an effective singlet oxygen quencher (Lee et al. 1997). Carotenoids are widely used as quenchers.

Lipoxygenase: Lipoxygenases which occur widely in plant and animal systems are non-haeme iron proteins. In plants they promote oxidation of C18 acids, particularly linoleic and linolenic. The fatty acids are probably the preferred substrate, but reactions can occur with phospholipids and triacylglycerols (Gunstone, 2004).

Lipoxygenase-derived products from linoleic and linolenic acids form substrates for several different enzyme families leading to over 150 different fatty acid derivatives. Under the influence of peroxygenases, the hydro- peroxides are converted to epoxy and dihydroxy acids (Gunstone, 2004).

$$R_2CH_2 \rightarrow R_2CH\bullet \rightarrow R_2CHOO\bullet \rightarrow R_2CHOO^{-} \rightarrow R_2CHOOH$$

Fig.3.22: Enzymic oxidation of polyunsaturated fatty acids. CH_2 represents a doubly allylic methylene function.

The relative importance of the oxidative stability of a fat or oil product depends on the intended use of the product, the temperature abuse to which it will be exposed, and the shelf life or use life expectancy. Fats differ considerably in the way in which their oxidation and accompanying flavor deterioration proceed. The more highly saturated fats and oils and hydrogenated isomerized products experience relatively little change in flavor during the early phases of oxidation, but off-flavor development is sudden and definite. Unsaturated oils exhibit gradual flavor deterioration, with a greater tendency to develop unpleasant flavors and odors. The amount of oxygen that must be absorbed to produce offensive flavors corresponds to the fatty acid composition of the oil, the position of the unsaturated fatty acid on the glycerol, the level of isomerized fatty acids, the presence of natural or added antioxidants, the metal content, and temperature exposure (O'Brien, 2009).

The oxidative stability of fat and oil products is determined by the distribution, geometry, and number of double bonds. Oxidation can occur only in the unsaturated fatty acid portions of the triglyceride molecule because the presence of a double bond is necessary for oxidation to occur under ordinary conditions. *Cis* fatty acids oxidize more readily than their *trans*-isomers. Conjugated double bonds are more reactive than nonconjugated bonds, and polyunsaturated fatty acids are more reactive than saturated ones. The oxidizability of each polyunsaturated fatty acid is increased approximately two fold for each active methylene group (Frankel, 2007). It is well established that the more unsaturated a fatty acid is, the less oxidative stability it naturally possesses, as illustrated by the relative oxidation rates of the fatty acids listed in table 3.13 (Chapman et al., 1996).

Monounsaturated fatty acids e.g., oleic acid, are the most oxidatively stable of the unsaturated fatty acids. Investigators have demonstrated that the natural *cis*-isomeric fatty acid form has less oxidative stability that the corresponding *trans*-isomer; therefore, a judicious selection of the source oil and processing conditions for the finished product formulation must be made to achieve the required oxidation stability. This is especially important when reformulating fat and oils products to eliminate *trans*-fatty acids or to incorporate omega-3 long-chain unsaturated fatty acids (O'Brien, 2009).

Table No 3.13. Fatty Acids Relative Oxidation Rates

Active Fatty Acid	Relative Methylene Groups	Oxidation Rates
C-18:1 Oleic	0	1
C-18:2 Linoleic	1	10
C-18:3 Linolenic	2	20
C-20:4 Arachidonic	3	40
C-20:5 Eicosapentaenoic	4	80
C-22:6 Docosahexaenoic	5	160

Fats and oils oxidative reactions are directly related to the fatty acid composition and more specifically to the type and amount of *cis* unsaturation. Iodine value measurements can be used to estimate the oxidative stability of a natural fat or oil, as the products with the highest unsaturation are most likely to experience autoxidation. The oxidative stability is different for each fat and oil raw material and must be considered when formulating fats and oils ingredients. The oxidative stability of different fats and oils is in the order as palm kernel oil > milk fat > rapeseed oil > soybean oil > sunflower oil (O'Brien, 2009).

3.3.2.6 Flavor Reversion

Flavor reversion, caused by oxidation, is most prevalent in oils high in polyunsaturates. Reverted flavors are observed long before other oxidized flavors are formed. At low levels of oxidation, the change generally known as flavor reversion is characteristic of the source fat or oil. For example, soybean oil flavor reversion has been described as beany and grassy at the more advanced stages, all objectionable flavors. In contrast, corn oil's reverted flavor has been described as pleasant, slightly nutty, and a slightly sweet flavor often associated with cooked sweet corn.

The reverted oil flavors have been characterized as somewhat pleasant or objectionable as given in table 3.14 (O'Brien, 2009).

High linolenic (C-18:3) and linoleic (C-18:2) fatty acids are the most important precursors of flavor reversion.

Table No 3.14: Reverted Oil Flavor Characterization

Pleasant	Objectionable
Cottonseed oil	Soybean oil
Peanut oil	Safflower oil
Corn oil	Canola oil
Sunflower oil	Palm oil
Olive oil	Lard
Butter oil	Tallow
Menhaden oil	

3.3.2.7 Hydrolysis

Edible fats and oils hydrolysis results in the formation of free fatty acids, di and monoglyceride, and glycerol, provided the moisture content of the oil exceeds a certain level. Fatty acids have distinct flavors and odors when their chain lengths are shorter than 14 carbons. For this reason, vegetable oils containing mostly C-16 and C-18 fatty acids, which are not too unsaturated, do not become unpalatable when only slightly hydrolyzed (i.e., 1.0 to 3.0% FFA). However, with palm kernel and coconut oils, the same FFA level gives a very distinct off-flavor because these oils contain high levels of C-6 to C-12 fatty acids. Enzymes may also cause hydrolysis. This occurs normally with oils produced from fruit coats with high moisture content, such as palm or olive oils. Because FFA and the accompanying substances are largely removed by processing, the concern for hydrolytic cleavage lies with the prepared food process or composition (i.e., fried foods or high moisture products). (O'Brien, 2009).

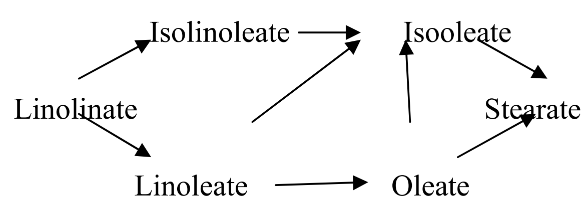
3.3.2.8 Hydrogenation

Hydrogenation of fats involves the addition of hydrogen to double bonds in the fatty acid chains. The process is of major importance in the fats and oils industry to convert the liquid oils into semisolid or plastic fats more suitable for specific applications, such as in shortenings and margarine, and to improve the oxidative stability of the oil(Fennema, 1996).

In practice, the oil is first mixed with a suitable catalyst (usually nickel), heated to the desired temperature (140-–225°C), then exposed, while stirred, to hydrogen at pressures up to 60 psig. Agitation is necessary to aid in dissolving the hydrogen, to achieve uniform mixing of the catalyst with oil, and to help dissipate the heat of the reaction. The starting oil must be refined, bleached, low in soap, and dry; the hydrogen gas must be dry and free of sulfur, CO_2, or ammonia; and the catalyst must exhibit long-term activity, function in the desired manner with respect to selectivity of hydrogenation and isomer formation, and be easily removable by filtration (Fennema, 1996).

The course of the hydrogenation reaction is usually monitored by determining the change in refractive index, which is related to the degree of saturation of the oil. When the desired end point is reached, the hydrogenated oil is cooled and the catalyst is removed by filtration (Fennema, 1996). Catalytic hydrogenation: The detail can be found elsewhere.

Selectivity**:** A simplistic scheme showing the possible reactions that linolenate can undergo during hydrogenation is shown here (Fennema, 1996):



In the case of natural fats, the situation is further complicated by the fact that they already contain an extremely complex mixture of starting materials.

The term "selectivity" refers to the relative rate of hydrogenation of the more unsaturated fatty acids as compared with that of the less unsaturated acids. When expressed as a ratio (selectivity ratio), a quantitative measure of selectivity can be obtained in more absolute terms. The term "selectivity ratio," as defined by Albright (1965) is simply the ratio (rate of hydrogenation of linoleic to oleic)/ (rate of hydrogenation of oleic to stearic)

Different catalysts result in different selectivities, and operating parameters also have a profound effect on selectivity. As shown in Table 3.15, larger SR values result from high temperatures, low pressures, high catalyst concentration, and low intensity of agitation. The effects of processing conditions on the rate of hydrogenation and on the formation of *trans* acids are also given (Fennema, 1996).

Table No 3.15 Effects of Processing Parameters on Selectivity and Rate of Hydrogenation

Processing parameter	SR	*Trans* acids	Rate
High temperature	High	High	High
High pressure	Low	Low	High
High catalyst concentration	High	High	High
High-intensity agitation	Low	Low	High

The concentration of hydrogen adsorbed on the catalyst is the factor that determines selectivity and isomer formation (Allen, 1978). If the catalyst is saturated with hydrogen, most of the active sites hold hydrogen atoms and the chance is greater that two atoms are in the appropriate position to react with any double bond upon approach. This results in low selectivity, since the tendency will be toward saturation of any double bond approaching the two hydrogens. On the other hand, if the hydrogen atoms on the catalyst are scarce, it is more likely that only one hydrogen atom reacts with the double bonds, leading to the half-hydrogenation-dehydrogenation sequence and a greater likelihood of isomerization.

Catalysts vary with regard to the degree of selectivity they provide. Nickel on various supports is almost invariably used commercially to hydrogenate fats. Other catalysts, however, are available. These include copper, copper/chromium combinations, and platinum. Palladium has been found to be considerably more efficient (in terms of the amount of catalyst required) than nickel, although it produces a high proportion of *trans*-isomers. The so-called homogenous catalysts, which are soluble in oil, provide greater contact between oil and catalyst and better control of selectivity. A host of different compounds are capable of poisoning the catalyst used, and these compounds are often the major source of problems encountered during commercial hydrogenation. Poisons include phospholipids, water, sulfur compounds, soaps, certain glycerol esters, CO_2, and mineral acids (Fennema, 1996).

3.3.2.9 Mouth Feel

Mouth feel is dependent on three factors: (1) temperature, (2) taste sensation, and (3) texture. The texture of a food fat is influenced by the liquidity of the product. It imparts tenderness and richness and improves the eating quality of the prepared food. Mouth feel can apply to either the ability of liquid oils to form an oily film, which is viscosity related, or how well a solid fat melts in the mouth to give a pleasant cooling effect instead of a pasty, waxy feeling that can mask desirable flavors. The melting point of common triglyceride mixtures can be separated into four liquidity zones to indicate their physical states at chilled, room, body, and heated temperatures. Triglycerides in the chilled-temperature zone will remain liquid under cool conditions. Room-temperature triglycerides will remain liquid only if consumed at ambient temperatures or higher. The third zone of triglycerides melts near body temperature to give a cooling effect in the mouth. The high-melting triglycerides help maintain plasticity until baking or cooking temperatures are attained. It should be noted that fats and oils are not composed of a single triglyceride or even a single liquidity zone and that the ratio of each particular triglyceride will determine the melting behavior. In most cases, a liquid oil fraction suspends a solid fat fraction in a seemingly solid product, whereas apparently liquid oil usually contains dissolved solid fractions; therefore, it is the predominance of triglycerides from one of the zones that determines liquidity characteristics (Bessler. and Ortheoefer, 1983; and Broady& Cochran, 1978).

3.3.2.10 Characteristics of fats and oils

The characteristics of the fats and oils selected for a particular application are of primary importance in the design of a product for a specific or general-purpose use. Formulation of margarines, shortenings and other fat-based products must be based primarily on an understanding of the relationships between specific physical measurements and the composition of the oil blends and their components along with an appreciation of processing effects. Blending and processing achieve desirable solids-to-liquid ratios. The crystalline structure of fats is important in formulation of shortening, margarine, and other fat products because each crystal form has its own physical property for plasticization, hardness, softness, texture, solubility, mouth feel, aeration, and other properties, depending on the food in which this ingredient is incorporated. Oils are chosen for their peculiar crystal habits resulting from nature or processing conditions. Each fat or oil component has an inherent crystallization tendency that can be modified with various processes to help produce the desired properties. Hydrogenation has been the primary process used to change the physical properties, but interesterification and fractionation can also be used to modify the melting rate and range properties.

The physical characteristics of a fat or oil are dependent upon the degree of unsaturation, the length of the carbon chains, the isomeric forms of the fatty acids, molecular configuration, and the type and extent of processing.

(a.) Degree of Unsaturation of Fatty Acids : Food fats and oils are made up of triglyceride molecules which may contain both saturated and unsaturated fatty acids. Depending on the type of fatty acids combined in the molecule, triglycerides can be classified as mono-, di-, and tri-unsaturated.

Generally speaking, fats that are liquid at room temperature tend to be more unsaturated than those that appear to be solid. It is not necessarily true, however, that all fats which are liquid at room temperature are high in unsaturated fatty acids. The fats containing short chain length fatty acids have low malting point and hence they are liquid at room temperature.

The degree of unsaturation of a fat, i.e., the number of double bonds present, normally is expressed in terms of the iodine value of the fat. Iodine value is the number of grams of iodine which will react with the double bonds in 100 grams of fat. Depending on these properties, each fat / oil has its own characteristic iodine value.

(b) Length of Carbon Chains in Fatty Acids: As the chain length of the saturated fatty acid increases, the melting point also increases. Thus, a short chain saturated fatty acid such as butyric acid has a lower melting point than saturated fatty acids with longer chains. Some of the higher molecular weight unsaturated fatty acids, such as oleic acid also have relatively low melting points. The melting properties of triglycerides are related to those of their fatty acids.

(c) Melting point: Melting points of fats will vary in their sharpness depending on the number of different chemical entities which are present. A simple triglyceride will have a sharp melting point. A mixture of triglycerides, as is typical of lard and most vegetable shortenings, will have a broad melting range.

A mixture of several triglycerides has a lower melting point than would be predicted for the mixture based on the melting points of the individual components. The mixture will also have a broader melting range than any of its components. Monoglycerides and diglycerides have higher melting points than triglycerides with a similar fatty acid composition.

(e)Polymorphism of Fats: Solidified fats exhibit polymorphism, i.e., they can exist in several different crystalline forms, depending on the manner in which the molecules orient themselves in the solid state. The crystal forms of fats can transform from lower melting to successively higher melting modifications. The rate of transformation and the extent to which it proceeds are governed by the molecular composition and configuration of the fat, crystallization conditions, and the temperature and duration of storage. In general, fats containing diverse assortments of molecules (such as rearranged lard) tend to remain indefinitely in lower melting crystal forms, whereas fats containing a relatively limited assortment of molecules (such as soybean stearine) transform readily to higher melting crystal forms. Mechanical and thermal agitation during processing and storage at elevated temperatures tend to accelerate the rate of crystal transformation. The crystal form of the fat has a marked effect on the melting point and the performance of the fat in the various applications in which it is utilized.

(f) Other physical properties:

(i) Density: Density may not seem an exciting physical property to many technologists, but it is very important in the trading of oils since shipments are sold on a weight basis but measured on a volume basis. These two values are related by density, so it is important to have correct and agreed values for this unit. This is not the same for all oils. It depends on fatty-acid composition and minor components as well as on the temperature. An equation taking these variables into account is based on iodine value, saponification value and temperature (Pantzaris, 1985).

$$D = 0.8543 + 0.000308(SV) + 0.000157(IV) - 0.00068t$$

Where D =apparent density (g/ml or kg/L), SV = saponification value, IV = iodine value, and t = temperature (°C).

Density can be defined in various ways and the correct form must be used when relating volume to weight. The further detail is found in Gunstone (2000) and Gunstone (2004).

(ii) Viscosity: Viscosity can be reported as kinematic viscosity or dynamic viscosity with the two values being related through density. The viscosity of a vegetable oil depends on its chemical composition and the temperature of measurement. Equations have been derived which permit calculation of viscosity from knowledge of the other three parameters. These have been developed empirically from observation with a range of oils at different temperatures (Duff & Prasad, 1989; Toro- Vazquez & Infante-Guerro, 1993). Coupland & McClements (1997) and Fisher (1998) have related viscosity with density, refraction, surface tension and other physical properties. The relation between temperature and viscosity for selected oils has been described by several authors (Timms, 1985; Ibemesi & Igwe, 1991; Lang et al., 1992; Noureddini et al., 1992; Tasioula-Margari & Demetropoulos, 1992).

(iii) Refractive index: Refractive index increases with chain length (though not in a linear fashion) and with increasing unsaturation. Geometric isomers differ from one another and methylene-interrupted polyenes differ from those with conjugated unsaturation. Triacylglycerols have higher values than free acids.

2.3.2.11 Sources

The principal sources of fat in the diet are meats, dairy products, poultry, fish, nuts, and vegetable fats and oils. Most vegetables and fruits consumed as such contain only small amounts of fat. Knowledge of the chemical composition of fats and oils and the sources from which they are obtained is essential in understanding nutrition and biochemistry (Gunstone, 2004).

3.3.2.12 Major oils and fats

One market analyst recognises 17 commodity oils and fats and produces market data for these on a weekly basis (Oil World) and on an annual basis (Oil World Annual). These comprise 13 vegetable oils and four animal fats (butter fat, lard, tallow and fish oil). The vegetable oils may be further subdivided into three categories (Gunstone, 2004):

1. By-products, where the crop is grown for another purpose other than seed oil: cotton (fabric), corn (grain), soybean (protein-rich meal).

2. Tree crops, which are generally slow to mature but then produce crops regularly for many years: palm, palm kernel, coconut, olive.

3. Crops, which have to be replanted each year to produce an annual harvest and where decisions about cultivation are made each sowing season by a large number of individual farmers: rape/canola, sunflower, groundnut, linseed, sesame, mustard, etc.

About 80 per cent of world production of fats and oils is used as human food, a further 6 per cent in animal feed (providing further food for humans), and the remaining 14 per cent is the basis of the oleochemical industry (Gunstone & Hamilton, 2001).

Some major oils/fats used for the preparation of sel-roti and other fried products and cooking purposes are discussed as follows:

1. Soybean oil

At almost 30 million tonnes per annum, soybean oil is produced in greater amounts than any other oil. Soybeans (Glycine max) are grown mainly in the United States, Brazil, Argentina and China. When extracted, the beans provide oil (18%) and a high quality protein meal (79%) which is used both as animal feed and in many processed foods for humans. There is considerable trade in soybean oil and in the beans that are then extracted in the importing country. The main producers of soybean oil are the United States, Brazil, Argentina, China and EU-15. Soybean oil is characterized by the presence of linoleic (53%), oleic (23%), palmitic (11%), linolenic (8%) and stearic acids (4%), and is an unsaturated oil containing useful proportions of the two essential fatty acids - linoleic and linolenic (Table 3.16). Because of its high level of linoleic acid (>50%) over half its triacylglycerols contain two or three linoleic chains. Most of the remainder has one linoleic chain. In a typical analysis, triacylglycerols exceeding four per cent were LLL (17.6%), LLO (15.3%), LLP (10.2%), LLLn (7.9%), LLSt (4.2%), PLO (6.9%), OLO (6.3%), LnLO (4.8%) and others (26.8%) (Gunstone, 2004).

Soybean oil contains 8% linolenic acid and 53% linoleic acid. The linolenic acid is oxidized twice as quickly as linoleic acid and produces short-chain aldehydes with flavors that are even stronger and less acceptable than those produced from linoleic acid. The usefulness of this oil is extended by brush hydrogenation to selectively reduce the level of linolenic acid and so enhance oxidative stability, or by partial hydrogenation which further reduces the level of unsaturation, thereby producing the solid acids (saturated or trans 18:1) required to make a good quality spread. Food products containing linolenic acid therefore have shorter shelf-life than those from which this acid is absent. Food producers want to maximize shelf-life, but against this is a growing awareness that on nutritional grounds, we should reduce our intake of n-6(e.g., Linoleic) acids and increase our intake of n-3 acids (e.g., linolenic acid). Despite this, pressure to reduce the content of linolenic acid in soybean oil remains and this is being achieved slowly by breeding programmes or more quickly by brush hydrogenation (Gunstone, 2004).

Attempts are being made to modify the fatty acid composition of this oil in order to enhance its usefulness. Oils with less or more saturated acid, with less linolenic acid, and with high levels of oleic acid are in various stages of development. Crude soybean oil contains several valuable minor components that can be recovered in some measure during refining eg. Lecithin, tocopherol, and phytosterols.These are valuable byproducts (Gunstone, 2002).

2. Sunflower oil

Sunflower seed oil is obtained from *Helianthus annuus* grown in temperate zone mainly in former Soviet Union and Ukraine, Argentina, Western and Eastern Europe (especially France, Spain and Italy), China and the United States. The oil normally contains 60-75 per cent of linoleic acid with >90 per cent of oleic and linoleic acids combined and virtually no linolenic acid. Its major triacylglycerols are typically LLL (14%), LLO (39%), LLS (14%), LOO (19%), LOS (11%) and others (3%). It is widely used as cooking oil and is valued as an important component of soft spreads. It is highly favoured, especially in Europe, for its high level of linoleic acid and is an important component of margarine rich in polyunsaturated acid. High oleic varieties have been developed. Sunola (Highsun) comes from a high-oleic variety and has about 85 per cent oleic acid (some samples reach 90%). It is used to meet the growing demand for high oleic oils. NuSun with around 60 percent oleic acid has been developed in the United States and it is hoped that it will replace regular sunflower oil in that country. The fatty acid composition and triacylglycerol are given in table no 3.16(Gunstone, 1999 and Gunstone, 2004).

3. Rapeseed oil (also called canola oil): The seed oil of Brassica napus or B. campestris was typically rich in erucic acid (22:1) and the seed meal had an undesirably high level of glucosinolates. These components reduced the value of both the oil and the protein meal but they have been bred out of modern rapeseed which is now known as double zero or

canola. Rapeseed (of all kinds) is now the third largest source of oil, at 13-14 million tonnes a year, after soybean oil and palm oil. It is grown mainly in northern climes and is the only vegetable oil cultivated on a large scale in northern Europe (Sweden, Germany, France, Britain, Poland etc). It is also grown extensively in Western Europe, China, India, and Canada (where it is known as the canola oil).It is also grown in Nepal where largest quantity is used as cooking oil. Typically, it contains palmitic (4%), stearic (2%), oleic (62%), linoleic (22%) and linolenic (10%) acids and has less saturated acids than any other commodity oil. In one example, its major triacylglycerols were LnLO (8%), LLO (9%), LnOO (10%), LOO (22%), LOP (6%), OOO (22%) and POO (5%) (Gunstone, 2004 and Gunstone, 1999).

The attempt are being made to develop the varieties containing less linolenic acid or rich in lauric acid , stearic acid, oleic acid and also being made to introduce unusual acids such as petroselinic, ricinoleic acid or vernolic acid and to develop seed with still high levels of oleic or erucic acid.. An oleic- rich variety developed in Australia, called Monola, contains about 78 per cent oleic acid (Gunstone, 2004 and Gunstone, 1999).

Edible rapeseed oil is rich in oleic acid (50 – 65%), it also contains significant quantities of linoleic (20 -30%) and linolenic (6-14%) and has a lower level of saturated acids than any other commercially available oil (Gunstone, 1999).

4. Rice bran oil

Rice (*Oryza sativa*) is an important cereal with an annual production of about 600 million tonnes. The oil from rice bran is a by-product of the rice crops grown primarily for its grain. It is extracted from rice bran. Lipases, liberated from the testa and the cross cells, promote rapid hydrolysis of the oil and therefore it should be extracted within hours of milling. The major acids in rice bran oil are palmitic (12 - 28%, typically 20%) oleic (35 - 50%, typically 42%) and linoleic acid (29 - 45%, typically 32%). The oil contains phospholipids (~5%), a wax which may be removed for industrial use and unsaponifiable material. Refined rice bran oil is an excellent salad and frying oil with high oxidative stability resulting from its high level of tocopherols and tocotrienols (~860 ppm) and from the presence of the oryzanols (ferulic acid esters of sterols and triterpene alcohols, ferulic acid is 3-methoxy-4-hydroxycinnamic acid). The oxidative stability of this oil is exploited in frying oil based on oleic-rich sunflower oil with up to six per cent of added rice bran and/or sesame oil to confer high oxidative stability. Rice bran oil also has several non-food uses. Rice bran oil is reported to lower serum cholesterol by reducing LDL and VLDL without changing the level of HDL (Gunstone, 2004 and Gunstone, 1999).

Table No 3.16 Fatty Acid Compositions of Some Edible Oils and Fat

Source	16:1	18:0	18:1	18:2	18:3	others	22:1
Palm	44	4	40	10	trace	-	-
Rape(high erucic)	3	1	16	14	10	6	50
Rape(low erucic)	4	2	56	20	10	2	-
Rice bran	16	2	42	37	10	21	-
Soybean	11	4	22	53	8	2	-
Sunflower(high lonoleic)	6	5	20	69	trace	-	-
Sunflower(high oleic)	4	5	81	8	,,	2	-

Sourc: Pandey (1994)

5. Ghee

Ghee is a clarified butter without any solid milk particles or water which originated in South Asia, (Shrestha, 2003) and is commonly used in South Asian (Indian, Bangladeshi, Nepali and Pakistani), North African (Egyptian and Berber) and Horn African cuisine (Somali, Ethiopian and Eritrean). It is used in India and throughout the South Asia in daily cooking. A good quality ghee adds a great aroma, flavor and taste to the food(Shrestha, 2003).The word ghee comes from Sanskrit (ghrita) and has several names around the world (Punjabi: ghyo, Hindi: ghī, Nepali: ghyū, Urdu: ghī, Bengali: ghi, Oriya: gheeo, Marathi/Konkani: tūp, Kannada: *tuppa*, Malayalam: *ney*, Tamil: *ney*, Telugu: *neyyi*, Somali: *subaag*, Arabic: *samna*, Persian: *roghan-e khoob*).

Traditionally, ghee is made from butter churned out of yogurt (curd). It is boiled and constantly stirred until all the water is evaporated, then, further heated to get a pleasant flavor, slightly cooled and filtered through muslin to remove sediment (Shrestha, 2003). Ghee has a cooked caramellised flavour varying slightly with the method of preparation (Achaya in Gunstone & Padley, 1997; Rajah in Rossell, 1999).

Ghee, also known as clarified butter in anglophone countries, is made by simmering unsalted butter in a cooking vessel until all water has boiled off, the milk solids (or protein) have settled to the bottom, and a scum has floated on top. After removing the scum, the cooked and clarified butter is then spooned off or tipped out carefully to avoid disturbing the milk solids on the bottom of the pan (Wkipedia, the free encyclopedia). Ghee can be stored for extended periods (about 6-8months or more) without refrigeration, provided that it is kept in an airtight container to prevent oxidation and remains moisture-free. The texture, color, or taste of ghee depends on the source of the milk from which the butter was made and the extent of boiling and simmering.

Milk fat is mainly triacylglycerols (97-98%) along with some free acids, monoacylglycerols and diacylglycerols. Also present are cholesterol (0.2-0.4%), phospholipids (0.2-1.0%) traces of carotenoids, squalene and vitamins A and D.

The milk fat (especially cow milk) contains lower chain fatty acids (7%), medium chain fatty acids (5.6%) and long chain fatty acid including unsaturated ones (87.4% in which saturated 49.3 and unsaturated 38.1%). Cow milk fat contains over 500 different fatty acids. Most of these are present only at exceedingly low levels but some are important, such as the lactones which provide important flavour notes. The fatty acid composition of milk depends on the diet of the cow so that in many countries there is a difference in composition of milk fat produced during the winter when cattle are fed indoors and that produced in the summer when cattle are pasture fed. Milk fat composition can be further modified by appropriate additions to the feed (Gunstone, 2004).

Ghee prepared from cow milk is used for different Hindu religious purposes e.g., *pooja, hawan, arati, panchamrit* etc.

Ghee is widely used in different food preparation such as sel-roti, halva, laddu, sweets, kadhi, biryani, etc. It is used as ingredients and for frying medium (Wkipedia, the free encyclopedia). Ghee is an ideal fat for deep frying because its smoke point (where its molecules begin to break down) is 250°C (485°F), well above desired cooking temperatures - around 200 °C (400 °F) and above most vegetable oils.

3.3.2.13 Products prepared from fats and oils

A wide variety of products based on edible fats and oils is available to the consuming public. Shortenings, margarines, spreads, butter, salad and cooking oils, mayonnaise, salad dressing, French, Italian, and other specialty salad dressings, and confectioners' coatings are some of the widely available products that are based entirely on fats and oils or contain fat or oil as a principal ingredient. Many of these products also are sold in commercial quantities to food processors, snack food manufacturers, bakeries, restaurants, and institutions.

3.3.2.14 Deep fat frying

Fried foods have continued to be popular in spite of the current guidelines which recommend a decrease in the content of fat in our diet (Li, 2005). Frying is a fast and convenient technique for production of foods with unique sensory properties including color, flavor, texture, and palatability that are highly appreciated by consumers. Therefore, it is important to understand the frying mechanism in order to manufacture, preserve, and market fried foods optimally (Moreira *et al*., 1999).

Deep fat frying is a process in which the food is cooked by immersion in hot oil. Despite the fact that the deep fat frying industry is well-established and highly automated, the deep fat frying process is considered to be an art rather than a science (Blumenthal, 1991). It is a complex process. During deep fat frying, thermal, oxidative, and hydrolytic reactions take place resulting in physical and chemical changes in the oil and the formation of new compounds (Li, 2005). Without any treatment, the cooking oil is generally used for only about 1 to 3 days and must be discarded after such time. According, there is a need to increase the useful life of such cooking oils (Clewell and Friedman, 1976).

The useful life of cooking oil can be able to increase by the addition of various adsorbents such as natural adsorbents and synthetic adsorbents. Natural adsorbent include such materials as bentonite, zeolite, activated carbon, diatomaceous earth, active alumina and active magnesia. Synthetic adsorbents have included blends of silicates with magnesium and aluminum oxides, and aluminum oxides with diatomaceous earth (Akoh and Reynolds, 2001).

Adsorbents materials or their combinations were found to effectively useful for the control of free fatty acids, polar compounds, dielectric constant and color of used frying oil (Mancini-Filho *et al*., 1986; Yates and Caldwell, 1992, 1993). Bleaching removes color bodies, residual soaps, and phosphatides from refined oil. Bleaching is an adsorption process. The adsorbents, referred to as bleaching clays, consist of calcium montmorillonite, natural hydrated alumina silicate, silicon dioxide, or activated carbon. Bleaching consists of adding adsorbents to oil followed by heating under a vacuum for complete removal of clay adsorbents. In addition, the oil replenishment techniques have to be reported to reduce the rate of oil deterioration. It was found that fresh oil replenishment at 15% every 4 h significantly delayed an increase in polymer contents and a decrease in the induction period of frying oil. Activated charcoal powder (ACH), aluminum oxide (ALO), aluminum hydroxide (ALH), activated clay (ACL), celite (CE) and silica gel (SG), activated carbon (ACA), frypowder (FP), britesorb (BR) and magnesol (MA) are most widely used adsorbents (Chuand Lin, 1996) .

(a)The mechanics of the deep-frying process: The basic process of frying of any product eg, doughnut, potato chips, sel-roti, French fries is similar. The frying kettle or pan or any vessel is loaded with fats/oils and heated to frying temperature. The fats/oils or shortening should be carefully heated to frying temperature to avoid the danger of acorching. During the frying the product, heat is transferred from the fat to the raw material or batter very rapidly. The frying time can vary with the products (Lawson, 1997).

The frying temperature is maintained by means as direct gasfired heating tube running throughout the fryer or electric heating unit in bakery or doughnut shop or retaurant or fire from hard wood in rural household or restaurant or shops (Lawson, 1997).

The fried products become golden brown in color as they become cooked and absorb fats/oils or shortening. In the fried product such as doughnut the fat level is approximately 20 – 30%. The sufficient shortening must be absorbed in order to give their proper eating quality and texture but excessive absorption will result in unappetizing, grease-soaked products. The shortening must be filtered regularly in order to remove browned dough particles, shich can become charred and cause excessive smoking and a more rapid breakdown of the frying fat (Lawson, 1997).

(b). Changes during frying : During deep-frying of food at temperatures in the region of 170° – 200°C, the oil used come under a heavy region of 170° – 200°C, the oil used come under a heavy three-prong attack, namely:

(i). Hydrolysis: Moisture from the food being fried vaporises and hydrolyses triglycerides (TGs) in the frying oil to glycerol, free fatty acids (FFAs) monoglycerides (MGs) and diglycerides (DGs) (Dana, 2001). The rate of hydrolysis or development of free fatty acids depend on primarily on the frying temperature, the amount of moisture put through the system (from food) and the rate of turmover of shortenings (Lawson, 1997). It is the major chemical reaction taking place during frying caused by the water in the food. It results in the formation of free fatty acids. The smoked point is reduced and the oil and food develop off-flavors. Baking powder and moisture in the food promote hydrolysis (Warner, 1985).

(ii). Oxidation: Triglyceride molecules in the frying oil undergo primary oxidation to unstable lipid species called "hydroperoxides" which cleave to form secondary oxidation products which comprise non-volatile and volatile compounds. Some of these secondary products polymerize (tertiary oxidation), increasing the oil viscosity, cause browning on the surface, and darken the oil (Dana, 2001).

The important factors that affect the rate or degree of oxidation in product frying operation include frying temperature, rate of turnover and metal contamination. The most products, frying must take place at 380 – 385°F (193 – 196°C), for yeast raised doughnut, at 375°F (191°C). Therefore, the frying fats must be able to take these temperatures without resulting excessive oxidation, which tends to result in a degree of polymerization that could cause the fat to foam or result in excessive gum deposites around the frying kettle at points where hot fat, metals, and O_2 in the air came together. As with color darkening, the more rapid the replacement of used fat with fresh, the less the amount of oxidation at equilibrium frying conditions. The kettle should be of the correct size to handle the volume of product frying required. The metals containing Cu, such as bronge or brass should keep out of contact with fats/oils. These metals greatly accelerate the rate of oxidation (Lawson, 1997).

(iii).Thermal Polymerization: High temperatures of the frying operation produce high molecular cyclic fatty acid (FA) monomers, and triglycerides dimers and oligomers (Billek, 1983).

The volatile secondary oxidation products (aldehydes breakdown products, alcohol and hydrocarbons such as pentane), acrolein formed from glycerol, and short-chain fatty acids move to the surface, aided by steam formed from moisture in the food fried. Both pleasant fried flavors (contributed mainly by 2, 4-decedienal from linoleic acid) and obnoxious odors (e.g. from acrolein) are formed. Several chemical and physical processes follow, namely: i) the food being fried absorbs oil as well as releases some of its own lipid content (sometimes colored) into the frying medium, ii) charring of food particles and lipid browning darkens the oil (Henry and Chapman, 2002).

Meanwhile, the potentially hazardous non-volatile compounds gradually build-up in the fried oil. The majority of these products are called "polar compounds" (PC) formed as secondary oxidation products- e.g. epoxides, polar dimmers, oxidized polymers, ketones and aldehydes (carbonyls), as well as hydrolysis products of triglycerides such as free fatty acids, monoglycerides and diglycerides. There is much uncertainty whether these products are actually harmful to humans at habitual intakes (Tony Ng Kock Wai, 2007).

Formed at a much slower rate than PC, but also given the "bad guy" tag are the polymerized lipid species formed by tertiary oxidation and thermal polymerization. Therefore, a spectrum of physical and chemical changes, much of which are inter-related, give rise to some 140 different compounds, which would certainly keep the oil chemist busy. These physical and chemical events taking place during the deep-frying of food in oil are as shown in Figure 3.23 (Warmer, 1985).

(c)Principles of Deep-Fat Frying: Frying technology is important to many sectors of the food industry: supplier of oils and ingredients, fat-food shop and restaurant operators, industrial producers of fully fried, par-fried and snack food, and manufacturers of frying equipment. The amount of food fried and oils used at both the industrial and commercial levels are huge. A deep-fat fryer consists of a chamber where heated oil and a food are placed. The speed and efficiency of the frying process depend on the temperature and the quality of the oil. The frying temperature is usually between 150 and 190 °C. Oil turnover time (mass of used oil/oil usage rate) is around 10 hours. Frying is defined as the process

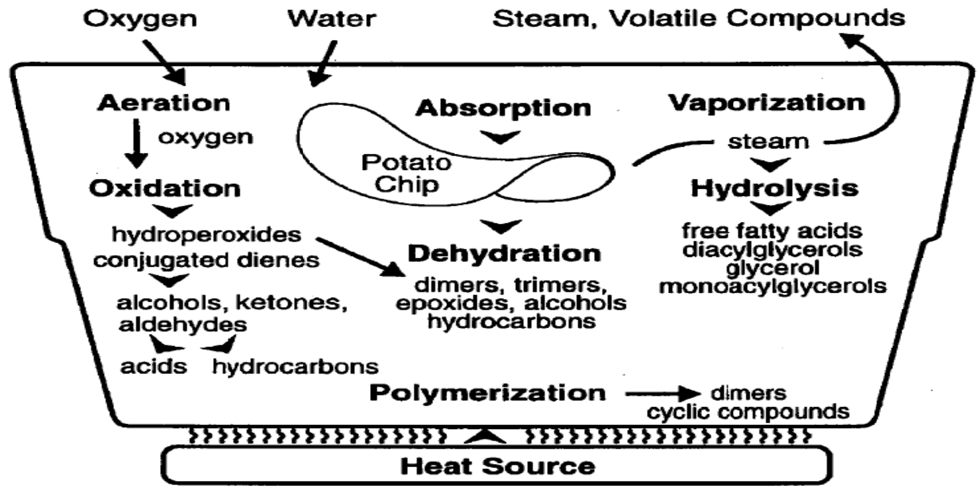


Fig.3.23 Physical and chemical reactions product that occur during frying (Warner, 2000).

of cooking and drying through contact with hot oil and it involved simultaneous heat and mass transfer. The oil not only acts as the heat transfer medium, but also enters into the product, providing flavor. (http://phoenix.eng.psu.ac.th/chem/ram/8Note.pdf)

The following factors can affect the frying process of foods: (Warner, 1985).

1. Depending on the process: a. Temperature, b. Frying time, c. Fryer type – batch vs. continuous

2. Depending on the frying oil: a. Properties of the oil – chemical and physical b. Additives and contaminants

3. Depending on the food: a. Properties of the food, b. Preparation c. Ingredients interchange with oil

(d).The Chemistry of Frying: The common element of all fats is a substance called glycerol. Also occurring in nature are compounds called fatty acids. Glycerol can combine with these fatty acids through esterification to form mono, di and triglycerides. All fats and oils are made up of a mixture of triglycerides. Some fatty acids possess double bonds and their presence tends to make these particular fatty acids more sensitive and more unstable. Many chemical reactions take place during frying and affect the quality and storage time of the oil. Several of these factors lead to the spoilage of the oil (Warner, 1985).

Isomerization and polymerization reactions occur rapidly during standby and frying periods. The molecule is rearranged and the double bonds can often end up closer together making the fat more unstable and more sensitive to oxidation (Warner, 1985).

Pyrolysis results in the extensive breakdown of the chemical structure of the fat resulting in the formation of lower molecular weight compounds (Warner, 1985).

(e) Changes in the oil during frying: Changes occur in frying fat which are characterized (Lawson, 1997) as:

1. Darkening of the frying fats, 2. Oxidation & polymerization, and 3. Hydrolysis or the development of free fatty acids. Oxidation, polymerization and hydrolysis are already discussed earlier.

Each fat and each frying system has a typical equilibrium level at which these changes are more or less stabilized. In doughnut and the other similar food products e.g, sel-roti frying system should be sufficiently efficient that it is never nessary to throw fat away (Lawson, 1997).

Color darkening: The rate of color darkening of fats/oils depends on such factors as the type of products, the equipments, and the system. The products rich in sugar (e.g, sucrose) and corn syrup (30 – 35% based on flour) will cause darkening at a more rapid rate than those containing low levels. Milk solid and egg solid are browning materials and they accelerate darkening of frying fats. The types of products have the greatest effect on darkening depending on the ingredients of the products. The more efficient the frying system, the more rapid replacement of used fat with fresh fats. Rapid turnover creates an equilibrium condition of relatively light colored oil in the system. With all other conditions being equal, the higher the frying temperature, the more rapid the rate of color darkening (Lawson, 1997).

Deep-fat frying is known to be one of the most energy extensive food processes, and there are a number of health concerns relating to fried products, principally relating to the amount of oil absorbed in the process. But it cannot be denied that fried products are universally liked and consumed. During frying, simultaneous heat and mass transfer occurs. Heat is transferred from the frying medium to the products surface by convection and from the surface to the inside by conduction. The moisture, on the other hand, is evaporated and transported from the interior to the surface of solid by diffusion, which then migrates from the surface through the frying medium (Blumenthal, 2001).

Interaction between oil and the food materials surface are complicated because of vigorous movement of water vapor bubbles escaping from food into the oil, which cause considerable turbullance and influence heat transfer coefficient (Singh, 1995). Moisture content decreases with frying time (Nema and Prasad, 2001). The oil content of fried samples increased with frying time while moisture content decreased (Ahromrit and Nema, 2010).

Totani et al (2006) found that oil absorption in commercial deep-fried food ranged between 22 and 48%. It is evident that the vegetables had oil absorption value in lowest than battered deep- fried products.

(f). Frying temperature: Deep frying is one of the methods of food preparation used both in home and in industry. Meat, fish, doughnuts, potato chips, French fries are dipped into fats /oils heated to about 180°C. After several minutes of frying, the food is sufficiently tender to be served.The frying fat /oil changes substantially in its chemical and physical properties after prolong use. The heating of oil causes reactions involving double bonds. This will result in a decrease in iodine number. As can be deduced from changes in composition of fatty acids, in case of soybean oil, linoleic acid and linolenic acid are the most affected. Peroxides formed at elevated temperature fragment immediately with formation of hydroxyl compounds thus increasing the hydroxyl number. Therefore, determination of peroxide value to evaluate the quality of fat/oil in deep frying is not appropriate. Unsaturated triglycerides polymerize during heating thus increasing the viscosity of the fat and di- and tri- meric triglycerides are formed (Belitz et.al, 2009).

In frying, food is cooked in hot fat. Fat has a much higher boiling point than water and can be heated almost to its boiling point without smoking. Frying is a quick method of cooking because of the high temperature used. In deep-frying, a deep pan and plenty of fat are used, so that when the food is added it is completely covered by the fat which should be very hot. Temperatures of between 150 to 200 °C are usually used. Such a method is quick and the food is cooked evenly on all sides. Refined vegetable oil or cooking fats which are made by hardening a bland of vegetable, animal and marine oil are best for deep-frying (Ramesh, 1999).

(g). Behaviour of the food during frying: The following events occur during frying of food (Fennema, 1996):

Water continuously released from the food into the hot oil. This produces a steam distillation effect, sweeping volatile oxidative products from the oil. The release moisture also agitates the oil and hastens hydrolysis. The blanket of steam formed above the surface of oil tends to reduce the amount of O_2 available for oxidation. Volatiles (eg. surface compounds and pyrazine derivative in potato) may develop in the food itself or from the interaction between food and oil. Food absorbs varying amount of oil during deep frying (eg. potato chips absorbs about 35% fat), resulting in need for frequent or continuous addition of fresh oil. The food itself can release some of its endigenous lipids (eg. fat from chicken) into the frying fat and consequently the oxidative stability of the new mixture may be different from that of the original frying fat. The presence of food causes the oil to darken at an accelareted rate.

(h). Behaviour of frying oil: The following classes of compounds are produced from the oil during frying (Fennema, 1996):

Volatiles like aldehydes, ketones, hydrocarbon, lactones alcohol, acids and esters are formed, however, a balance is achived between formation of the volatiles and loss through evaporation or decomposition. Other compounds formed are non polymeric polar compounds of moderate volatility; dimer and polymeric acids and dimeric and polymeric glycerides, free fatty acids. All of these cause physical and chemical changes in oil which cause increase viscosity and free fatty acids contents, development of dark colour; decrease iodine value and surface tension; change in Refractive Index and increase tendncy to foam.

(i). Deep-Fat Fryers

The processes used to fry food products can be divided into two broad categories: (1) Batch fryers which are static and smaller, and used in the catering restaurants, (2) Continuous fryers which are large and used in the food industry (R.D. *et.al.* 2000).

1. Batch Frying Systems: Batch fryers should be of the appropriate size and installed in the proper number. Other factors such as (a) fuel source (b) speed of temperature recovery, and (c) safety should be taken into consideration when selecting a frying apparatus (R.D. *et.al.* 2000).Different types of batch fryers include: gas-fired, electric, and pressure fryers.

2. High-Capacity Frying Systems: The industrial fryer consists of several basic components, which are familiar for both continuous and batch systems. In designing a continuous fryer, factors, such as the amount of food, the conveyor system, the food characteristics, and the handling system after the frying are important to effectively produce high quality products. An oversized fryer can be very inefficient, causing severe oil degradation, creating cleanup problems, and resulting in poor quality of the product. It is better to design a fryer for maximum efficiency in producing one product type than multiple products inefficiently (R.D. *et.al.* 2000).

A continuous fryer system consists of at least five independent set of equipment: (1) the kettle or tank containing the frying oil, (2) a heating unit with a control system for generating thermal energy, (3) a conveying system for moving the product into, through, and out of the frying process, (4) a fat system, which pumps and filters the frying oil, and (5) an exhaust system for removing the hot vapours emerging from the product (R.D. *et.al.,* 2000).

3.3.3 Sugar

Only a few of the sugars occurring in nature are used extensively as sweeteners. Besides sucrose (saccharose), other important sugars are glucose, invert sugar, maltose, lactose, and fructose. In addition, some other sugars and sugar alcohols (polyhydric alcohols) are used in diets or for some technical purposes. These include sorbitol, mannitol, maltitol etc. Some are used commonly in food and pharmaceutical industries (Belitz et.al 2009).

Sucrose is widely distributed in nature, particularly in sugar cane 12−26%; sweet corn 12−17%; sugar millet 7−15%; palm sap 3−6%); in fruits and seeds (stone fruits, such as peaches, pineapples, and in roots and rhizomes (sweet potatoes 2−3%; peanuts 4−12%; onions 10−11%; beet roots and selected breeding forms 3−20%). The two most important sources for sucrose production are sugar cane (Saccharum officinarum) and sugar beet (Beta vulgaris ssp. vulgaris var. altissima) (Belitz et.al 2009).

Sucrose is the most economically significant sugar and is produced industrially in the largest quantity. Sucrose is known under many trade and popular names. These may be related to its purity grade, to its extent of granulation or crystal size (icing, crystal, berry and candy sugar, and cube and cone sugar) and to its use (canning, confectionery or soft drink sugar). Liquid sugar is a sucrose solution in water with at least 62% solids (Belitz et.al 2009).

The chemical composition of a given type of sugar depends on the extent of sugar refination.The sucrose content of sugar ranges from 96 – 100 % (Belitz et.al, 2009).

Sucrose has maximum stability in alkaline pH. The thermal stability of sugars is also quite variable. Sucrose and glucose can be heated in neutral solutions up to 100°C, but fructose decomposes at temperatures as low at 60°C. Sugar alcohols are very stable in acidic or alkaline solutions (Belitz et.al, 2009).

Sugar is a basic ingredient of *Sel-roti* and is used to provide sweetness *in Sel-roti* and adds the calories value. Sugar dissolves at the time of kneading. Sugar develops the characteristic color which is due to caramelization during frying. *Shakkhar* or *Mishri* can be used as alternatives for sugar. Addition of shakkhar gives more intense dark red color. The quantity of sugar used depends on the taste but higher sugar burst the crumb and it also burns the crust fast (Personal communication, 2007).

Nutritionally speaking, sugar and other sweeteners provide little except calories. However, they do help make food more palatable, which can be critically important in a crisis situation. Popular sweeteners include white sugar, brown sugar, honey, maple syrup, and molasses. Honey and white sugar have the longest shelf life of all the sweeteners; both can be kept indefinitely if stored properly.

Sugar performs the following functions (Lawson, 1997):

- Adds caloric food value
- Improves keeping quality. High amount of sugar as well as the use of invert sugar and glucose , honey may further improve keeping quality,
- Improve the grain and texture. Product containing ample amount of sugar have a softer, richer texture and a more uniform grain,
- Improve flavor and
- Helps in color formation from carmelization.

3.4 Microbiology and biochemical changed in *Sel-roti* batter

Sel-roti is a unique fermented cereal food of the Nepali people in the Himalayas. Fermentation takes place due to the growth of lactic acid bacteria and yeast, during ageing process of batter for the preparation of *Sel-roti* (Yonzan and Tamang, 2010). Lactic acid bacteria (LAB): Leuconostoc mesenteroides, Enterococcus faecium, Pediococcus pentosaceus, and Lactobacillus curvatus; yeasts: Saccharomyces cerevisiae, S. kluyveri, Debaryomyces hansenii, Pichia burtonii, and Zygo- saccharomyces rouxii (Yonzan, 2007).

Yonzan and Tamang (2010) studied and reported first on the microbiology and nutritive vlue of sel-roti batter. They collected selroti batter samples from different villages and markets of Dargeeling and Sikkim; different restaurants, local food stalls, and canteens at Gantok in Sikkim; and lab-samples and studied microbial load, isolation, characterization, and identification of microbes, their antimicrobial and enzymic activities, seasional variations of their presence, and biochemical changes i.e., nutritive value of *sel-roti* batter. They reported their result as follows:

In home-made samples of selroti batters, the microbial populations of LAB (Lactic acid bacteria) and yeasts were 10^4 to 10^8 cfu/g and 10^4 to 10^5 cfu/g, respectively. The average count of LAB and yeasts in market samples of fermented batters was 10^8 cfu/g and 10^5 cfu/g, respectively, whereas the microbial population of LAB and yeasts in lab-made samples was 10^7 cfu/g and 10^5cfu/g, respectively. Mycelial fungi, Bacillus cereus, Listeria sp., Salmonella sp., and Shigella sp. were not detected in any sample of fermented batters. No bacterial contaminants were detected in any sample of lab-made sel-roti batters

A total of 167 bacterial isolates were isolated from sel-roti batters collected from different sources. All bacterial isolates were considered lactic acid bacteria. The most dominant LAB (Lactic acid bacteria) in all samples of sel-roti batters were *Leuc. mesenteroides* at 42.9%, followed by *P. pentosaceus* (23.8%), *E. faecium* (20.4%), and *L. curvatus* (13.0%) out of 167 strains of LAB.

A total of 141 yeast isolates were isolated from *sel-roti* batters collected from different sources. The most dominant yeast recovered in all samples of selroti batters were *S. cerevisiae*, which represented 35.6% of all yeasts, followed by *D. hansenii* (17.6%), *P.burtonii* (17.1%), *Z. rouxii* (16.3%), and *S. kluyveri* (13.4%) out of 141 isolates of yeasts.

Food-borne pathogens *Bacillus cereus, Listeria sp., Salmonella sp.* and *Shigella sp.* were not detected in any sample of fermented batters of selroti due to the slightly acidic nature of the products. High population (>10^8 cfu/g) of LAB in *sel-roti* batters could restrict the growth of other organisms simply by their physical occupation of available space and uptake of most readily assimilative nutrients (Adams and Nicolaides, 1997). Lactic acid produced by LAB may reduce pH to a level where pathogenic bacteria may be inhibited (Tsai and Ingham, 1997; Adams and Nout, 2001). Another safety aspect of selroti is deep frying prior to consumption. There has been no report of any food poisoning or infectious disease infestation by consuming *sel-roti*.

It was observed that seasons affect the prevalence of microorganisms in the fermented batters. During summer, the microbial load of LAB increased due to a rise in temperature, which may accelerate fermentation rate; winter was favorable for yeasts. Similar observation on effect of seasonal variation was made during idli fermentation favoring the bacterial load (Soni et al., 1986).

Moisture content in *Sel-roti* batters was higher than that of raw materials due to soaking prior to fermentation and to the addition of water and milk during its preparation. The content of reducing sugar, total sugar, fat, and carbohydrate in selroti batters increased compared to the raw materials. There was a remarkable increase in water-soluble and TCA-soluble nitrogen in selroti batters due to solubilization of proteins, indicating its protein digestibility. Increase in free amino acids in tarhana has been reported (Erbas et al., 2005). The energy value of fermented batters increased slightly more than the unfermented raw materials. Contents of sodium and calcium increased in fermented products Food value of *sel-roti* batters are almost same as reported in other fermented cereal foods such as idli (Soni and Sandhu, 1989) and tarhana (Erbas et al., 2005).

They concluded that lactic acid bacteria and yeasts co-exited as the predominant organisms in *sel-roti*, enhancing the functional properties as well as food value of the product. The isolated microorganisms may contribute to the development of the unknown microbial resources in commonly consumed ethnic foods in the Himalayas. Development of these microbial resources has benefits for development of specific starter cultures and also use of unique microbial processing for development of functional foods using cereals of the Himalayas as fundamental resources to add value.

Table No 3.17 Proximate composition of *Sel-roti* batter.

	Raw materials [a]		Fermented product
Parameter	Rice (n = 6)	Wheat flour (n = 6)	Selroti batter (n= 46)
pH	5.50 ± 0.10	5.90 ± 0.10	5.80 ± 0.40
Titratable acidity % (as lactic acid)	0.09 ± 0.01	0.1 ± 0.01	0.08 ± 0.01
Moisture %	16.30 ± 0.40	18.40 ± 0.70	42.50 ± 4.60
Reducing sugar %	0.01 ± 0.01	0.02 ± 0.01	2.10 ± 0.50
Total sugar %	63.80 ± 0.90	58.40 ± 1.20	69.20 ± 4.40
Ash (% DM)	0.70 ± 0.06	0.50 ± 0.07	0.80 ± 0.08
Fat (% DM)	1.00 ± 0.01	0.90 ± 0.01	2.70 ± 0.30
Water-soluble nitrogen (% DM)	0.02 ± 0.01	0.06 ± 0.01	0.06 ± 0.02
TCA-soluble nitrogen (% DM)	0.0016 ± 0.001	0.0017 ± 0.003	0.004 ± 0.002
Protein (% DM)	8.30 ± 0.01	11.00 ± 0.50	5.70 ± 0.50
Carbohydrate (% DM)	90.00 ± 1.00	87.60 ± 0.90	91.30 ± 0.60
Sodium (mg/100 g)	5.90 ± 0.70	5.90 ± 0.50	8.90 ± 0.60
Potassium (mg/100 g)	47.40 ± 1.10	117.50 ± 2.50	29.70 ± 1.10
Calcium (mg/100 g)	9.40 ± 0.50	20.80 ± 0.20	23.80 ± 1.60
Energy value (Kcal/100g DM)	402.20 ± 0.40	402.50 ± 0.50	410.30 ± 0.50

n, total number of samples (n) collected from each source is given in parenthesis.

Data represent the means (± SD) of triplicate of each sample.

DM = dry matter. TCA = trichloro-acetic acid. a - Raw materials purchased from Gangtok.

3.5 Changes on heating

(a) Physical changes: In cooking process with heat and water, the hydrogen-bond network are altered and reformed. In case of starch containing materials, the starch granules swell and eventually brust releasing the polysaccharide components. This 'gelatinization' phenomenon is of very great importance, for it is this changing which is the essence of the conversion of raw starch to metabolize carbohydrate. The starch granule is not chemically homogenous, and can be separated into at least two distinct fractions: amylose and amylopectin. On cooking rice, these two components are released (Priestley, 1979).

(b). Chemical changes: First, Maillard reaction occurs when carbohydrates are heated in the presence of amino acids. In this reaction, the reducing part of a sugar molecule reacts with suitable nitrogen compounds such as amino acids and proteins. The reaction may be inhibited by certain food additives such as sulphur dioxide and is dependent on such factors as temperature, acidity and water activity. The reaction rate can double or trible for every 10°C rise in temperature. As pH increases, browning increases and the browning rate is also much influenced by water activity. Second, there is the chemical change brought about by interaction with lipids. Not much is known of the nature of these interactions, but it is thought that an amylose-lipid complex may control many of the physical changes undergone by rice starch on heating such as gelatinization and solubility. Third, there is the chemical change brought about by interaction with enzymes. The solubility of amylases during cooking of starch is important, since this governs the course of dextrinization and saccharification which occurs in baking. Lastly, there is the chemical change brought about by interaction with minerals. As the rice is heated the granules swell and burst above gelatinization temperature releasing amylose and amylopectin (Spicer, 1975*)*.

(c). Biological changes: The most important biological change in starch brought about by heating is that of making the carbohydrate accessible to enzyme in the digestive tract. Another important biological change in heating is the loss of nutritional value of the food (Springer, 1999).

3.6 Food Texture

According to Oxford English Dictionary (1989) the texture is defined as "the constitution, structure or substance of anything with regard to its constituents, formative elements". After various attempts of defining food texture, some international agreement has reached in ISO(International Organization for Standardization [1992]), and this defines texture as "All the mechanical, geometrical and surface attributes of a product perceptible by means of mechanical, tactile and, where appropriate, visual and auditory receptors." Clearly, food texture is about perception, making it above all other things a human experience. It is about our perception of a foodstuff that originates in that product's structure and how the product behaves when handled and eaten. Furthermore, it incorporates all the attributes (mechanical, geometric, and surface) of the food, suggesting that the experience of texture is one of many stimuli working in combination (Rosenthal, 1999).

Food texture can be defined as the way in which the various constituents and structural elements are arranged and combined into a micro- and macrostructure and the external manifestations of this structure in terms of flow and deformation. Most of our foods are complex physicochemical structures and, as a result, the physical properties cover a wide range from fluid, Newtonian materials to the most complex disperse systems with semisolid character. There is a direct relationship between the chemical composition of a food, its physical structure, and the resulting physical (texture) or mechanical properties (deMan. 1999).

Bearing above given definitions in mind, is it reasonable to presume that such a complex array of interactions of stimuli could be measured instrumentally? Have any relation of the results produced from instrumental method to human perception? Prior to the 1940s, it was generally considered that sensory measurements of food texture were purely subjective and as such generally unreliable. Variation in individuals as well as variability of any one person from day to day seemed to make the sensory analysis of food an art and not worthy of serious scientific study. It was inconceivable that an individual's response could be anything other than personal, hedonic, and prejudiced by that person's beliefs and biases. Since our scientific ethos was founded on reproducibility, most serious researchers were persuaded to rely on instrumental testing techniques carried out under standardized conditions. Such techniques were considered to be reliable, with relatively small inherent variation or error. An attitude developed in which instrumental tests were referred to as "objective" while sensory work was designated as being "subjective" (Rosenthal, 1999).

In these early years of texture measurement, the study of texture focused on the efforts of the rheologist, who measured flow and deformation of food materials. In his discussion paper "Is Rheology Enough for Food Texture Measurement?" Bourne (1975) suggested that rheological measurements, which often focus on a single large deformation, resulting in the sample's breaking into pieces, were inadequate in defining food texture. When an individual eats a foodstuff, the sample is chewed beyond this initial breakdown, and the stimuli that result form part of the overall texture sensation. While the initial bite is an important aspect of texture, so too are the subsequent bites, the viscosity, stickiness, and consistency of the food as it mixes with saliva. Equally important are aspects of the food's appearance, the mechanical properties, and sounds that occur when it is handled, cut, and eaten. Clearly, rheology is not enough to explain all the rich and complex aspects of texture that are experienced by humans (Rosenthal, 1999).

Attitudes about the objectivity of sensory research began to change shortly after the Second World War. After researches conducted on food acceptability and choice, development of controlled sensory testing procedures, the separation (in people's minds) between "sensory" and "affective" tests, and advances in multivariate statistical techniques that were made possible by the application of relatively powerful computers, all helped to bring the perception of sensory testing into scientific respectability (Rosenthal, 1999).

Without a doubt, texture plays a key role in our appreciation of food. Our perception of food texture often constitutes a criterion by which we judge its quality and is frequently an important factor in whether we select an item or reject it. We squeeze and prod fruits and cheese to gauge their ripeness and tilt bottles to estimate the viscosity of their contents. Texture can be expressed in the sounds that foods make when handled, to the extent that we listen to foods to estimate their quality. Familiarity with a product brings knowledge about how its texture and behavior change during processing and storage. With continued contact with a specific food, certain individuals have developed great expertise, to the extent that they become expert judges of that product's quality. Such individuals often determine the texture of foods with empirical test methods such as prodding, tapping, or squeezing. These so-called "foreman's finger tests" have become established measures of quality for some products and may even set market prices. Surely, if an individual can assess texture by prodding, then a machine that prods and measures the force involved will give a reproducible measure of that aspect of texture and therefore quality. By applying suitable calibration, we are able to create machines that might provide information that formerly only our expert could offer (Rosenthal, 1999).

Having accepted the idea that a machine might take the place of a human to assess food texture, we must remember that before all else, food texture is essentially a human experience that arises from our interaction with food. It is worthwhile to be cautious when considering physical test procedures, for data can be collected by subjecting any material to any procedure, but results from the test do not necessarily mean anything in terms of texture. Such a comment is not intended to disqualify instrumental tests that may not relate directly to human perception, for such procedures may be valid for all kinds of other reasons. For example, viscosity of a liquid is frequently measured to gain an idea of resistance to flow and therefore the pumping requirements to push the fluid down a pipe (Rosenthal, 1999).

Human perception of food has been described as a cyclic process that starts with an anticipation originating primarily from visual cues but also flavored by our prior experiences.

Various aspects of appearance, such as color, size, and shape, as well as aspects of structure (e.g., openness), preempt our physical interaction with the food (Kramer, 1973). Though not always associated with texture perception, visual cues provide a gauge of viscosity (Shama, Parkinson & Sherman, 1973) and the "wobbly" behavior of semisolid, jelly like foods. Our participation leads to manual manipulation either directly or with tools (e.g., cutting with a knife). Visually perceived changes in the food with handling add to our impressions of the food's texture. Even before the food is in the mouth, we have gathered a substantial amount of knowledge about the food's texture from visual, tactile, and even auditory stimuli.

Initial perception in the mouth (i.e., without biting) is at a relatively low shear rate due to only touch and with small amount of deformation. With no shear at all, we gather impressions about the food's homogeneity, such as the presence, size, and shape of particles or air cells. At slightly higher shear rates caused by movement of the tongue, the food is deformed and flows. Under these conditions, characteristics such as elasticity, stickiness to the palate, and viscous behavior are perceived (Sherman, 1969).

During the first few chews, much of the structure is broken. Brittle materials fracture, fibrous materials are torn, and the food is kneaded and mixed with saliva to form a coherent bolus (Heath, 1991). During these chewing cycles, a high degree of shearing is achieved, and a wide variety of textural characteristics are perceived. Attributes that relate to physical makeup (e.g. hardness-softness) and deformation and breakdown (e.g. brittleness, plasticity, crispness, and sponginess) are detected (Sherman, 1969).

Movement of the jaw during subsequent chewing cycles is more regular than in the early stages of mastication. During this period, saliva is secreted into the bolus as it is further kneaded prior to swallowing. Textural attributes perceived are those that relate to the particular nature (e.g. smoothness, coarseness, powderiness, lumpiness, and pastiness), consistency (e.g. creaminess, wateriness), and adhesion to the palate (e.g. stickiness).

Hutchings and Lillford (1988) developed a model to explain the breakdown path to which a food is subjected before it is ready for swallowing. During mastication, the structure is broken down by mechanical action. Lubrication is due in part to the release of saliva during chewing but also arises from the composition of the food in terms of moisture and fat, both of which act as lubricants. Changes in structure and lubrication occur until a threshold is reached, at which point the material is swallowed.

After swallowing, we perceive a residual masticatory impression that arises from the remains of disintegrated food and any mouth coating materials. Such attributes include meltdown properties on the palate, greasiness, gumminess, and stringy sensations (Sherman, 1969).

Since perception is a cyclic process, the information gathered during the handling, biting, chewing, and swallowing feeds back into our anticipation of the next portion.

Many stimuli contribute to our perception of texture, including visual and auditory cues as well as those related to touch and movement. Visual and auditory cues are gathered through specialized sense organs—the eyes and ears. In contrast, the sensors of material characteristics are spread throughout the body, sometimes being categorized as those sensitive to touch *(somasthesis)* and movement/ position *(kinesthesis).* Various skin organelles have been identified, which have been associated with the perception of certain attributes. In addition to the tactile sense organelles in the hard and soft palate, tongue, gums, and periodontal membrane surrounding the teeth, there are vitally important nerve endings in the oral muscles and joints. Signals from these nerves provide information on jaw position, muscle tension, and length.

In comparison to the sensing apparatus of the human body, instrumental testing devices rely on transducers to convert material and physical measurements into visual or electrical outputs that can be either observed directly or fed into data-recording/processing equipment.

Instrumentation depends on the type of test being performed, but for mechanical testing, it often involves strain gauges and load cells to measure forces and position or movement detectors. Crucial to the type of test being applied is the geometry of the test cell and how the sample is held. Tests carried out on solid and viscoelastic materials are often done under compression, shear, torsion, or tension.

Successful transducers usually have a linear response that, through calibration with standards, can represent defined physical characteristics in terms of absolute units. In contrast, human perception is governed by psychophysical phenomena, which tend to be nonlinear. The body adapts to the forces that are exerted, being most sensitive when small forces are applied.

Moreover, the response to a stimulus is most noticeable when a change in that stimulus occurs; if the stimulus is held constant, the response lessens with time. Factors like temperature are frequently influential on rheological behavior and consequently most apparatus for measurement of such parameters will be accurately thermostated. Typical instrumental methodology would involve introducing the sample to the device and leaving it to reach a steady temperature before the physical test is applied. But this approach is quite different from what occurs in the mouth during eating. While the temperature within the center of the body is fairly constant at 37°C, the mouth is normally a few degrees below that. Food that is introduced is rarely at the same temperature, and there follows a brief change in the temperature of the food, which may lead to a change in its physical behavior. A well known example of how this temperature change affects the texture of food is provided by chocolate and ice-cream when they are taken into mouth (Schlichter-Aronhime & Garti, 1988).

In addition to thermal melting, the presence of saliva within the mouth leads to a dissolution of water-soluble materials. Saliva is a dilute non-Newtonian liquid that contains digestive enzymes (α amylase) as well as a variety of unusual proteins and polypeptides. Histatins, for example, are a group of polypeptides found only in saliva that have exceptional antibacterial properties (Schenkels, Veerman, & Amerongen, 1995). Saliva acts as a lubricant as well as a solvent, allowing food materials to be effectively dissolved and broken down during mastication. Most rheological test equipment does not have any facility to introduce a solvating lubricant onto the sample during testing.

The speed of movement of the jaw and the tongue within the mouth is a critical factor in our perception of food texture. Tornberg et al. (1985) showed that when chewing meat, the jaw can move at between 200 and 400 cm/ min in contrast to typical instrumental testing machines, which operate around at 20 cm/ min. Bearing in mind that only a few liquid foods behave as Newtonian, while most foods are non-Newtonian, and their apparent viscosity will depend on the shear rate applied. Shama and Sherman (1973) matched shear rates applied in an instrumental test with those that might be experienced in the mouth, and showed that the measured viscosity instrumentally might not equate to what would be perceived orally. They also showed that the shear rate applied in the mouth actually depends on the viscosity of the food, such that low-viscosity foods receive relatively high shear rates while high viscosity foods tend to be sheared more slowly.

The action of mastication and secretion of saliva combine in the breakdown path until the bolus is suitable for swallowing (Hutchings & Lillfbrd, 1988). Clearly, this is a time-dependent process and one in which the nature of the food, and hence its texture, is changing. Few instrumental tests consider this kind of broad time frame; in fact, most focus on the first or the first and second bites. While a considerable amount of the structural breakdown may occur during these early parts of mastication, other sensory attributes experienced closer to the time of swallowing frequently do not get evaluated.

A key aspect of food texture is that it can arise from a combination of physical properties; sensations such as wetness have been attributed to the simultaneous stimuli of cold and pressure, while stickiness is due to the sequence of a gentle pressure followed immediately by pulling on the skin (Szczesniak, 1990). Despite these multifarious sensations, few texture- measuring instruments focus on more than one physical property at a time.

3.6.1 Classification of Textural Properties

Most studies in which the importance of different sensory modalities to consumer acceptability is investigated conclude that flavor is the most important modality, followed by texture and then appearance. Research with consumers carried out by some researchers showed that awareness of texture lies at a subconscious level and that textural properties are taken for granted. If the expectations of texture are violated, however, awareness of textural defects is accentuated, and texture becomes a focal point for criticism and rejection of the food. Expectations are being increasingly recognized as important factors in food choice by consumers.

Bourne (1982) classified textural characteristics into three groups:

critical*:* those foods for which texture is the dominant quality characteristic for example meat, potato chips, celery.

important*:* foods in which texture makes a significant, but not dominant, contribution in comparison with flavor and appearance for example, fruits, bread, and sugar confectionery

minor*:* foods in which texture makes a negligible contribution to overall quality for example, beverages and thin soups

Such a classification is quite arbitrary but is potentially useful to both product developer and sensory analyst.

Some researchers showed that the awareness of texture depended on factors such as gender (women were more texture conscious than men), experience (people working with food were texture conscious), socioeconomic class (consumers in higher socioeconomic groups were more texture conscious than those in the lower groups), and food type (bland, crispy, and crunchy foods provoked greater texture awareness). They also investigated the possibility that there might be innate preferences for specific textures (Kilcast, 1999).

The complex nature of food texture has led to several attempts to design classification schemes to aid the assessment of food texture and to classify specific terms. The most extensive and important early studies were carried out by Szczesniak and colleagues at General Foods in the United and published papers. These initial papers formed the basis for the Texture Profile Method, described further below, and the starting point lay in the classification scheme described in the first paper in this sequence (Szczesniak, 1963). Three categories of textural characteristics were defined in that paper:

1. mechanical characteristics relating to the reaction of food to stress

• primary parameters: hardness, cohesiveness, viscosity, elasticity, adhesiveness

• secondary parameters: brittleness, chewiness, gumminess

2. geometrical characteristics relating to the size, shape, and orientation of the particles within the food for example, powdery, gritty, lumpy, flaky, fibrous, cellular, aerated, crystalline.

3. other characteristics relating to the perception of the moisture and fat contents of the food, for example, dry, moist, oily.

In practice, the temporal nature of sensory perception was also recognized, and the attributes were divided into initial (first bite), masticatory, and residual (after-swallowing) phases.

An alternative classification scheme was proposed by Sherman (1969) in which three categories were defined.

1. primary-fundamental property of the food; geometric characteristics such as particle size, shape, size distribution, air content, cell size, cell size distribution, cell shape

2. secondary-derived by a combination of two or more attributes in unknown proportion; rheological characteristics such as viscosity, elasticity, adhesion

3. tertiary-subdivided according to the type of process involved:

• mastication: hard, soft, brittle, plastic, crisp, rubbery, spongy, smooth, coarse, powdery, lumpy, pasty; creamy, watery, soggy, sticky, and tacky.

• disintegration: greasy, gummy, stringy, melt-down properties.

• nonmasticatory: appearance; sampling and slicing characteristics; spreading, creaming characteristics, pourability.

The need to take these classifications further to a more practical level was recognized by Jowitt (1974), who proposed a system of definitions for textural terms. The terms were classified into the following groups:

1. general structure, texture, consistency

2. terms relating to the behavior of the material under stress or strain—for example, firm, chewy, stringy, rubbery,sticky, glutinous, brittle, crumbly, crisp.

3. terms relating to the structure of the material

• relating to particle size or shape for example, smooth, chalky, gritty, mealy

• relating to shape and arrangement of structural elements for example, flaky, stringy, aerated, glassy, gelatinous,spongy

4. terms relating to mouth-feel characteristics for example, body, watery,greasy, slimy, mushy, astringent, cooling.

Among the varieties of terms used for describing the textural characteristics, some textural terms which have direct practical importance have received particular attention and have been the subject of numerous studies (Guinard & Mazzucchelli, 1996). These terms include firmness and hardness, crispness and crunchiness, creaminess, smoothness, viscosity- related properties, juiciness, astringency, and carbonation.

3.6.2 Instrumental Measurement of Texture

Scott-Blair (1958) categorized the instrumental techniques used to measure food texture into three groups:

1. empirical tests, which measure something physical under well-defined conditions

2. imitative tests, which attempt to simulate the conditions to which the material is subjected in the mouth

3. fundamental tests, which measure well-defined physical properties such as viscosity or elastic modulus

Advances in medical instrumentation have created a fourth category of techniques that examine the neurophysiology of the eating experience. The test is Physiological Tests.

(a). Empirical Tests: By definition, empirical tests are developed by experimentation and observation, and as such they may lack a rigorous scientific basis. However, in some sectors of the food industry, empirical tests act as standards that are used to grade food quality. For example, the Adam's consistometer is used as a standard test to ascertain the quality of apple puree or creamed corn. The working principle and procedure is found elsewhere. Empirical tests have been criticized as usually being specific to particular narrow ranges of products. Each empirical test measures characteristics of the food in an arbitrary way, and since they are uniquely different from each other, they tend not to compare well and cannot be used predictively (Bagley & Christiansen, 1987).

(b). Imitative Tests: Imitative tests attempt to mimic mastication with some kind of machine that chews the food. The machine is instrumentated to provide measurements of stress and/or strain during the test sequence. Some machines actually incorporated human dentures that rocked over each other, imitating the movement of the jaw. While there is some sense in creating a test cell with a geometry similar to the human mouth, gaining data from the machine depends on other factors such as the type and position of the sensors and the relative motion of the jaws. However, some minor modifications, such as replacing the dentures with plungers of known cross-section area so that defined stresses can be applied, allow them to yield valuable data for comparative applications such as quality assurance.

An imitative test that has caught the imagination of many food technologists because it purports to provide standardized values of food texture is *Texture Profile Analysis* (TPA). Szczesniak and her coworkers defined a variety of textural terms (Szczesniak, 1963). These were tested by employing trained assessors on different food products.

In addition to these sensory standards, a compressive force-deformation instrument was described (Friedman, Whitney, & Szczesniak, 1963). Based on an instrument that deformed the food via a pivotal motion (resembling the human jaw), the General Foods Texturometer used a flat-ended plunger to contact the food sample. In an attempt to relate the sensorial texture definitions already defined ,a mathematical function was attributed to each term on the basis of the data from the texturometer's stress-strain curve, which was achieved through "careful experimentation and consideration of the important dependent variables" (Friedman et al., 1963). Illustrations of how these instrumental measures were determined have been incorporated into fig.3.24.

It is evident that the development of TPA has proved a valuable aid to assessing food texture. However, care should be exercised in accepting the results for purposes other than comparative evaluation. The technique is clearly imitative of what goes on in the mouth.

But it should be noted that quite apart from the differences, identified earlier, between instrumental and human testing (e.g. temperature control, saliva), the relationships between some of the sensory characteristics that TPA purports to measure are not linear. Despite some shortcomings, the greater availability of other force-deformation compressive testing machines on the market has encouraged transposing TPA to other instruments for comparative tests. For example, Bourne (1966) substituted an Instron Universal Testing Machine and performed TPA to compare pears at different stages of ripeness

As long as TPA is limited to comparative testing, some of its shortcomings may not matter, but if workers overlook such points and treat the instrumental analogues of these sensory terms as absolute values, the basis becomes risky. Szczesniak and Hall (1975) recognized this potential for abuse and stated that "proper use of the Texturometer is still much of an art since the operator must supply the thinking of which the instrument is not capable".

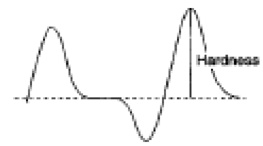
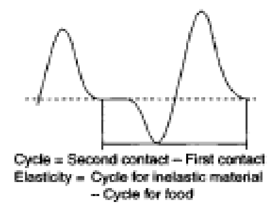
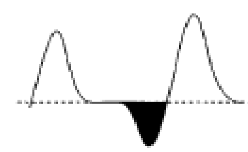
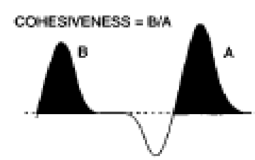
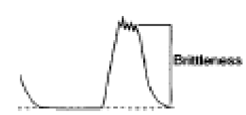
(c). Fundamental Tests: Fundamental tests measure innate physical properties of materials such as their Young's modulus or Poisson's ratio. Such tests are scientifically rigorous, and data are expressed in well-defined scientific units. Moreover, relationships between fundamental properties of materials allow prediction of values for one property based on known values for others for e.g. coefficient of viscosity of food.

Knowledge of fundamental physical properties of food can be very valuable for reasons other than establishing food texture for example, developing packaging material to prevent bruising of fruits.

(d). Physiological Tests: In recent years, considerable interest has been paid to measuring physiological activity during eating. Various techniques have been used to investigate characteristics such as jaw movement, muscle activity (electromyography), and sounds made during mastication (gnathosonics) (Boyar & Kilcast, 1986a).

Food texture can be evaluated by mechanical tests (instrumental methods) or by sensory analysis. In the latter case, we use the human sense organs as analytical tools. A proper understanding of textural properties often requires study of the physical structure. This is most often accomplished by light and electron microscopy, as well as by several other physical methods. X-ray diffraction analysis provides information about crystalline structure, differential scanning calorimetry provides information about melting and solidification and other phase transitions, and particle size analysis and sedimentation methods provide information about particle size distribution and particle shape (deMan, 1999).

Fig. 3.24 Parameters Measured by Texture Profile Analysis:

Parameter	*Sensorial Definition*	*Instrumental Definition*
Hardness	Force required to compress a food between the molars.	
Elasticity	The extent to which a compressed food returns to its original size when the load is removed.	
Adhesiveness	The work required to pull the food away from a surface.	
Cohesiveness	The strength of the internal bonds making up the food.	
Brittleness	The force at which the material fractures. Brittle foods are never adhesive.	
Chewiness	The energy required to chew a solid food until it is ready for swallowing.	= Hardness × Cohesiveness × Elasticity
Gumminess	The energy required to disintegrate a semisolid food so that it is ready for swallowing.	= Hardness × Cohesiveness

In the study of food texture, attention is given to two interdependent areas: the flow and deformation properties and the macro and microstructure. The study of food texture is important for three reasons (deMan, 1999):

1. to evaluate the resistance of products against mechanical action, such as in mechanical harvesting of fruits and vegetables,

2. to determine the flow properties of products during processing, handling, and storage, and

3. to establish the mechanical behavior of a food when consumed.

There is sometimes a tendency to restrict texture to the third area, although the other two are equally important. Because most foods are complex disperse systems, there are great difficulties in establishing objective criteria for texture measurement. It is also difficult in many cases to relate results obtained by instrumental techniques of measurement to the type of response obtained by sensory panel tests.

The terms for the textural properties of foods have a long history. Many of the terms are accepted but are often poorly defined descriptive terms (deMan 1999). Following are some examples of such terms:

• Consistency denotes those aspects of texture that relate to flow and deformation. It can be said to encompass all of the rheological properties of a product.

• Hardness has been defined as resistance to deformation.

• Firmnessis essentially identical to hardness but is occasionally used to describe the property of a substance able to resist deformation under its own weight.

• Brittlenessis the property of fracturing before significant flow has occurred.

• Stickinessis a surface property related to the adhesion between material and adjoining surface. When the two surfaces are of identical material, the term cohesionis used.

A variety of other words and expressions are used to describe textural characteristics, such as body, crisp, greasy, brittle, tender, juicy, mealy, flaky, crunchy, and so forth. Most have no objective physical meaning and cannot be expressed in units of measurement that are universally applicable (deMan, 1999). Many of these terms have been discussed by Szczesniak (1963) and Sherman (1969); and Kokini (1985) has attempted to relate some of these ill defined terms to the physical properties involved in their evaluation. Through the years, many types of instruments have been developed for measuring certain aspects of food texture. Unfortunately, the instruments are often based on empirical procedures, and results cannot be compared with those obtained with other instruments. Recently, instruments have been developed that are more widely applicable and are based on sound physical and engineering principles.

3.6.3. Texture Profile

Texture is an important aspect of food quality, sometimes even more important than flavor and color. Szczesniak and Kleyn (1963) conducted a consumer-awareness study of texture and found that texture significantly influences people's image of food. Texture was most important in bland foods and foods that are crunchy or crisp. The characteristics most often referred to hardness, cohesiveness, and moisture content. Several attempts have been made to develop a classification system for textural characteristics. Szczesniak (1963) divided textural characteristics into three main classes, as follows:

1. mechanical characteristics,

2. geometrical characteristics, and

3. other characteristics, related mainly to moisture and fat content.

Mechanical characteristics include five basic parameters:

1. Hardness: the force necessary to attain a given deformation.

2. Cohesiveness: the strength of the internal bonds making up the body of the product.

3. Viscosity: the rate of flow per unit forces.

4. Elasticity: the rate at which a deformed material reverts to its undeformed condition after the deforming force is removed.

5. Adhesiveness: the work necessary to overcome the attractive forces between the surface of the food and the surface of other materials with which the food comes in contact (e.g. tongue, teeth, and palate).

In addition, there are other three following secondary parameters:

1. Brittleness: the force with which the material fractures. This is related to hardness and cohesiveness. In brittle materials, cohesiveness is low, and hardness can be either low or high.

Brittle materials often create sound effects when masticated (e.g. toast, carrots, celery).

2. Chewiness: the energy required to masticate a solid food product to a state ready for swallowing. It is related to hardness, cohesiveness, and elasticity.

3. Gumminess: the energy required to disintegrate a semi-solid food to a state ready for swallowing. It is related to hardness and cohesiveness.

Geometrical characteristics include two general groups: those related to size and shape of the particles, and those related to shape and orientation, these include smooth, cellular, fibrous, and so on. The group of other characteristics in this system is related to moisture and fat content and includes qualities such as moist, oily, and greasy. A summary of this system is given in Table 3.18.

Based on the Szczesniak system of textural characteristics, Brandt et al. (1963) developed a method for profiling texture so that a sensory evaluation could be given that would assess the entire texture of a food.

The Szczesniak system was critically examined by Sherman (1969), who proposed some modifications. The Sherman system contains three groups of characteristics (Fig. 3.25). The primary category includes analytical characteristics from which allother attributes are derived. The basic rheological parameters, elasticity, viscosity, and adhesion form the secondary category; the remaining attributes form the tertiary category since they are a complex mixture of these secondary parameters. This system is interesting because it attempts to relate sensory responses with mechanical strain-time tests. Sensory panel responses associated with masticatory tertiary characteristics of the Sherman texture profile for solid, semi-solid, and liquid foods are given in Fig. 3.26.

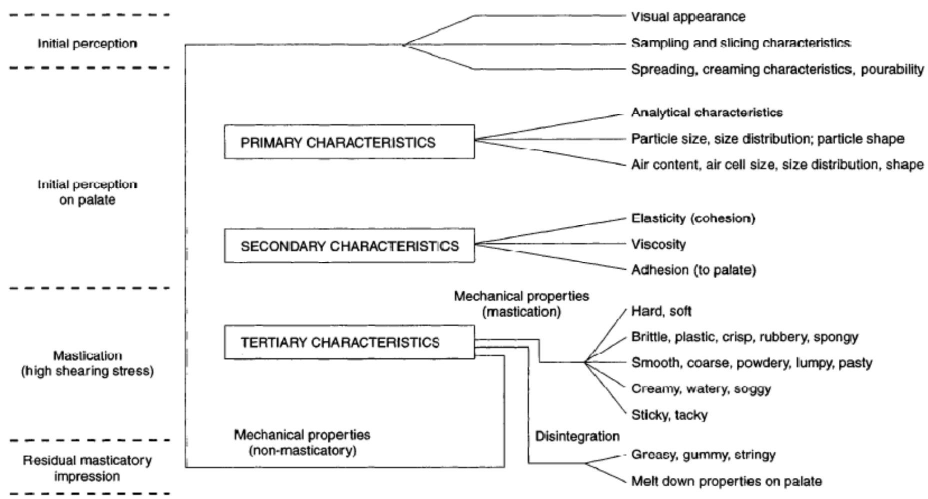


Fig.3.25 The Modified Texture Profile (Sherman, 1969)

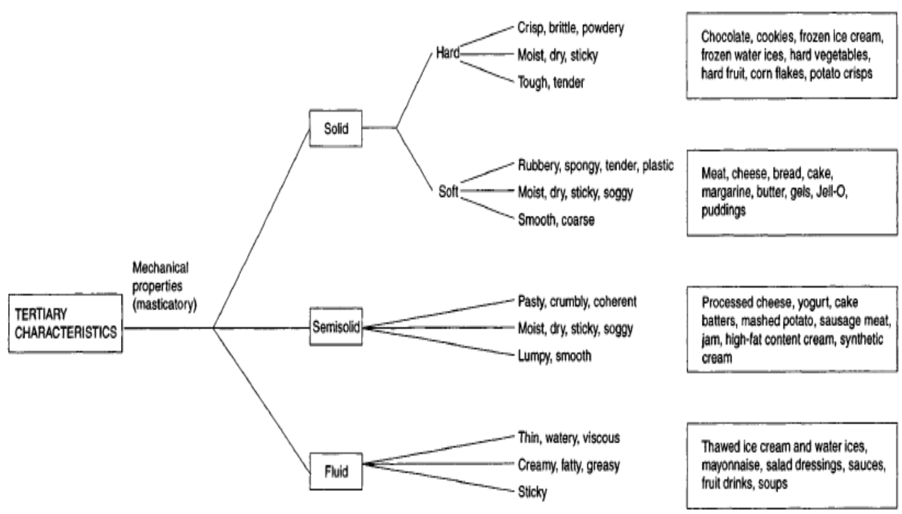


Fig. 3.26 Panel Responses Associated with Masticatory Tertiary Characteristics of the Modified Texture Profile

Table No 3.18. Classification of Textural Characteristics

MECHANICAL CHARACTERISTICS

Primary Parameters	*Secondary Parameters*	*Popular Terms*
Hardness		Soft → Firm → Hard
Cohesiveness	Brittleness	Crumbly → Crunchy → Brittle
	Chewiness	Tender → Chewy → Tough
	Gumminess	Short → Mealy → Pasty → Gummy
Viscosity		Thin → Viscous
Elasticity		Plastic → Elastic
Adhesiveness		Sticky → Tacky → Gooey

GEOMETRICAL CHARACTERISTICS

Class	*Examples*
Particle size and shape	Gritty, Grainy, Coarse, etc.
Particle shape and orientation	Fibrous, Cellular, Crystalline, etc.

OTHER CHARACTERISTICS

Primary Parameters	*Secondary Parameters*	*Popular Terms*
Moisture content		Dry → Moist → Wet → Watery
Fat content	Oiliness	Oily
	Greasiness	Greasy

Source: Szczesniak, (1963)

3.6.4 Objective Measurement of Texture

The objective measurement of texture belongs in the area of rheology, which is the science of flow and deformation of matter. Determination of the rheological properties of a food does not give complete texture of the product, but gives knowledge of some of the rheological properties of a food which is important to its acceptability as well as determining the nature and design of processing methods and equipment. Food rheologyis mainly concerned with forces and deformations. In addition, time is an important factor; many rheological phenomena are time-dependent. Temperature is another important variable. Many products show important changes in rheological behavior as a result of changes in temperature (deMan 1999).

In addition to flow and deformation of cohesive bodies, food rheology includes such phenomena as the breakup or rupture of solid materials and surface phenomena such as stickiness (adhesion) (deMan 1999).

Deformation may be of one or both of two types, irreversible deformation, called flow, and reversible deformation, called elasticity. The energy used in irreversible deformation is dissipated as heat, and the body is permanently deformed. The energy used in reversible deformation is recovered upon release of the deforming stress, when the body regains its original shape (deMan 1999).

(a). Force and Stress: When a force acts externally on a body, several different cases may be distinguished: tension, compression, and shear. Bending involves tension and compression, torque involves shear, and hydrostatic compression involves all three. All other cases may involve one of these three factors or a combination of them. The forces acting on a body can be expressed in grams or in pounds. Stress is the intensity factor of force and is expressed as force per unit area. There are several types of stress: tensile stress; and shearing stress. A uniaxial stress is usually designated by the symbol δ, a shearing stress by τ. Shear stress is expressed in dynes/cm^2 when using the metric system of measurement; in the SI system it is expressed in N/m^2 or pascal (P) (deMan 1999).

(b). Deformation and Strain: When the dimensions of a body change, it is deformation. Deformation can be linear, as in a tensile test when a body of original length L is subjected to a tensile stress. The linear deformation ΔL can then be expressed as strain $\varepsilon = \Delta L/L$. Strain can be expressed as a ratio or percent; inches per inch or centimeters per centimeter. In addition to linear deformations, there are other types of deformation, such as in a hydrostatic test where there will be a volumetric strain $\Delta V/V$ (deMan 1999).

(c). Viscosity: The relationship between shearing stress and rate of shear can be used to define the flow properties of materials. In the simplest case, the shearing stress is directly proportional to the mean rate of shear $\tau = \eta\dot{\gamma}$. The proportionality constant T is called the viscosity coefficient, or *dynamicviscosity,* or simply the viscosity of the liquid. The metric unit of viscosity is the dyne.s cm^{-2}, or Poise (P). The commonly used unit is 100 times smaller and called centiPoise (cP). In the SI system, η is expressed in N.s/m^2. Or Pa.s. Therefore, 1 Pa.s = 10 P = 1000 cP. Materials that exhibit a direct proportionality between shearing stress and rate of shear are called Newtonian materials. These include water and aqueous solutions, simple organic liquids, and dilute suspensions and emulsions. Most foods are non-Newtonian in character, and their shearing stress-rate-of shear curves are either not straight or do not go through the origin, or both. This introduces a considerable difficulty, because their flow behavior cannot be expressed by a single value, as is the case for Newtonian liquids (deMan 1999).

The ratio of shearing stress and rate of shear in such materials is not a constant value, so the value is designated *apparent viscosity*. To be useful, a reported value for apparent viscosity of a non-Newtonian material should be given together with the value of rate of shear or shearing stress used in the determination. The relationship of shearing stress and rate of shear of non-Newtonian (deMan 1999) materials such as the dilatant and pseudoplastic bodies of Figure 3.28 can be represented by a power law as follows (deMan 1999):$\tau = A\dot{y}^n$

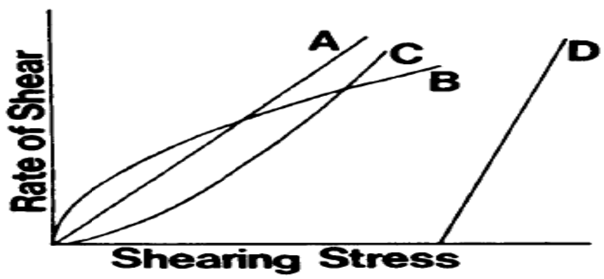


Fig.3.27. Shearing stress-rate of Shear digram, (A) Newtonian, viscous flow, (B) Dialetant flow (C) Pseudoplastic flow, (D) Plastic flow.

Where *A* and *n* are constants. *A* is the consistency index or apparent viscosity and *n* is the flow behavior index. The exponent is $n = 1$ for Newtonian liquids; for dilatant materials, it is greater than 1; and for pseudoplastic materials, it is less than 1.

3.6.5. Principles of Measurement

For Newtonian fluids, it is sufficient to measure the ratio of shearing stress and rate of shear from which the viscosity can be calculated. This can be done in a viscometer, which can be one of various types, including capillary, rotational, falling ball, and so on. For non-Newtonian materials, such as the dilatant, pseudoplastic, and plastic bodies the problem is more difficult.

3.6.6 Microstructure

With only a few exceptions, food products are non-Newtonian and possess a variety of internal structures. Cellular and fibrous structures are found in fruits and vegetables; fibrous structures are found in meat; and many manufactured foods contain protein, carbohydrate, or fat crystal networks. Many of these food systems are dispersions that belong in the realm of colloids.

Colloids are characterized by their ability to exist in either the sol or the gel form. In the former, the dispersed particle exists as independent entities; in the latter, they associate to form network structures that may entrap large volumes of the continuous phase. Disperse systems can be classified on the basis of particle size. Coarse dispersions have particle size greater than 0.5 μm. Colloidal dispersions have particles in the range of 0.5 μm to 1 μm. These particles remain in suspension by Brownian movement and can run through a paper filter but cannot run through a membrane filter. A solid dispersed in a liquid is called a sol e.g. margarine, which has solid fat crystals dispersed in liquid oil, is a sol. Dispersions of liquid in liquid are emulsions e.g. milk and mayonnaise. Dispersions of gas in liquid are foams e.g. whipped cream (deMan 1999).

The size of dispersed particles has a profound effect on the properties of dispersions (Schubert 1987). As particle size decreases, fracture resistance increases. The particles become increasingly uniform, which results in a grinding limit below which particles cannot be further reduced in size. Wetting becomes more difficult as size decreases. The specific surface area (the surface per unit volume) increases rapidly with decreasing particle size.

Colloidal systems, because of their large number of dispersed particles, show non-Newtonian flow behavior.

3.6.7. Water Activity and Texture

Water activity (a_w) and water content have a profound influence on textural properties of foods. Three regions of the sorption isotherm can be used to classify foods on the basis of their textural properties (Figure 3.28). Region 3 is the high moisture area, which includes many soft foods. Foods in the intermediate moisture area (region 2) appear dry and firm. At lowest values of a_w (region 1), most products are hard and crisp (Bourne 1987). Katz and Labuza (1981) examined the relationship between a_w and crispness in a study of the crispness of popcorn (Fig. 3.29). They found a direct relationship between crispness and $a_{w.}$

Many foods contain biopolymers and low molecular weight carbohydrates. These can be presented in a metastable amorphous state that is sensitive to temperature and the state of water. The amorphous state can be in the form of a rubbery structure or a very viscous

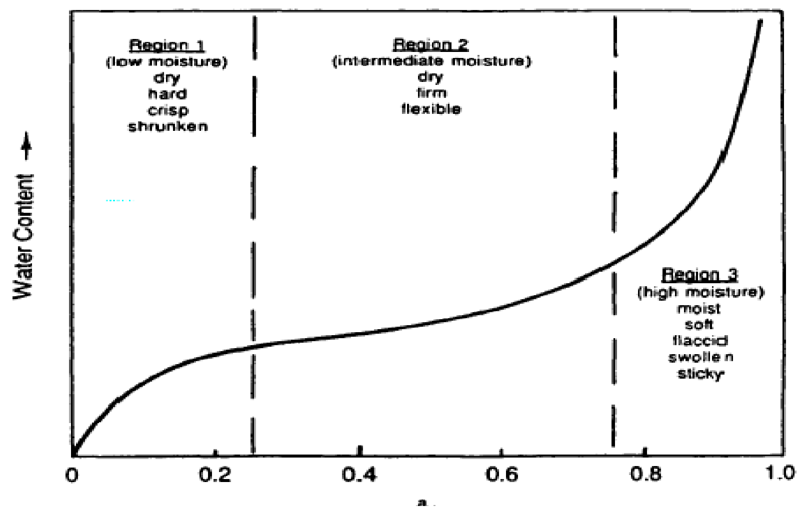


Fig. 3.28. Three Regions of the Sorption Isotherm Related to the Textural Properties of Food Systems (Bourne1987)

glass, as shown in Fig. 3.30 (Slade and Levine 1991; Levine and Slade 1992; Roos and Karel 1991). A more detailed analysis of the effect of temperature on textural properties expressed as modulus is presented in Figure 3.31). Below the melting temperature, the material enters a state of rubbery flow. As the temperature is lowered further, a leathery state is observed. In the leathery region the modulus increases sharply, until the glass transition temperature (Tg) is reached and the material changes to a glass.

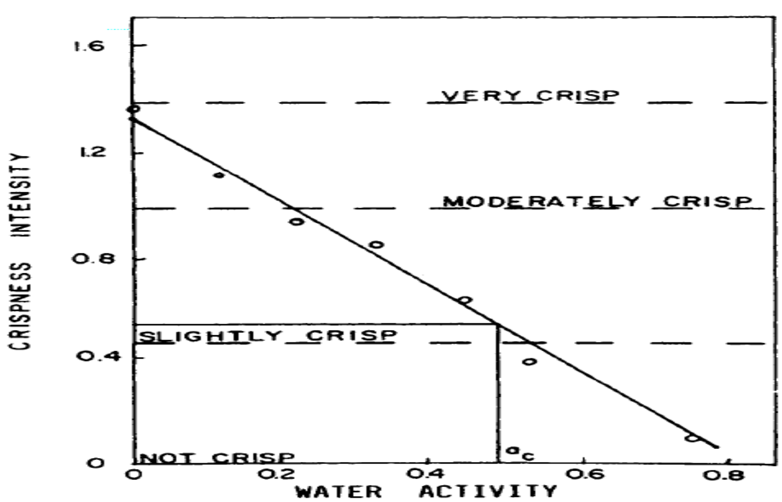


Fig. 3.29 Relationship between a_w and Crispness of Popcorn (Katz and Labuza, 1981).

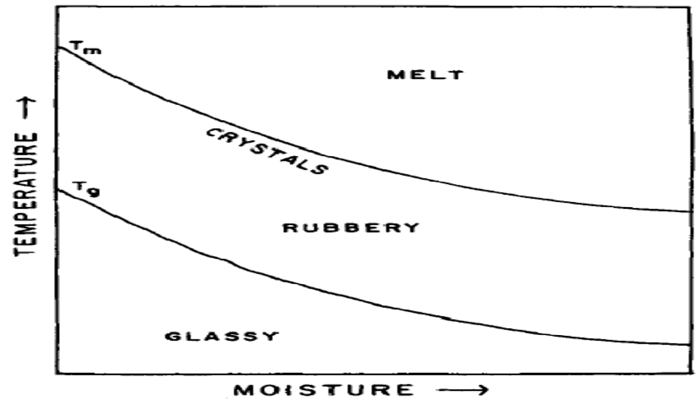


Fig.3.30 Rubbery and Glassy State of Moisture-Containing Foods as Affected by Temperature. Tm = melting point; Tg = glass transition temperature.

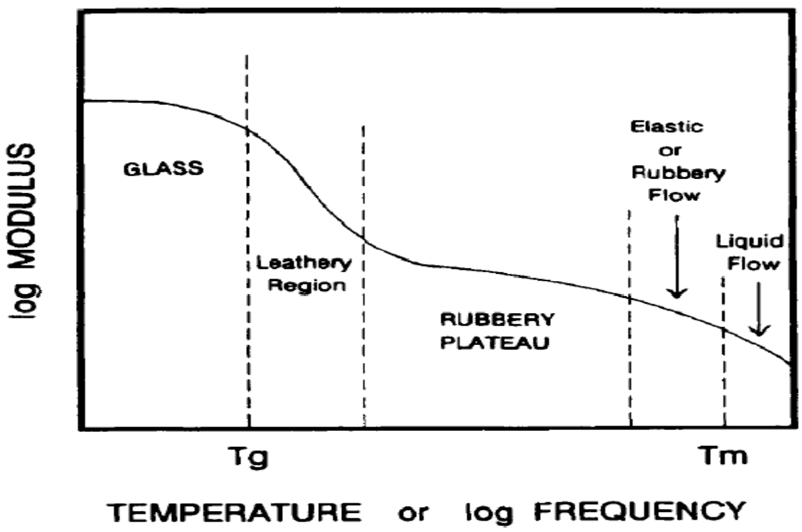


Fig.3.31. Effect of Temperature on the Texture as Expressed by Modulus. Tm = melting temperature, Tg = glass transition temperature.

3.6.8. Sensory Evaluation of Texture of Foods

The perception of texture involves the interaction of food with the teeth, mucosa, and saliva. It varies with each chew as particle size is reduced by comminution and as the bolus is ensalivated. When two or more materials are taken into the mouth, they interact so that the properties of the mixture may differ markedly from the individual foods if eaten in isolation, as with boiled potatoes and gravy. Any attempt at describing the texture of food should therefore take its dynamic nature into account (Heath and Frinz, 1999).

The mouth is richly innervated, and sensations that arise during chewing provide much of the pleasure that contributes to appetite. Animals have evolved sensory mechanisms to evaluate palatability by taste and texture in response to the need to evaluate the suitability of potential materials as food. Texture is especially important to herbivores, providing an assay of nutritional content (Hill & Lucas, 1996). Toughness has been shown to be an important cue in food selection: monkeys show a marked preference for tender young (protein-rich) leaves over tougher (high fiber) mature leaves. Their decision on whether to eat the leaves appears to be made after rubbing the leaves between the fingers and taking a small trial bite; tough old leaves are rejected while less tough, more nutritious leaves are eaten (Choong et al., 1992).

The evaluation of the palatability of food begins even before it is placed in the mouth. If it can be said that "the first bite is made by the eyes," the second is made by the hands as the food is handled. For foods from which a portion must be bitten off (e.g. an apple), the force required to bite off the piece of food provides an assessment of its mechanical properties. Some of this information is derived from periodontal receptors in the incisors (Simet al., 1993) but some is also derived from proprioception in the arm.

The most sensitive oral sensors are in front of the mouth, allowing the food to be rejected easily. But as anyone who has had to give a tablet to a dog will know, once the food item reaches the back of the mouth it is almost invariably swallowed.

In addition to the nutritional assay of food, an assessment of the food's potential to abrade the teeth is important. For many animals, life span is determined by tooth wear, so it is of vital importance that an animal detect and if possible avoid abrasive food items (Utz, 1983). The wear of teeth is becoming an increasing dental problem as more people keep their natural teeth throughout life.

Mastication:

Mastication, the first stage in the digestion of food, is a complex process whereby food taken into the mouth is processed into a form suitable for swallowing. This involves the breakdown of the food into smaller particles, the incorporation of saliva, the agglomeration and shaping of the resultant mixture into a cohesive bolus, and finally the transport of the bolus to the pharynx to prepare for swallowing. Even foods that can be swallowed whole are generally chewed to some extent. For many processed foods, chewing is physiologically unnecessary, but the drive to chew remains. Probably a number of factors give a masticatory drive. Chewing releases flavor and smell, increasing the pleasure to be derived from the food, but no single factor such as particle size, viscosity, or the persistence of taste gives simple correlations with the number of chews

made prior to swallowing. Masticating is effected by voluntary muscles that are normally unconsciously controlled by a wide range of sensory stimuli from the mouth (Takada et al. 1994), although conscious interference with the reflex patterns is possible. The inputs to the masticatory control system are the sensations arising in the oral mucosa, periodontium, teeth, muscles, and receptors in the temporomandibular joint (TMJ). The outputs are the control of bite force, mandibular trajectory, soft tissue behavior, and initiation of swallowing. By comparing how different foods are chewed, we can gain an insight into the sensory mechanisms by which the food is assessed.
The masticatory sequence can be divided into three phases: (a) ingestion—transfer of food to between the teeth by the tongue, (b) main sequence rhythmic chewing in which the food is comminuted and the bolus formed, and (c) clearance and swallowing. Texture is evaluated during all three stages.

The physical properties of food can be divided into two broad classifications; intrinsic and extrinsic (Fig. 3.32). The intrinsic properties are those such as hardness, strength, and elasticity, which are sensed mainly in terms of force-deformation behavior by the muscles of mastication during the closing stroke. The extrinsic properties are those determined by the surface characteristics, such as the particle size distribution, surface profile, and frictional coefficient, which are sensed by the tongue and mucosa mainly during the opening stroke (Chew & Lucas, 1988). The sensory homunculus illustrates the relative importance of the mouth and its sensory apparatus; although the system works together as a whole, it is possible to ascribe some aspects of sensation to individual components of the system.

Food placed on the tip of the tongue is normally transferred to the cheek teeth. In route, some foods are pressed up against the palate, a process that provides additional information on the physical properties of the food. These slow manipulations "tongue chews" typically occur with foods that are expected to be soft or for which the texture is unknown (banana, ice cream, and frozen yogurt) (Hiiemae et al., 1978; Prinz & Lucas, 1995).

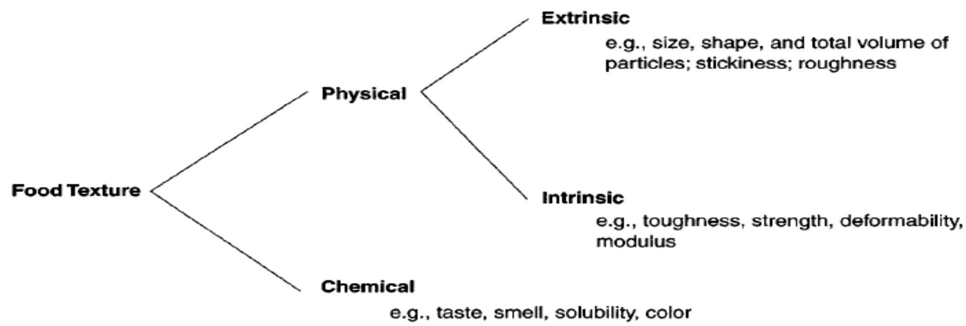


Fig.3.32 Categorizations of Perceived Food Characteristics

Perception of the extrinsic and intrinsic characteristics of different foods probably contributes to the subconscious control of the different teeth used to chew through the sequence of one mouthful. The periodontal membrane of the teeth is a very sensitive load detection system (Mioche & Peyron, 1995). Particles as small as 15 μm can be detected between teeth (Utz, 1986). The widely differing morphologies of the teeth suggest that their functions are different. The position of the bolus during chewing (and hence the teeth used) appears to be influenced by the mechanical properties of the food. The positioning of the food between the teeth is at least partially dependent on how "hard" the food is: hard foods are placed more anteriorly and are moved backwards as they fragment, imbibe saliva, and soften (Heath and Prinz, 1999).

Probably the most important phase in the assessment of texture is incision and the first manipulations. Agrawal et al., (1997) tested a range of 15 foods varying in texture from soft processed cheese to nuts. They were able to show a high correlation of masticatory muscle activity with a mechanical index E/ξ (where E is Young's modulus and ξ is toughness). This index also correlates well with the rate of production of new surface area.

Once the food has been placed between the cheek and the teeth, the jaws close and the main chewing sequence starts. The most obvious change to hard foods effected by the teeth is particle size reduction as the food is fractured. The rate of particle size reduction and the resulting particle size distributions are of obvious importance. A simple count of the number of main-sequence chewing strokes prior to swallowing provides a measure of food quality (Tornberg et al., 1985).

Clearance is performed by the tongue prior to swallowing. During the clearance phase, the tongue attempts to collect any particles that were not incorporated into the bolus.

Clearance is rarely completely successful, and many food particles are left adhering to the tongue, oral mucosa, and teeth; this debris may remain in the mouth for many minutes before it is finally removed. Swallowing is arbitrarily divided into three stages based on the position of the food bolus (Jenkins, 1977). Stage I is in the mouth and is initiated normally by a subconscious reflex. Stage II is in the pharynx and lasts only about 1 s. Stage III is in the esophagus and ends only at the entrance to the stomach. The initiation of swallowing is supposed to depend only on conditions surrounding Stage I, but information based on experience concerning Stages II and III may well influence this.

The peristaltic muscular waves of the pharynx/ esophagus may drive softer particles down to the stomach more rapidly than harder particles. Particle size, wetness, and/or plasticity as perceived orally may influence the initiation of swallowing.Hutchings and Lillford (1988) described two thresholds that need to be satisfied before swallowing is initiated: a food particle size threshold and a lubrication threshold. Although these thresholds can be quantified (Prinz & Lucas, 1995), this "two-threshold" concept appears to have deflected interest from another function of saliva, which is that it helps food particles to adhere together to form a coherent mass, the bolus.

The net sensations from the teeth, mucosa, and mandibular joint all contribute to the monitoring of food quality from first contact on the lips until after swallowing. Subconscious monitoring probably also accounts for the prompt consciousness of any discrepancy between the qualities expected by eye and hand-feel and those perceived intraorally (Heath and Prinz, 1999).

The food industry aims to produce foods that are both pleasurable and not too difficult to eat. Pleasure is derived from taste, smell, temperature, and vision. However, the perception of texture also gives pleasure and is the sensation that is the most relevant to a consideration of food structures (Heath and Prinz, 1999).

3.6.9 Relationship between Instrumental and Sensory Measures of Texture

The advantages and disadvantages of both sensory and instrumental techniques have been discussed, and while these techniques are clearly different, an understanding of the relation between them is necessary to enable correlating one with the other, as is desirable in formulating procedures such as quality control. Many researchers have investigated such relationships, and the approaches taken have been comprehensively reviewed by

Kapsalis et al., (1973); other review articles consider some of the relationships that have been found to exist (e.g. Szczesniak, 1987).

Before considering how sensory and instrumental measures of food texture interact, it is worthwhile to reflect on what is being measured and compared. Bearing in mind that texture can arise from multifarious stimuli and that most instrumental measurements tend to concentrate on one property of the food, we should not assume that there will necessarily be any relationship between an instrumental measurement and the sensory experience.

Some distinction needs to be made between trained and consumer panels of assessors. The former are often composed of individuals who have been selected on the basis of their sensory discrimination and descriptive power. Moreover, they are often trained to develop and fine-tune their power of perception. As such, they may be far more discriminating between subtle nuances of texture than members of the general public. Both trained and consumer panels have a role to play, yet that role is very different. One should not assume that the measurements of texture that come from a trained panel are similar to those perceived by a consumer panel. The consumer may not detect the same detail as the trained assessor, and as such it is probably appropriate that the consumer's opinion be the final arbiter in assessing acceptability. Nevertheless, in the past, some prestigious research institutes have claimed that their trained panel can identify quality characteristics such as acceptability in the same way as the general public.

Concepts of quality such as ripeness frequently involve changes in texture. Identifying correlations between sensory and instrumental tests can prove useful for quality assurance applications.

Texture arises from the mechanical, geometrical, and surface attributes of foods, and since these are themselves dependent on structure and chemical composition, it would seem reasonable to attempt to monitor changes in chemical composition as a measure of food texture and possibly quality. Szczesniak (1973) reviewed some of these indirect measurements of food texture.

3.6.10 Sensory Techniq ues to Study Food Texture

Eating food should be a pleasurable experience, and in developed countries in which consumers enjoy the choice of a wide range of foods, eating experiences that are not pleasurable will ultimately result in the failure of that product. If, on the other hand, the available range of foods is limited by factors such as non-availability or poverty, the eating experience is much less important than satisfying hunger and providing adequate nutritive value (Kilcast, 1999).

The consequence of examining these extreme circumstances is that we must recognize that in trying to understand what consumers' desire from food, no single factor can be considered in isolation from other factors. For some years, psychology researchers have been developing models to understand consumer behavior (e.g. Shepherd & Sparks, 1994). Although there are many possible circumstances under which non sensory factors such as price and nutritional image can have dominant effects, the sensory characteristics of foods are central to continued purchase of foods.

The sensory evaluation of food is frequently defined by the term 'tasting'. A brief moment's thought will reveal that this term is inadequate to describe all the perceptions involved in eating food. When we eat food, we perceive a whole range of different characteristics relating to the appearance, flavor, and texture of the food. Numerous tools are available for investigating the sensory properties of foods, and the information required must be carefully defined if appropriate tools are to be selected. Systematic development of new products will inevitably depend on the use of different tools at different stages of the development cycle (Kilcast, 1999).

According to the Sensory Evaluation Division of the Institute of Food Technologists (Anonymous, 1975) the sensory evaluation is defined as: "Sensory evaluation is a scientific discipline used to evoke, measure, analyze and interpret reactions to those characteristics of foods and materials as they areperceived by the senses of sight, smell, taste, touch and hearing".The definition makes clear that sensory evaluation encompasses all the senses. The definition seeks to make clear that sensory evaluation is derived from several different disciplines, but emphasizes the behavioral basis of perception. These disciplines include experimental, social, and physiological psychology, statistics, home economics, and in the case of foods, a working knowledge of food science and technology (Stone and Sidel, 2004). It is the ultimate criterion for judging the quality of food. It provides important and useful information to the food industry and food scientists about the sensory characteristics of food. It is used at several stages of new product development and for comparison of similar type of products. The field was comprehensively reviewed by Amerine et al. (1965) and more recent texts have been published by Moskowitz et al. (2006), Stone and Sidel (2004), Meilgaard et al. (2006), Kemp et al. (2009) and Lawless and Heymann (2010). As the definition implies, sensory evaluation involves the measurement and evaluation of the sensory properties of foods and other materials. Sensory evaluation also involves the analysis and the interpretation of the responses by the sensory professional; i.e. individual who provides the connection between the internal world of technology and product development and the external world of the market-place, within the constraints of a product marketing brief (Kilcast, 1999).

Sensory evaluation can be divided into two categories: objective and subjective. In objective testing, the sensory attributes of a product are evaluated by a selected or trained panel of judges. In subjective testing, the reactions of consumers to the sensory properties of products are measured and no prior training is given to them (Kemp et al. 2009). Three types of sensory testing are commonly used, discrimination testing, descriptive testing and affective testing (Lawless and Heymann 2010). Discrimination tests determine whether there are sensory differences between samples; whereas, Descriptive tests identify the nature of a sensory difference and/or the magnitude of the difference (Kemp et al. 2009; Lawless and Heymann 2010). Descriptive tests may be specific to different attributes of the food sample like, hardness, sweetness etc. And it is generally carried out with a small number (6–18) of well trained assessors (Kemp et al. 2009). Affective tests determine how much a product is preferred to consumers. One of the commonly used methods to determine the acceptability of a product is 9-point hedonic scale (Yeh et al. 1998)

3.6.11 Principles of sensory evaluation

Sensory evaluation principles have their origin in physiology and psychology. Information derived from experiments with the senses has provided a greater appreciation for their properties, and this greater appreciation, in turn, has had a major influence on test procedures and on the measurement of human responses to stimuli. As Geldard (1972) has pointed out, classically the “five special senses” are vision, audition, taste, smell, and touch. These senses are evaluated by using our sense organs like eyes, ears, tongue, nose and skin respectively.

Human beings employ a range of senses in perceiving food quality (Fig.3.33). The discussion below summarizes these senses briefly. Fuller descriptions can be found in other references.

The Human Senses

The visual senses are of particular importance in generating an initial impression of food quality that often precedes the input from the remaining senses. Indeed, if the appearance of the food creates a negative impact, then the other senses may not come into play at all. The visual sense is often equated only with color but provides input on many more appearance attributes that can influence food choice, such as size, shape, surface gloss, and clarity. In particular, the visual senses can provide an early, and strong, expectation of the flavor and textural properties of foods.

Fig. 3.33 The Human senses

Sense	Perception		
Vision	Appearance		
Gustation	Taste		⟶
Olfaction	Odor/aroma	Flavor	⟶
Chemical/Trigeminal	Irritant		⟶
Touch	Texture		
Hearing	(Texture)		

Taste (gustation) is strictly defined as the response by the tongue to soluble, non-volatile materials. These have classically been defined as four primary basic taste sensations—salt, sweet, sour, and bitter—although in some countries this list is extended to include sensations such as metallic, astringent, and *umami,* this last sensation associated with monosodium glutamate. The taste receptors are organized groups of cells, known as taste buds, located within specialized structures called *papillae.* These are located mainly on the tip, sides, and rear upper surface of the tongue. Sweetness is detected primarily on the tip of the tongue, salt and sour on the sides of the tongue, and bitter on the rear of the tongue. Taste stimuli are characterized by the relatively narrow range between the weakest and the strongest stimulants (10^{4}) and are strongly influenced by factors such as temperature and pH (Meilgaard et al., 1991).

The odor response is much more complex. Odors are detected as volatiles entering the nasal passage, either directly via the nose or indirectly through the retronasal path via the mouth. The odorants are sensed by the olfactory epithelium, which is located in the roof of the nasal cavity. Some 150 to 200 odor qualities have been recognized, and there is a very wide range (about 10^{12}) between the weakest and the strongest stimulants (Meilgaard et al., 1991). The odor receptors are easily saturated, and specific anosmia (blindness to specific odours) is common. It is thought that the wide range of possible odor responses contributes to variety in flavor perception.

Both taste and odour stimuli can be detected only if they are released effectively from the food matrix during the course of mastication.

The chemical sense corresponds to a pain response through stimulation of the trigeminal nerve. This effect is produced by chemical irritants such as ginger and capsaicin (from chilli), both of which give a heat response, and chemicals such as menthol and sorbitol, which give a cooling response. With the exception of capsaicin, these stimulants are characterized by high thresholds. The combined effect of the taste, odour, and chemical responses gives rise to the sensation generally perceived as flavor, although these terms are often used loosely (Kilcast, 1999).

Texture is perceived by the sense of touch and comprises two components: *somesthesis,* a tactile, surface response from skin, and *kinesthesis* (or proprioception), a deep response from muscles and tendons. The events contributing to texture perception are shown schematically in Figure 3.34. For many foods, visual stimuli will generate an expectation of textural properties. The touch stimuli themselves can arise from tactile manipulation of the food with the hands and fingers, either directly or through the intermediary of utensils such as a knife or spoon. Oral contact with food can occur through the lips, tongue, palate, and teeth, all of which provide textural information (Kilcast, 1999).

Colour, which is obviously an important appearance characteristic, can be shown to have an influence on flavor perception. Textural properties of foods have substantial effects on the perception of flavor, with the effect of viscosity having received particular attention.

There is the effect of viscosity on taste. Sound emission from crisp and crunchy foods has been shown to be of great importance in the perception of their texture and to form a basis for the discrimination of crisp and crunchy foods (Kilcast, 1999).

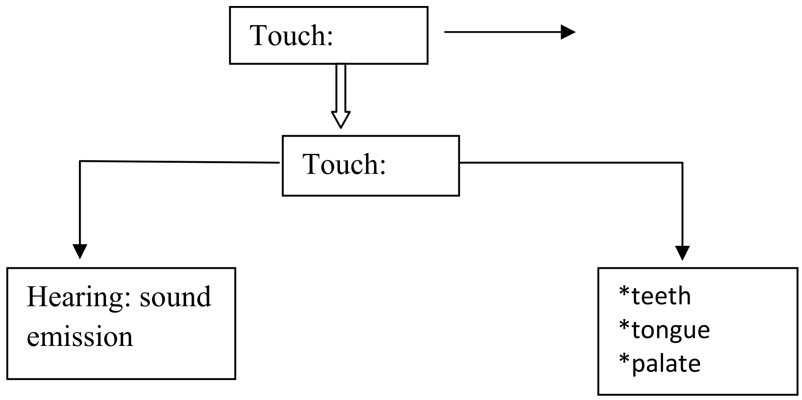


Fig.3.34 Schematic Diagram of the Processes Leading to the Perception of Texture (Kilcast, 1999).

Strong expectations of the flavor and texture characteristics can be generated before the food is introduced into the mouth. As food enters the mouth and is either bitten or manipulated between tongue and palate, catastrophic changes occur to the structure of the food that strongly influence the way in which tastants and odorants are released from the food. Of particular importance are temperature increase (cold foods) or decrease (hot foods) and dilution by saliva. Salivary introduction also serves to lubricate the food bolus. The factors that influence such release include (Kilcast, 1999): rate and mode of production of new surface, rate of production of saliva, dissolution and dispersion of the food, release of involatile tastants and volatile odorants, and transport of volatiles to the nasal cavity.

3.6.12. Factors Influencing the Quality of Sensory Data

The complex nature of food quality perception creates many difficulties for the sensory analyst, whose primary task is to use human subjects as an instrument to measure the sensory quality of foods. The factors that should be considered in assessing the performance of human subjects in this way are accuracy, precision and validity (Piggott, 1995).

The wide range of responses of human beings to sensory stimuli is reflected in highly variable (low-precision) sensory data, but the precision can be improved by careful selection of a range of human subjects who can produce a response with lower variability, and by extensive training. Improving accuracy can be achieved by recognizing the various sources of physiological and psychological biases that can influence human subjects (Meilgaard et al., 1991). Some of the most important effects are shown in Tables 3.19 and 3.20.

Other important psychological effects that are more obvious but are nevertheless frequently over-looked are those arising from unwanted interaction between assessors, from lack of motivation, and from extrovert/introvert personality traits that can influence how assessors use assessment systems. A major role of the sensory analyst lies in minimizing the effects of such biases, and consequently improving test accuracy, by careful design of the testing protocol. Of particular importance are the minimizations of adaptation, enhancement/ suppression, and contrast effects by careful selection of the type and number of samples and the elimination of presentation order effects by using

Table No 3.19 Physiological Factors Influencing Sensory Response

Name	Effect
Adoptaion	The decrease in, or change in sensitivity to, a given stimulus as a result of continued exposer to that stimulus (adaptation) or a similar stimulus (cross-adaptation). Increase in response (cross-potentiation) can also occur between different stimuli.
Enhancement	The effect of the presence of one substance increasing the perceived intensity of a second substance.
Supression	The effect of the presence of one substance decreasing the perceived intensity of a second substance.
Synergy	The effect seen when the perceived combined intensity of two subatances is greater than the sum of the individual intensities.

Table No 3.20 Psychological Factors Influencing Sensory Responses

Name	Effect
Expectation error	Information given or learned about the sample can trigger preconceived ideas and lead assessors to find what they expect to find. This is particularly prevalent threshold tests in which stimuli presented in increasing order of intensity but can be observed in many other situations.
Error of habituation	When presented with a series of samples of slowly increasing or decreasing stimuli, assessors tend to continue to give the same responses. This can result in different samples being missed, especially in routine quality testing.
Stimulus error	This error can occur when irrelevant criteria, such as packaging format, influence the observer.
Logical error	This error can occur when two or more characteristics of the samples are associated in the minds of the assessors.
Halo effect	This effect is frequently seen when multiple sample attributes are associated. The score given to one attribute can influenced the score given to different attributes. This can occur within the same sensory modality, between modalities, or between sensory and acceptabily assessments.
Presentaion order important being as follows:	There are several effects in this general categories, the most
Contrast effect	Presentation of one sample with a higher stimulus intensity than the other samples in the set will give a lower intensity rating to the other samples and can compress the range between them.
Error of central tendency	Responses are biased toward the samples presented in the centre of a set. In addition, there is an effect resulting from

	the reluctance to use scale extremes, which effectively focuces scoring to the central portion of the scale.
Pattern effect	Assessors will seek to use all available clues and to find patterns in presentation order.
Positional biases	Attitudes and judgements will change over a period of time – for example, satiation, fatigue, or boredom may affect assessors. The first sample presented in a sequence is often seen as abnormal.

balanced presentation orders. Reduction of random variation can be achieved by careful assessor selection procedures, followed by training and periodic calibration of the panel. Sensory measurement of sensory characteristics is, of course, of far greater validity than any instrumental measurement of sensory characteristics, but nonetheless great care is needed to define the nature of the data required and to select the appropriate experimental procedures (Kilcast, 1999).

3.6.13. Basic Requirements for Sensory Analysis

The principles that must be considered in satisfying the requirements and the systems that need to be implemented for their practical application are common to the investigation of all sensory modalities. Only one method has been designed specifically for assessing food texture (see the section "The Texture Profile Method"), and the remaining methods require only a change in emphasis for the investigation of specific modalities. More detailed discussions are given in standard texts (e.g.,Mason and Nottingham, 2002; Meilgaard et al., 1991; Munoz et al., 1992; Piggott, 1988; Larmond, 1977; Stone & Sidel, 2004; Watts et al., 1989).

In developing and implementing a high quality sensory evaluation system, a number of interrelated requirements can be defined (Fig.3.35*)* (Kilcast, 1999).

(a) Clear Definition of the Objectives of the Sensory Evaluation System

Clear definition of the objectives of the sensory evaluation system is central to the establishment of any system that will be of sufficient accuracy to measure the required

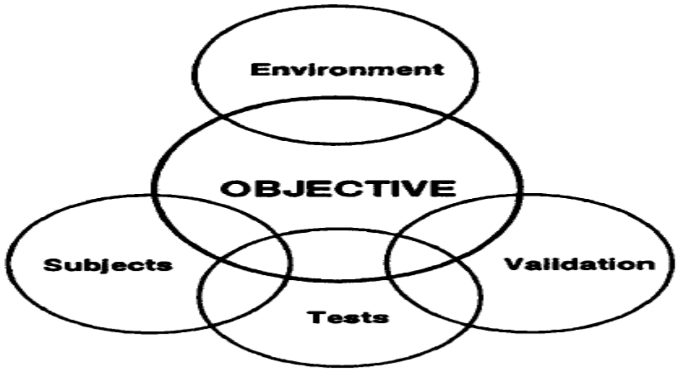


Fig. 3.35 Requirements for Formal Sensory Analysis and Their Relationships.

parameters with maximum precision and that will be cost-effective. Factors that need to be considered include (Kilcast, 1999)

• The primary purpose of the system*:* for research and development and quality assurance purposes; different facilities, assessors, and locations may be needed.

• To whom, and by what route, the sensory data are to be directed and acted upon: The management structure of the system including clear lines of responsibility.

• The resources that will be available: facilities, equipment, personnel, and finances for both start-up and ongoing use, including projected improvements.

• The purpose for which the sensory data are required: (e.g. product optimization, cost reduction, shelf-life determination). Clear identification of such requirements.

• The extent to which the system will be applied: to all or part of the product range in from a company producing a single high volume product to a multiproduct company.

• Likely frequency of use: needs careful consideration in assessing resource requirements.

• Flexibility to upgrade or adapt for different use: in particular, location and design to permit future installationof a computerized data acquisition system.

• Possible need for integration with instrumental data: Instrumental measurements of flavor and texture are unlikely to replace the need for sensory testing, but specific measurements of quality factors can be particularly useful in quality control operations, provided that they are carefully calibrated against suitable sensory assessments.

(b). Provision of appropriated Sensory Testing Environment

A suitable environment is crucial to providing high-quality sensory data. The environment must provide the required working conditions for the assessors as well as a work area for sample preparation and for data analysis. Detailed advice is given in a number of publications (e.g. Stone & Sidel, 2004; British Standard BS 7183, the equivalent of International Standard ISO 8589; British Standards Institution, 1989a). A major requirement for any environment is that there is easy access for the assessors. There are three main components of a sensory evaluation environment: preparation area, testing environment, and booth design (Kilcast, 1999).

(i). Preparation Area: The preparation area should be adjacent to the testing area but separated to prevent access by the assessors. Equipments in the area should be appropriate to the products being tested, and specialized equipments may be needed. The size of the area is determined by the amount of work to be undertaken, but an extensive work surface should be available for preparing and organizing the presentation of large sample numbers. Ventilation should be sufficient to clear cooking odors, and equipment and cleaning materials should be odor-free (Kilcast, 1999). Temporary cooking facilities can be set up in a laboratory using hot plates, and styrifoam containers can be used to keep food warm for short periods. Prepared trays can be set out on carts when counter space is limited. The food preparation area should be well furnished/equipped with needed facilities (Elias et al., 1989).

(ii). Testing Environment: The basic test area should provide individual booths for assessors, but equally important is the availability of a room for round table discussions, especially for deriving descriptive vocabularies for profiling studies. The test area should have easy accessibility and be located near but separate from the preparation area. The assessors must not enter or leave through the preparation area, as this could bias their judgment. The test area must be easy to reach and away from noise, such as that of main roads, offices, busy corridors, and process machinery (Kilcast, 1999).

The temperature must be comfortable for the assessors. Air conditioning should ensure a steady ambient temperature of about 22°C. Good temperature control is particularly important for the assessment of the texture of temperature-sensitive products. There should preferably be a relative humidity of between 45% and 50%, although controlling this precisely may be impractical.

The area must be odour-free. Ventilation is necessary to extract odours, and activated carbon filters may be necessary to treat incoming air supplies. Slight positive air pressure from testing booth to preparation area helps minimize odour transfer. Flooring, wall coverings, and furniture should be odor-free and nonporous (Kilcast, 1999).

Neutral colors such as off-white, light gray, cream, and light green have been found to be more restful for the assessor to work in than white, but white or pale gray surfaces in the immediate assessment area should be used to give reliable colour rendition. Lighting should be uniform, shadow-free, and controllable (Kilcast, 1999).

(iii). Booth Design: Booths should be set up so that the assessors can make independent personal judgments with the minimum of distraction from the surrounding environment and from other assessors. The space allocated to booths is determined by the number of tests, people, and space available. The minimum number is 3, and usually 5 to 10 booths are sufficient for most purposes. Temporary booths can be set up if there is little space available. These are similar to booths used at polling stations and are collapsible for easy storage (Kilcast, 1999).

Each booth should have enough space to hold the samples, utensils, expectoration cups, palate cleansers, questionnaire, and pencil, and computer-based data input if this is to be used. General dimensions are 70 to 90 cm wide and 45 to 60 cm deep. The height can be either a normal desk sitting height of 70 to 80 cm or a kitchen counter height of 90 to 95 cm.

Lateral dividers between booths extend beyond the counters, usually by 30 to 45 cm. Seats should preferably not be fixed or on castors but should be easily movable. Spittoons are sometimes used, but their operations can be noisy, and drain smells can occur.

Correct lighting is important if appearance judgments are to be carried out. Colour rendition should be constant for all booths, shadow-free, and comfortable for the assessor. Types of light that can be used include tungsten and fluorescent, including point-of sale lighting. Diffusion filters should be placed over all lighting to minimize the spotlight effect. Dimmer switches are useful, as are coloured green and red light filters if colour masking is needed for the product (Kilcast, 1999). There should be the facilities for oral rinses and sample expectoration (Heitz and Kader, 1983).

Serving hatches to the preparation area are important if there is to be minimum disturbance to the assessors. Hatches can slide horizontally or vertically or be "bread box" style. The detailed design will often depend on the available space. Ready signals are useful to allow the assessors to signal both their arrival and their completion of tasting (Kilcast, 1999).

Every booth should have a pass-through from the food preparation area to allow samples and trays to be passed to panelists directly. The pass through opening should be approximately 40cm wide, 30cm height, and should be flush with the counter top. The opening can be fixed with a sliding hinged or flip-up door (Elias et al., 1989).

In addition to the above discussed facilities the following facilities should also be managed:

(iv). Panel discussion area: For product oriented testing it is necessary to have a room where the panelists can meet the panel leader for instruction; training and discussion.This discussion area should be completely separated from the food preparation area so that the noise and cooking odors do not interfare with the panelists' tasks. It should be located so that there are no interruptions from other laboratory personnel. A comfortable well lit area, with a large table and chairs or stools to seat atleast 10 people, is ideal. This room should also be well facilited with necessary materials for panel discussion (Elias et al., 1989).

(v). Office area: In addition to the space needed for the actual sensory testing, a place where the panel leader can prepare ballots, and reports, analyze data and stored results is required. This area should be equipped with a desk, a filing cabinet, and either a statistical calculator or a computer equipped with a statistical program for data analysis (Elias et al., 1989).

(vi). Desk area: The panel leader will need space for preparing ballots, planning sensory tests, and analyzing data, and will need access to a calculator with statistical capabilities (Elias et al., 1989).

(c). Supplies for sensory testing: The sensory area should be equipped with utensils for food preparation and with equipments and small containers for serving samples to the panelists. All utensils should be made of materials that will not transfer odours or flavours to the foods being prepared or sampled. Food preparation and serving equipments, utensils and glassware for the sensory testing area should be purchased new and used exclusively for sensory testing

(i). Utensils for food preparation: An accurate balance or scale, graduated cylinders, pipettes, volumetric flasks and glass beakers of various sizes will be needed to make precise measurements during food preparation and sampling. Glass or glass-ceramic cooking pots should be selected rather than metal cookware. If only metal is available, then stainless steel is a better choice than aluminum, tin or cast iron cookware. Thermometers and standard kitchen utensils such as sieves and strainers, can openers, knives, forks, spoons, bowls, pot holders and covered storage containers will also be needed (Elias et al., 1989).

(ii). Sample containers: Sample containers should be chosen according to the sample size and characteristics. The size of the containers will vary with the type of product being tested and with the amount of sample to be presented. Disposable paper, plastic or styrofoam containers of 30-60 ml size with lids, disposable petri-plates and paper plates are convenient but may prove costly. Reusable containers such as glasses, shot glasses, glass egg cups, small beakers, glass custard cups, bottles, glass plates or petri-plates and glass jars are suitable alternatives. Lids or covers of some sort are necessary to protect the food samples from drying out or changing in temperature or appearance, and to prevent dust or dirt from contaminating the samples. Lids are particularly important when odours of the food samples are being evaluated. Lids allow the volatiles from the sample to build up in the container so that the panelist receives the full impact of the odour when bringing the sample container to the nose and lifting the lid (Elias et al., 1989).

(iii). Additional supplies: Plastic spoons, forks and knives, napkins, disposable or glass cups for water and expectoration, and large jugs or pitchers, preferably glass, for drinking water will also be needed. Odourless dish washing detergent is suggested for washing equipment (Elias et al., 1989).

3.6.13.1 Selection and Training of Suitable Test Subjects

The testing instrument for sensory analysis is the panel of human judges who have been recruited and trained to carry out specific tasks of sensory evaluation. Recruiting panelists, training them, monitoring their performance, providing leadership and motivating is the job of the panel leader.

The subjects to be used are defined by the objective of the test and by the consequential choice of test. The numbers of subjects to be used depends on the level of expertise and training of the assessors. Recommended minimum numbers are given in British Standard BS 5929, Part 1 (the equivalent of International Standard ISO 6658; British Standards Institution, 1986), which also discriminates among assessors, selected assessors, and experts (Kilcast, 1999).

Both discriminative and descriptive tests use small panels of assessors chosen for their abilities to carry out the tests. Guidelines for establishing such assessors are given in British Standard BS 7667, Part 1 (the equivalent of International Standard ISO 8586-1; British Standards Institution, 1993). A general scheme for establishing a panel requires the following steps (Kilcast, 1999):

(i). Recruitment: Assessors can be recruited from within the company, or dedicated part time assessors can be recruited from the local population (in no circumstances should company employees be compelled to participate) (Kilcast, 1999). The majority of the people within an organization are potential panelists. They will usually be interested in participation if they feel that their contribution is important (Elias et al., 1989).

In either case, a suitable advertisement should be devised, and responses should be followed up with a questionnaire that gathers information on availability likes and dislikes, state of health, and known food allergies. Important aspects that should be established at this stage are interest and motivation, availability, ability to articulate, and literacy (Kilcast, 1999).

(ii) Orienting panelists: Potential panelists should be invited to the sensory panel, in groups of no more than 10 at a time, to allow the panel leader to explain the importance of sensory testing, show the panelists the tesing facilities, and answer questions that may arise. The individuals participating only in in-house acceptability panels (untrained panels) do not need to be given any subsequent taining. However, it is useful to demonstrate the way in which the ballots should be marked, using enlarged ballots shown on an overhead projector or a blackboard. Explaining the test procedure/method will reduce confusion and make it easier for panelist to complete the task. It is important that all panelists understand the procedures and score cards so they may complete the test in a similar manner. Panelist should be advised to avoid strong odorous materials, such as soaps, lotions, and perfumes prior to participating on panels and to avoid eating, drinking or smoking at last 30mins prior to a sensory test (Elias et al., 1989).

(iii). Screening: These preliminary tests are used to establish that sensory impairment is absent, to establish sensitivity to appropriate stimuli, and to evaluate the ability to verbalize and communicate responses. These tests will depend mainly on the defined objectives of the sensory program but will typically consist of the following (Kilcast, 1999):

• The ability to detect and describe the four basic tastes: sweet, sour, salt, and bitter. Identification of tastes may be extended to cover metallic, *umami,* and astringent.

• The ability to detect and recognize common odorants, together with those characteristic of the product range of interest.

• The ability to order correctly increasing intensities of a specific stimulus for example, increasing sweetness or increasing firmness.

• The ability to describe textural terms characteristic of relevant food types.

• Absence of color vision deficiencies.

Selection of suitable assessors is usually made on the basis of a good performance across the entire range of tests rather than excellence in some and poor response to others. If the assessors are to be used for a specific purpose, then the tests relevant to that purpose can be weighted appropriately (Kilcast, 1999).

(iv). Training: In the initial stages, training is limited to the basic principles and operations, following which further selection can be made. More closely targeted training can then be carried out using the products of interest and aimed toward the specific tests to be used in practice (Kilcast, 1999).

(v). Monitoring: Close monitoring of assessors' performance is essential, and any drift that is identified must be corrected by retraining procedures. Care should be taken to ensure adequate motivation, especially when carrying out long-term routine testing (Kilcast, 1999).

(vi). Motivating: Panelists who are interested in sensory evaluation, the products under evaluation and the outcome of the study will be motivated to perform better than uninterested panelists. It is important to maintain this interest and motivation throughout the study to insure and encourage optimum panelist peformance (Elias et al., 1989).

Subjects (respondents) for hedonic tests are chosen to represent the target consumer population and to reflect any inhomogeneity in that population. Consequently, they need to be used in sufficient numbers to give statistical confidence that they are representative, and they must be given the opportunity to behave as they would in a real consumption environment. In particular, they must not be selected on the basis of sensory ability and must not be given any training. Numbers in excess of 100 respondents are normally used. For the early stages of concept development, qualitative studies using focus groups with small numbers of respondents can be used, but the data generated should be treated carefully, and conclusions must not be generalized (Kilcast, 1999).

The same subjects must not be used for both types of test, and, in particular, in-house staff must not be used to generate hedonic data that may be viewed as consumer related (Kilcast, 1999).

3.6.14 Data Handling, Analysis, and Presentation

Sensory experiments can generate large amounts of data, and it is rare that reliable conclusions can be drawn without validation using statistical techniques. Details of suitable statistical methods can be found in a number of texts (e.g. Lahiff & Leland, 1994; Meilgaard et al., 1991; O'Mahony, 1986; Smith, 1988). Different types of sensory test procedures generally use specific analysis procedures, but in the case of the more sophisticated profiling techniques, a wide range of options is available, both univariate and multivariate. These appropriate procedures are also given in more detail respective descriptions of the individual tests. Many statistical software packages are now available. The most sophisticated require a sound understanding of statistical principles, but more user-friendly packages are available that satisfy most requirements. However, it is usually found that no single package can cover the entire range of basic requirements (Kilcast, 1999).

Clear and effective presentation of sensory data, including the results of statistical tests, is essential. Most standard spreadsheets are now able to offer a wide range of presentation possibilities for both univariate and multivariate data (Kilcast, 1999).

3.6.15 Selection of Suitable Test Procedures

Sensory test methodologies fall into three main classes (Kilcast, 1999):

1. Discrimination/difference tests: "Is there a difference?"

2. Descriptive tests: "What is the difference?" and "How big is the difference?"

3. Hedonic/Affective Tests: "Which is liked?" and "Why is it liked?"

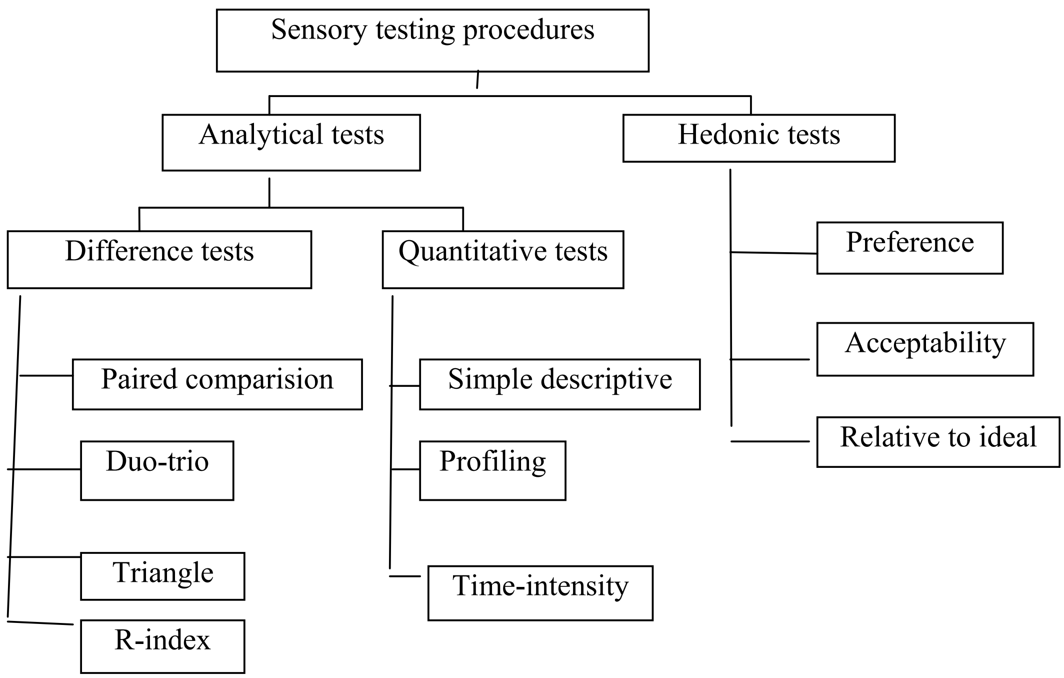


Fig. 3.36 Classification of the Main Types of Sensory Testing Procedures

The first two classes are quite different from the third class, as illustrated in Figure 3.36(above).

They are analytical, and their purpose is to use human subjects as a form of instrument to measure properties of the food. Hedonic tests measure the response of consumer populations to the food in terms of likes or dislikes. In general, there is no simple linear relationship between the two types of data. Of great practical importance, the types and numbers of subjects used for the analytical and hedonic tests are quite different (Kilcast, 1999).

Difference tests are used to identify relatively small overall differences in sensory characteristics. They find extensive use in product maintenance and product matching. Most new product development requires sensory tests with much higher information content, and descriptive profiling is the most powerful test class available. Hedonic tests require larger numbers of respondents, who act as a sub-sample of the target population. Although often regarded as the preserve of marketing functions in companies, they should be used at early stages of new product development to give development programs more accurate direction (Kilcast, 1999).

The different tests used in sensory evaluation are given as follows (Kilcast, 1999):

3.6.15. 1 Discrimination Tests

Discrimination tests are perceived as one of the easiest classes of sensory testing to apply in an industrial environment and are consequently heavily used. The tests can be used in two ways: to determine whether there is an overall difference between two samples or to determine whether one sample has more or less of a specific attribute than another. However, there are inherent limitations of such tests for example, the restricted information content and the difficulty in determining whether the absence of a difference can be interpreted as the samples being the same. Difference tests are almost universally used to ascertain whether two samples are different, not to ascertain whether two samples are the same (Kilcast, 1999).

In addition to determining if a sensory difference exists between two samples, the tests can be used as a means of measuring thresholds and sensitivity. Three types of difference tests are used most frequently: paired comparison, duo-trio, and triangular. Two other tests, the two-out-of-five test and the "A," "not A" test, are used less commonly, and many other forms of the test have been described but have found little application. A shortcut signal detection test *(R* index) has been described and may have future applications (Kilcast, 1999).

Below the main types of test with practical value will be described in detail, and other forms will be described only briefly:

(a). Paired-Comparison Test: In the most common form of the test (less commonly referred to as the 2-AFC [alternative forced-choice] test), two coded samples are presented either sequentially or simultaneously in a balanced presentation order (i.e., AB and BA). There are two variations on the test. In the directional difference variant, the assessors are asked to choose the sample with the greater or lesser amount of a specified characteristic. They are usually instructed to make a choice (forced-choice procedure) even if they have to make a guess, but they may be allowed to record a "no-difference" response. The distinction between these two procedures will be expanded on in the discussion on statistical analysis later. In the directional form, it is important that the assessors clearly comprehend the nature of the attribute of interest. This might not necessarily be clearly defined to either the test organizer or the assessors, however, especially if interactive effects are operating or if textural differences are sought that might be difficult to describe precisely. It has been pointed out that if time is needed to train assessors to recognize a specific characteristic, then a descriptive test should be selected (Stone & Sidel, 1993). These authors have also pointed out that the test can be adapted to a nondirectional format in which the assessors are asked to judge whether pairs of samples are the same or different (simple difference test). In this case, all possible pairs of samples must be presented (AB, AA, BB, and BA). However, little or no use has been made of this format. The most common use for nondirectional paired-comparison testing is consumer preference testing (Kilcast, 1999).

An additional form of paired-comparison testing is the "A," "not A" test. The assessors are presented with a single product and asked to evaluate the sample and remember its characteristics. They are then presented with the test product and asked whether the products are the same or different. The test is more frequently used as an identification test, however, in which a series of samples is presented for evaluation (Kilcast, 1999).

(b). Duo-Trio Test: In the most common variant of the duo-trio test, the assessors are presented with a sample that is identified as a reference followed by two coded samples, one of which is the same as the reference and the other of which is different. These coded samples are presented in a balanced presentation order:

A (reference) AB   A (reference) BA

The assessors are asked to identify which sample is the same as the reference. A more rigorous procedure, the balanced reference procedure, is to use both samples as the reference in a balanced presentation order:

A (reference) AB   A (reference) BA

B (reference) AB   B (reference) BA

The constant reference variant is usually used, especially in circumstances in which one sample can be used as the reference that is familiar to the assessors. This can be especially useful for quality control procedures. The duo-trio test is particularly useful when testing foods that are difficult to prepare in identical portions. Testing such heterogeneous foods using the triangle test, which relies on identical portions, can give rise to difficulties, but in the duo-trio test there are no inherent difficulties in asking the question: Which sample is most similar to the reference? (Kilcast, 1999)

(c). Triangle Test:Three coded samples are presented to the assessors, two of which are identical, using all possible sample permutations:

ABB AAB BAB ABA BBA BAA

The assessors are asked to select the odd sample in either fixed-choice or no-difference procedures. The increased number of samples compared with a paired-comparison test can result in problems with flavor carry over when using strongly flavored samples, making identification of the odd sample more difficult. Difficulties can also be encountered in ensuring presentation of identical samples of some foods (Kilcast, 1999).

A less commonly used variant of the triangle test is the 3-AFC procedure. In the test itself, the assessors are then asked to identify the sample (or samples) with the specified characteristic (Kilcast, 1999).

(d). Two-out-of-Five Test: Assessors are presented with five samples: three of one material and two of another. They are asked to pick out the two samples that are the same but different from the remaining three. There are 20 possible orders of presentation:

AAABB	AABAB	ABAAB	BAAAB	AABBA
ABABA	BAABA	ABBAA	BABAA	BBAAA
BBBAA	BBABA	BABBA	ABBBA	BBAAB
BABAB	ABBAB	BAABB	ABABB	AABBB

This test is highly sensitive, but the five sample presentation can cause severe fatigue when carrying out oral testing and is more commonly used for visual, auditory, and tactile assessments. The test also requires good memory capability (Kilcast, 1999).

(e). Difference-from-Control Test: In the difference-from-control test, this is sometimes used when a control is available; the assessors are presented with an identified control and a range of test samples. They are asked to rate the samples on suitable scales anchored by the points not differentfrom control and very different from control. The test results are usually analyzed as scaled data. This type of test is sometimes classified as similarity/dissimilarity scaling and analyzed using multidimensional scaling methods (Kilcast, 1999).

(f). R-Index Test: This method is a relatively new development (O'Mahony, 1979, 1986) and is a shortcut signal detection method. The test samples are compared against a previously presented standard and are rated in one of four categories. For difference testing, these categories are "standard," "perhaps standard," "perhaps not standard," and "not standard." The test can also be carried out as a recognition test, in which case the categories are "standard, recognized," "perhaps standard, recognized," "perhaps standard, not recognized," and "standard, not recognized." The results are expressed in terms of *R* indices, which represent probability values of correct discrimination or correct identification (Kilcast, 1999).

Analysis of Discrimination Tests:

The basic principle underlying the analysis of difference is to test the actual response obtained against the response that would have occurred purely by chance. In the case of the main difference tests described above, the probabilities of guessing the result are shown in Table 3.21. Frijters (1988) has tabulated the probabilities of guessing for a more generalized set of difference tests.

One consequence of the different probabilities is that the statistical power of the tests

differs, together with the numbers of responses that are needed to give a meaningful and reliable result. These numbers are related to the levels of risk that are deemed acceptable. These are the Type 1 risk (incorrectly concluding that there is a difference that does not exist) and the Type 2 risk (not identifying a difference that is present). Table 3.22 shows

Table No 3.21 Probability of Guessing the Result in Discrimination Tests

Test	Probability
Paired comparison	1/2
Duo-trio	1/2
Triangle	1/3
Two-out-of-f ive	1 /10

the minimum numbers of assessors recommended in British Standard BS 5929, Part 1 (equivalent to International Standard ISO 6658; British Standards Institution, 1986). It is possible to generate the required number of judgments by replicated tests with a smaller number of assessors. Such a procedure should be used with care (e.g. generating 15 responses by using three assessors in five replicates is not recommended), and each replicate should be set up as a separate test. This table also illustrates the principle that the number of assessors required decreases with increasing expertise. However, these numbers should be used for guidance only, and it is probable that future revisions of ISO standards will recommend the use of higher numbers of assessors (Kilcast, 1999).

Table 3.22 Minimum Numbers and Experience of Assessors[a]

Test	*Experts*	*Trained Assessors*	*Assessors*
Paired comparison	7	20	30
Triangular	5	15	25
Duo-trio			20
Two-out-of-five		10	
"A," "not A"		20	30
Ranking	2	5	10 (100[b])
Simple descriptive	5	5	
Profile (quantitative descriptive analysis)	5	5	

a. British Standard BS 5929, Part 1 (the equivalent of International Standard ISO 6658; British Standard Institution, 1986.
b. Consumer tests.

The test results are usually analyzed using tables of the binomial expansion, although other distributions have been used. The 5% level of significance is frequently used in sensory tests, but an increasingly common procedure is to calculate exact probability levels (Kilcast, 1999).

The duo-trio, triangle, and two-out-of-five tests are all inherently one-tailed tests, but the paired-comparison test can be either a one- or a two-tailed test. The one-tailed test is used only when a difference in a specific direction is sought (Kilcast, 1999).

If a strict statistical interpretation is required, then a forced-choice response must be used. Similarly, if relatively inexperienced assessors, or consumers, are being used, then a forced-choice test must be used to prevent "fence sitting." However, if highly experienced assessors are used, then a no-difference response can be highly informative in specific circumstances (Kilcast, 1999).

Descriptions of the nature of any difference can provide useful guidance for further testing.

A simple scaled assessment of the degree of confidence in the decision *(*absolutely sure, fairly sure, not very sure, only guessed*)* is very useful, especially when using forced choice procedures. Assessment of the degree of difference is likely to be of value only if assessors have been trained in scaling procedures (Kilcast, 1999).

3.6.15.2 Descriptive Tests

Descriptive analysis is the most sophisticated of the methodologies available to the sensory professional (when compared with discrimination and acceptance methods). Results from a descriptive analysis test provide complete sensory descriptions of an array of products, provide the basis for mapping product similarities and differences, and provide a basis for determining those sensory attributes that are important to acceptance. The results enable one to relate specific ingredient or process variables to specific changes in some (or all) of the sensory attributes of a product (Stone and Sidel, 2004).

Descriptive analysis is a sensory methodology that provides quantitative descriptions of products, based on the perceptions from a group of qualified subjects. It is a total sensory description, taking into account all sensations that are perceived visual, auditory, olfactory, kinesthetic, etc. when the product is evaluated. The word “product” is used here in the figurative sense; the products may be an idea or concept, an ingredient, or a finished product as purchased and used by the consumer. The evaluation also can be total or only one aspect. The evaluation is defined in part by the product characteristics as determined by the subjects, and in part by the nature of the problem (Stone and Sidel, 2004).

Before describing specific test methods, it is important to first review the more fundamental issues on which all descriptive methods are based. In particular, we refer to the subject selection process; the extent and duration of the training, including the development of the descriptive language (for the array of products being evaluated); the quantification of the judgements; and finally, the analysis of the data leading to actionable recommendations. Such a discussion is particularly important because there are numerous decisions made by the panel leader in the course of the organization, development and use of a descriptive panel. These decisions and actions derived from that person's knowledge and understanding of the perceptual process, in general, and the descriptive process, in particular. Unlike discrimination and acceptance tests, where subjects exhibit choice behavior in a global sense; i.e., all perceptions are taken into account to yield a single judgment, the descriptive test requires the subject to provide numerous judgments for each product (Stone and Sidel, 2004).

A descriptive test involves relatively few subjects (as few as ten to as many as twenty) and there must be good evidence that the specific differences obtained are reliable and valid, and not the result of spurious responses from one or two more sensitive subjects. In the case of Flavour Profile, the number of subjects was limited to six; placing great reliance on the group achieving agreement before a decision could be reached about a product. Implicit in the use of a limited number of subjects is the knowledge that the subjects are qualified. It enables one to use the fewest number of subjects without loss of information. In addition, it must be kept in mind that selecting individuals based on their sensitivity to particular chemicals (e.g. sweet, sour, salt, and bitter stimuli or a selection of odorants) or based on various personality tests will not substitute for demonstrated sensory ability with the products to be tested. That sensitivity to basic taste and odor stimuli continues to be recommended (Powers, 1988; Meilgaard *et al*., 1999).

In using the QDA methodology (Stone *et al*., 1974), we observed that the discrimination methodology has been and continues to be the most effective procedure for identifying subjects who can and cannot perceive differences (after first determining that they are regular users of the specific product category). It takes relatively little time to identify individuals who can and cannot perceive differences (Stone and Sidel, 2004).

Sensory evaluation, as treated, is an applied science that deals with measuring responses to selected products or product attributes. Those measures are used, directly or indirectly, to describe or predict consumer behavior. There is little impetus or value to deal with cognitive mechanisms that may, or may not, explain that behavior. Using unobservable (and usually unmeasurable) "intervening variables," "underlying structures" and "hypothetical constructs," does little to clarify sensory issues and assist in the decision-making process (Stone & Sidel, 2004).

A descriptive test yields a large sensory database (in comparison with discrimination or an acceptance test) including both univariate and multivariate components and, as such, it permits a wide range of statistical analyses to be done. One of the main features of the QDA methodology (Stone *et al*., 1974) was the use of statistical analysis of the data, which represented a significant development for sensory evaluation. With the availability of statistical packages and of PCs, panel leaders have unlimited and low cost resources, providing an online capability for obtaining means, variance measures, ranks, pair-wise correlations, and for factor analysis, multiple regression, cluster analysis, discriminant analysis, and so forth (Powers, 1988).

The descriptive test is a very dynamic system in which the panel leader must make numerous decisions when organizing a panel, through screening, training, and product evaluation. Without sufficient knowledge, inadequate or incorrect product decisions will be reached (Stone and Sidel, 2004).

Test Method

The methods are classified according to whether the results are qualitative or quantitative, although it is recognized that one could be transformed to the other. As shown in Table 3.23, five methods are assigned specific names, one qualitative and four quantitative, reflecting a relatively wide range of approaches to descriptive analysis. A sixth method, designated as diagnostic descriptive analysis, is included because it represents a broad category of methods. A number of different procedures fit within this designation (Stone and Sidel, 2004).

Flavour Profile:

The Flavour Profile method (Cairncross and Sjöstrom, 1950; Sjöstrom and Cairncross, 1954; Caul, 1957) is the only formal qualitative descriptive procedure and is probably the most well known of sensory test methods.

The Flavour Profile method utilizes a panel of four to six screened and selected subjects who first examine and then discuss the product in an open session. Once agreement is reached on the description of the product, the panel leader summarizes the results in report form. Subjects are selected for training based on a series of screening tests, including sensory acuity, interest, attitude, and availability. This selection process is common to all formal descriptive methods, and, in principle, one can find little disagreement with this approach. In practice, however, the sensory acuity tests are concerned only with basic taste and odour sensitivity, skills that appear to have minimal connection with product evaluation (Mackey and Jones, 1954).

Table No 3.23. Classification of descriptive analysis methods

Qualitative	Quantitative
Flavour Profile[a]	Texture Profile[b]
Product experts (perfumer, flavorist,	QDA[c]
Brewmaster, etc.)	Spectrum analysis[d]
Free-Choice profiling[e]	
Diagnostic descriptive analysis[f]	

a Cairncross and Sjöstrom (1950),Caul (1957).b Brandt *et al*.(1963),Szczesniak *et al*. (1963).c Stone *et al*. (1974, 1980). d Meilgaard *et al*. (1991). e Williams andLangron,(1984).f.Cross*etal*.,(1978),Larson-PowersandPangborn,(1978), Lyons(1987).

Texture Profile

Chronologically, the next descriptive method of importance was the Texture Profile method developed at the General Foods Research Center (Brandt *et al*., 1963; Szczesniak, 1963; Szczesniak *et al*., 1963). This method represented advancement in descriptive analysis from a structural point of view; however, conceptually it did not take into account the behavioral issues, which in our experience limits its usefulness.

Brandt and co-workers (1963) defined a texture profile as "the sensory analysis of the texture complex of a food in terms of its mechanical, geometrical, fat and moisture characteristics, the degree of each present and the order in which they appear from first bite through complete mastication." (Table No 3.24) This definition could be applied to

Table No 3.24 Relationship between textural parameter and popular nomenclatures

<u>Mechanical characteristics</u>		
Primary parameters	**Secondary parameters**	**Popular terms**
Hardness		Soft, firm, hard
Cohesiveness	Brittleness	Crumbly, Crunchy, brittle
Chewiness	Tender, chewy, tough	
Gumminess	Short, mealy, pasty, gummy	
Viscosity		Thin, viscous
Elasticity		Plastic, elastic
Adhesiveness		Sticky, tacky, gooey
<u>Geometrical characteristics</u>		
Class	**Examples**	
Particle size and shape	Gritty, grainy, coarse, etc.	
Particle shape and orientation	Fibrous, cellular, crystalline, etc.	
<u>Other characteristics</u>		
Primary parameters	**Secondary parameters**	**Popular terms**
Moisture content		Dry, moist, wet, watery
Fat content	Oiliness	Oily
Greasiness	Greasy	

From (Stone and Sidel, 2004).

any descriptive analysis; in this situation, the focus is on texture, which implies independence of responses from other sensations (Stone and Sidel, 2004).

A first concern with this method is the objective, associated problems and their minimization. The objective is to eliminate problems of subject variability, allow direct comparison of results with known materials, and provide a relationship with instrument measures (Szczesniak *et al.*, 1963). These objectives are accomplished through the use of standard rating scales for each texture term and specific reference materials to represent each scale category for each of the terms. The method required subjects to score products according to these aforementioned parameters (Table No 3.24). Comparison of results with the specified references enabled product formulation to occur according to known physical and chemical parameters (Szczesniak *et al.*, 1963). Having a reference (high and low) for every scale may seem like an ideal means of focusing responses (and minimizing variability); however, it will not eliminate variability. In fact, human behavior is variable from day to day and from subjects to subject, hence the need for more than a single subject for a test. Responses obtained from a panel are analyzed statistically to separate main effects (e.g. the variable being tested) from other effects or other sources of variability. In the evaluation, the use of products as scale anchors also presents its own set of problems. These products are not invariant and change over time as a function of marketing and other considerations. Normal production variation will cause a subject's response to a product to be offset to some extent as a function of that variability. It also is reasonable to expect that a subject's liking (or dislike) for a reference will further impact response behavior. Finally, extensive use of references during a test will cause sensory fatigue. Possibly, experienced subjects overcome this latter difficulty by limiting their tasting of the references. Obviously, the solution to this problem is to avoid use of such references (Stone and Sidel, 2004).

A second concern with this method is the, a priori, decision as to the attributes (chewiness, hardness, and so on) to be used. There are inherent risks in experimenter-assigned attributes; the subjects could ignore a perception or use one or more of the listed words to "represent" the particular perception. These are not necessarily the only ones or these most appropriate to reflect texture perceptions for a particular product (Stone and Sidel, 2004).

A third concern associated with the method is the separation of texture from other sensory properties of a product such as colour, aroma, taste, and so forth. As a rule, perceptions are interdependent, and the exclusion of some attributes from a score card does not eliminate their perceptions. In effect, the subject is likely to use other attributes to acknowledge these perceptions, and the visible manifestation is increased variability and decreased sensitivity. In addition, these other perceptions will influence the responses to the textural perceptions and vice versa. It is a weakness of every sensory test that requires the subject to respond to a limited set of product descriptors. However, it is a more obvious problem when subjects can only respond to a single sensory category; for example, texture but not colour, taste, aroma, or aftertaste. By measuring responses to all perceptions, the experimenter can derive a more complete picture of the product's sensory properties (Stone and Sidel, 2004).

Quantitative Descriptive Tests (The QDA Method)

The major advantages of discrimination tests are their relative simplicity to set up and operate and their high sensitivity. Development of the Texture Profile method stimulated interest and research on new descriptive methods and especially methods that would overcome the weaknesses previously identified – reliance on qualitative information, use of product attributes established by the experimenter, reliance on a limited number of subjects and so forth. Further interest in descriptive methods developed as a result of the growth of new products and competition in the market-place for products with unique sensory properties, as well as by advances in measurement and improved data processing systems. The QDA method (Stone *et al*., 1974; Stone and Sidel, 1998, 2003) represented an opportunity for sensory evaluation to satisfy these needs; the approach was primarily behavioral in orientation, with a consensus approach to language development (no expectation that all subjects will be equally sensitive), use of replication for assessing subject and attribute sensitivity and for identifying specific product differences and defined statistical analyses. In effect, the method required a different approach to the concept of descriptive analysis, beginning with the subject selection procedure and concluding with communication of results in an understandable and actionable manner. The development of the method evolved from a number of considerations, including responsive to all the sensory properties of a product; reliance on a limited number of subjects for each test; subjects qualified before participation; able to evaluate multiple products in individual booths; use a language development process free from leader influence; be quantitative and use a repeated trials design; and have a useful data analysis system (Stone and Sidel, 2004).

The details of these features of QDA methodology can be found in books and papers (Stone and Sidel, 2004).

The data are analyzed using a two-way AOVA general linear model showing both subject and product effects. Subject-by-product interactions are also estimated when the experiment includes repeated judgments. QDA data lends itself well to multivariate analyses to better understand subject performance and attribute relationships (Stone and Sidel, 2004).

The ANOVA model also enables the panel leader to determine whether the mean scores for several products differ from one another in sufficient magnitude to justify considering them different at some stated (and low) level of risk. The analysis does not specify which products are different and one must do additional computations after the *F* test, sometimes referred to, as multiple-range tests. There are a variety of these tests and some needless controversy has developed concerning which one is most appropriate. These tests include the following: Duncan, Newman–Keuls', Tukey (a), Tukey (b), Scheffé, and Dunnett. The first three tests and the Scheffé test are most commonly used in sensory tests. In effect, one computes a critical value and those mean differences that are greater are considered significantly different. Their formula and additional discussion for their computations, can be found in the books and paper (Winer (1971) and Bruning and Kintz (1977).

Free-Choice Profiling

Williams and Langron (1984) described a radically different approach to descriptive analysis in which no subject screening or training were required and subjects could use any words they wanted to describe the products being evaluated. In addition, each subjects' words were unique to that subject as was their score cards. This approach was presented as an alternative to the protracted time required training subjects to develop a language and to achieve agreement amongst the subjects using conventional descriptive methods.

Other Methods and Developments:

Descriptive methods continued to be described in the literature since further evidence of the growing popularity of the methodology have seen. It is clear that this popularity derives from the seeming ease with which results can be obtained and their usefulness in a variety of business applications. For the most part, these methods are more diagnostic in character and/or are variations of established methods (Stone and Sidel, 2004).

Examples of methods are Profile Attribute Analysis (Hanson *et al*., 1983), "Quantitative Flavor Profiling." (Stampanoni, 1993), generic descriptive analysis (DA)(Lawless and Heymann 1999).

Applications for Descriptive Analysis

There are numerous applications for descriptive information, including monitoring competition, storage stability/shelf-life, product development, quality control, physical/ chemical and sensory correlations, advertising claim substantiation, and so forth.

The detailed discussion on the aforementioned applications can be found in the book and paper (Stone and Sidel, 2004).

3.6.15.3 Affective Testing:

Acceptance testing is a valuable and necessary component of every sensory program. In the product evaluation process, acceptance testing usually, but not always, follows discrimination and descriptive tests, which have reduced the number of product alternatives to some limited subset, and precedes larger-scale testing done outside of research and development by others, such as marketing research. This evaluation task is referred to as acceptance, preference, or consumer testing, labels that can have different meanings depending on one's experience and professional responsibilities. From a sensory evaluation perspective, however, acceptance testing should have a specific meaning insofar as the purpose for the test, how it will be done, who will participate, and how the results will be used (Stone and Sidel, 2004).

By acceptance testing we mean measuring liking or preference for a product. Preference is that expression of appeal of one product versus another. Preference can be measured directly by comparison of two or more products with each other, that is, which one of two, or more products, is preferred. Indirect measurement of preference is achieved by determining which product is scored significantly higher (more liked) than another product in a multiproduct test, or which product is scored higher than another by significantly more people. There is an obvious and direct relationship between measuring product liking/acceptance and preference. To be most efficient, sensory evaluation should emphasize measuring product liking/acceptance in multiproduct tests and from these data determine preference. Scaling methods allow us to directly measure the degree of liking and to compute preferences from these data. While the reverse is possible (Guilford, 1954), it is more complex, time consuming, and costly. The hedonic continuum is another frequently used expression for product liking and may be considered the more generic representation of the affective process. As Young (1961) noted, the hedonic continuum represents "the sign, intensity and temporal changes of affective processes."

This particular information, the measure of liking, is logical and necessary before substantial capital has been invested in equipment, production and distribution, advertising, and so forth. Obviously, we would be reluctant to invest in a product if we knew that it was not liked because of a sensory deficiency! Therefore, we organize a test methodology that will give us an estimate of product acceptance based on what Cardello and Schutz (2004) refer to as its intrinsic (e.g. ingredient and process related) sensory properties. This measure of sensory acceptance does not guarantee success in the market-place, since extrinsic variables (Cardello and Schutz, 2003) such as packaging, price, advertising, market segmentation, and so forth will have an effect. However, it does provide us with a good indication of the products potential as a product without any other of these accompanying features that we expect will enhance its acceptance in the market-place. Also, the sensory acceptance test neither measures purchase intent nor infers share of market; these topics are beyond the scope and responsibility of sensory evaluation (Stone and Sidel, 2004).

Methods: The two methods most frequently used to directly measure preference and acceptances are the paired-comparison test and the nine-point hedonic scale, respectively. Other methods are described in the literature, but many of them either are modifications of these two methods or are types of quality scales; for example, excellent to poor and palatable to unpalatable.

(a). Paired Comparison: The paired comparison is probably the first formal sensory test method developed to assess preference (Cover, 1936). Therefore, it should be no surprise that there is extensive literature about the method and especially on the topics of test design, statistical analysis, and mathematical models to help explain choice behavior in the paired-comparison situation (Bradley and Terry, 1952; Bradley, 1953, 1975; Gridgeman, 1955a, 1959; Day, 1974). The test may involve one or more pairs of products, and the subjects may evaluate one or more pairs of products within a single session.

The method requires the subject to indicate which one of two coded products is preferred. A frequently used option allows the inclusion of a "no preference" as a third choice, while another option allows inclusion of a fourth choice, "Dislike both equally". Examples of types of score cards with instructions are presented in Fig. 3.37.

Name ________________________ Code ____________Date _______________

Option A

Evaluate both products starting from the left. Check the box for the product you prefer. You must make a choice.

347 ☐ 602 ☐

Option B

Evaluate both products starting from the left. Check the box for the product you prefer. You must make a choice.

347 □ 602 □ No preference □

Option C

Evaluate both products starting from the left. Check the box for the product you prefer. You must make a choice.

347 □ 602□ Like both equally □ Dislike both equally □

Fig. 3.37 Example of the score card for the paired-preference test, showing Option A which limits the subjects to two choices; Option B which includes a no-preference choice for the subject; and Option C which includes two additional choices.

(b). Hedonic Scale: For measuring product liking and preference, the nine-point hedonic scale is probably the most useful sensory method. The method occupies a unique niche for sensory evaluation. Since its development (Jones *et al*., 1955; Peryam and Haynes, 1957), it has been used extensively with a wide variety of products and with considerable success.

An example of the scale is shown in Fig. 3.38. The scale is easily understood by naive consumers with minimal instruction, results have proven to be remarkably stable, and product differences (in liking) are reproducible with different groups of subjects. Not surprisingly, the nine-point hedonic scale is used extensively by many companies with considerable success in terms of the reliability and validity of the results.

Name ________________ Code __________ Date ___________________

Please circle the term that best reflects your attitude about the product whose code matches the code on this scorecard.

Like extremely	Like very much
Like moderately	Like slightly
Neither like nor dislike	Dislike slightly
Dislike moderately	Dislike very much
Dislike extremely	

Fig. 3.38 An example of the nine-point hedonic scale. The subject's task is to circle the term that best represents their attitude about the product. Boxes adjacent to the terms could also be used. The responses are converted to numerical values for computational purposes: like extremely, 9; dislike extremely, 1.

In recent years most professionals make use of (or should make use of) the nine-point hedonic scale than any others.

Criticisms of the hedonic scale method are primarily the same issues that are directed to many methods: the use of parametric methods for analysis with a scale that is bipolar, the lack of definitive evidence of the equality of the intervals, and avoidance of the neutral category (Day, 1974).

For sensory evaluation, the results from use of this scale are most informative. Computations will yield means, variance measures, and frequency distributions, all by order of presentation and magnitude of difference between products by subject and by panel, and the data can be converted to ranks as well, which yields product preferences. Vie *et al*. (1991) have recommended calculating *R*-indices for nine-point hedonic scale data. Additional information about product differences is obtained from the analysis of variance or the *t*-test, depending on the number of products and number of responses per product per subject. When one considers all of this information relative to the information from the paired test, the usefulness of the former method to sensory evaluation is understandable.

(c). Other Methods

In addition to the nine-point hedonic scale, other scoring methods have been used and continue to be used to measure product liking and preference. Many of the most common of these methods were described by Amerine *et al*. (1965) and for the most part they tend to be associated with particular product categories or with a specific company. For example, meat product evaluation usually relied on an eight-point scale measuring product desirability or an eight- or ten-point product quality scale (excellent to poor); other products also made use of such scales (and continue to be used). Another variation uses the ten-point numerical scale anchored at one extreme with a frowning smiley face and anchored at the other extreme with a happy smiley face. The ends of the scale, 1 and 10, are also defined with word extremes such as, "doesn't appeal/very appealing" for appearance, and "particularly bad/particularly good for taste." Quality scales, whether devised to establish an excellent to poor measure should never be used with untrained subjects (i.e. consumers) let alone used with trained subjects (Stone and Sidel, 2004).

Another alternative is to rank products from best liked or most preferred to least liked or least preferred. Although these are among the least costly and most efficient multiproduct tests to administer, they involve the same compromises described for paired-preference tests (i.e. sensory interaction or memory) (Stone and Sidel, 2004).

Subjects: The subjects participating in a sensory acceptance test should be qualified based on typical demographic and usage criteria or preference scores from survey data, if the former cannot always be satisfied. It may not be possible or even necessary, to select subjects based on demographic criteria when employees are the subjects, and a large majority of sensory acceptance tests do involve employees. However, in recent years there has been an increase in the use of local residents in place of employees. Employees who volunteer to participate should be screened for their product usage and likes/dislikes. Screening is best done using a survey questionnaire (Stone and Sidel, 2004).

Individuals who are qualified for discrimination and descriptive tests should not be used for acceptance testing regardless of their willingness to participate. The training process, especially for descriptive analysis, results in subjects who have an analytical approach to product evaluation that will bias the overall response required for the acceptance-preference task. Similarly, individuals who may possess technical or related information about specific products should not be used because of their potential bias. Objectivity must be maintained if the results are to be considered as reliable and valid (Stone and Sidel, 2004).

4. Materials and Methods

4.1 Survey of *Sel-roti*

A survey study was designed to collect the information on different aspect such as definition, historical background, quality, production and marketing of *Sel-roti* with the help of respondents of different district of Eastern and Central development region of Nepal using questionnaire, a tool for collecting the relevant information

The survey of *Sel-roti* was carried out mainly in Eastern Development Region and also included samples from Kathmandu of Central Development Region. One hundred twenty six respondents as sample were selected as per purposive sampling method (Bhandarkar and Wilkinson, 1993, Singh, 2005, Tongco, 2007) to gather the information about historical background, definition, ingredients, uses as well as other related information about *Sel-rot*i to be utilized as the basis for further study of the S*el-roti.* The samples covered different cast/tribes/races of different geographical locations. The samples selected were those respondents who knew better about *Sel-roti* and used to prepare frequently. They were identified asking the local people. The respondents were mainly females and some males as well. The samples included the respondents who used to prepare *Sel-roti* in their home in different occasion and some traders who used to sell *Sel-roti* in the market place and in their restaurant and shop. The tool for collection of information and data was questionnaires which include history, definition, ingredients used, production, consumption and sale amount; and characteristics of *Sel-roti* as well.

The respondents were asked questions about different aspects of *Sel-roti* indicated in questionnaires given in appendix (B.) and wrote what they responded including their experiences. The respondents were interviewed going to their door to door.

The collected information data were analysis for mean, standard deviation (Ottet al., 1981) and results are given in result and discussion section.

4.2 Preparation of flour and *Sel-roti*

4.2.1 Materials

a. *Kanchhi mansuli* rice was purchased from local rice mill of Dharan. The rice was prepared from approximately more than one year old paddy. This is coarse type of rice which was used throughout the study.
b. Sugar: It was purchased from Dharan market.

c. Ghee: Ghee used was prepared from Dairy Development Corporation (DDC), Biratnagar, Nepal. It was purchased when needed from the shop organized by DDC, in Dharan.
d. Frying oil: It was refined soybean oil. It was purchased from retail shop in Dharan market.
e. Standard sieves, weighing balance, and analytical equipments available at Central Department of Food Technology and Central Campus of Technology, Dharan were used. A small wooden box type for measuring the volume of *Sel-roti* was fabricated and used.
f. Iron mortar and pestle (Khal *Bachcha*) was used to prepared flour from rice. They were purchased from hardware shop in Dharan.
g. *Tai* was used to fry the Sel-roti. It was purchased from Blacksmith's shop of local market, in Dharan.

4.2.2 Method

4.2.2.1 Flour sample collection and preparation

Five rice flour samples were collected from four *Sel-roti* traders and one from the household of Dharan, Sunsari and one from the mill in Biratnagar. The traders used wooden mortar and pestle (i.e., *Okhli* and *musli*) to prepared flour and household used Khal-bachcha for this purpose. Experimental flour sample was prepared by using *Khal-Bachcha* in the lab. All collected and prepared flour samples were prepared from *Kanchh*i *Mansuli* rice. All together there were seven rice flour samples.

4.2.2.2 Screen analysis of flour

Both the collected rice flour samples from different sources and prepared rice flour samples in laboratory were analyzed for particle size distribution by using ASTM Standard set of sieves manufactured by Pradeep Trading Co. 25B, Inderlok, Old Rohtak road Delhi – 110035 India. The used test sieves were of clear opening of 2000, 1180, 600, 300, 150, 90 and 75 microns. A screen analysis of flour was carried out by placing a weighed amount of sample on the coarsest of a set of standard screens. Below this screen were arranged the remaining screens in the series in the order of decreasing mesh size. The pile of screens with the sample on the top screen was shaken in a definite manner manually (Badger and Banchero, 1955, Toledo, 1997). The sample remaining in each sieve were collected and weighed. The average particle size and weight percent retained were calculated. The mean particle diameter i.e. weighted mean diameter of particle was determined summing up the value obtained by multiplying the mass fraction with mean particle size in each screen. Likewise, formulated flour samples from the combination of coarse, medium and fine as given in table no 4.2, 4.3 and 4.4 were also analyzed for their particle size distribution and to calculate the mean particle diameter.

4.2.2.3 Recipe formulation and Optimization

1. Recipe formulation

During survey, the different recipes were collected from the respondents (household, *Sel-roti* merchants, food stalls and restaurants) who were experience on *Sel-roti* preparation. Among many recipes collected only five recipes which were reported by majority of the respondents were selected for optimization. The recipes selected for test were given in table no 4.1.

Table No 4.1 Recipe

Recipe Code	Ingredients			
	Rice(kg)	Sugar(g)	Ghee(g)	Water(g)
A	1	125	0	300 ±9.6
B	1	125	62.5	300± 9.6
C	1	125	125	300± 9.6
D	1	250	125	300± 9.6
E	1	250	250	300 ±9.6

2. Recipe optimization

(i). *Sel-roti* preparation: According to recipe given in table no 4.1 the ingredients such as flour, ghee and sugar were mixed well, rubbed/kneaded and prepared batter with addition of water separately and allowed to stand for 2 hrs. The *Sel-roti* was prepared from batter frying into hot oil in *Tai*. For this purpose, the oil was heated in *Tai* and the required hotness of oil for *Sel-roti* frying was tested traditionally by frying small portion of batter as reported by most of the respondents; the batter was poured in ring shape in hot oil by using ladle and when lower side of *Sel-roti* became reddish brown it was turn upside down and fried continue till whole *Sel-roti* become reddish brown in color, and then *Sel-roti* was lifted by *jhir,* drained oil and piled in a *ari* (steel container) or any flat dish. Likewise *Sel-roti* were prepared from all recipes. The *Sel-roti* were evaluated sensorially by panelists as given in sensory evaluation (ii).

(ii). Sensory Evaluation: The sensory attributes, including, appearance, taste, texture, flavor and overall acceptability of *Sel-roti*, were evaluated by 45-consumer-member panel (12 female and 33 males, age 25 to 55yr). They were the staffs and students of Central Campus of Technology, T.U., Dharan, Nepal. Each subject tested each sample, which were presented in random order and marked with 3-digit random code. The samples were presented in plastic plate containing one *Sel-roti*. One cup of warm water was also provided for rinsing the mouth between tests. The consumers evaluate the sample using a 7-point Hedonic scale with 1 representing the least score (Dislike very much) and 7 the highest score (Like very much). They were asked to evaluate the *Sel-roti* and score on the provided evaluation card (given in apendex C). The panelists were also requested to write answer of the question "what should be the characteristics (e.g., shape and size, color, flavor, taste, texture) of good *Sel-roti* in your opinion"? in the given space of evaluation card. Sensory evaluation of *Sel-roti* was carried out in individual booth under day light supported with tube light. The obtained data were analyzed applying suitable statistics i.e. Mean, ANOVA and LSD and the optimum recipe was found out. The desirable characteristics of *Sel-roti* according to the information reported by panelists were found out.

4.3 Efect of particle size of flour on physical and sensory parameter of Sel-roti

(a). *Sel-roti* Preparation: The prepared and sieved rice flour was divided into three categories on the basis of mean particle size i.e. Coarse (>890 micron), Medium (225-450 micron) and Fine (<120 micron) for the ease of handling and formulation for *Sel-roti* preparation to see the effect of particle size on different physicochemical and sensory parameters as well as to find out the mixture of flour having optimum mean particle diameter to produce good quality *Sel-roti*. From those three classes of flour of different combinations were made.

Among the different combination of coarse, medium and fine particle of flour, the following combination in three phases (given in table 4.2, 4.3 and 4.4) were taken to prepare and analyze the *Sel-roti*.

Table No.4.2. First Phase: Formulation F1

Sample code	Combination in proportion of C M F	Mean Particle Size in micron
a	0 : 0 : 100	91 ±2
b	0 : 50 : 50	327±6
c	0 : 100 : 0	383±7
d	25 : 50 : 25	495±8
e	50 : 0 : 50	615±4
f	50 : 50 : 0	752±9
g	100: 0 : 0	1133±14

Table No.4.3.Second Phase: FormulationF2

Sample code	Combination in proportion of C M F	Mean Particle Size in micron
A	10 : 60 : 30	359±4
B	20 : 50 : 30	425±6
C	30 : 30 : 40	465±6
D	30 : 50 : 20	520±6
E	40 : 50 : 10	614±8
F	50 : 30 : 20	652±8
G	60 : 30 : 10	746±10

Table No.4.4.Third Phase: FormulationF3

Sample Code	Combination in proportion of C M F	Mean Particle Size in micron
D	30 : 50 : 20	520 ±6
H	35 : 50 : 15	566 ±4
I	35 : 45 : 20	552 ±3

C= Coarse; M=Medium; and F= Fine. Mean particle size are in mean ± standard deviation.

The recipe used for the preparation of *Sel-roti* contained rice flour, 21% sugar, and 10.5% ghee on the basis of fresh weight of rice flour. This recipe was used throughout the experiments. This recipe was selected by using consumer panel testing of different recipes of combination of different ingredients which were found out from the respondents during survey.

According to the above recipe *Sel-roti* was prepared following the method given below:

1. Sugar and ghee were mixed with rice flour in the proportion as given in table no.4.2, 4.3 and 4.4 and kneaded/rubbed well for about 10 minutes.
2. The batter of optimum consistency was prepared with water (25±0.8 ml per 100gm flour) from the kneaded mixture of flour.
3. The batter was allowed to stand for about one hour.
4. Then the batter was poured in ring shape into heated oil in *Tai*, fried till reddish brown color of the surface of the down side appeared and turned upside down with the help of *Jhir* and again fried till the whole *Sel-roti* become reddish brown color and taken out draining oil.

(b). Analysis of physical and sensory parameters of *Sel-roti*: Prepared *Sel-roti* were analyzed for bulk density, moisture content and fat-uptake. Triplicate analysis was carried out for each parameter. *Sel-roti* were evaluated for their sensory attributes and texture profile by trained panelists.

(i). Bulk density: A volumetric replacement method using mustard seed as the replacement medium (Nepal Standard, 2037B.S.) was applied to determine the bulk density of *Sel-roti*. A special wooden box suitable for *Sel-roti* was prepared and was used to measure the volume of *Sel-roti*. Mustard seeds with more or less similar in size were used. The bulk density of *Sel-roti* was calculated according to the equation (Eq. 1):

$$\rho_s = \frac{W_s}{W_m} \; X \; \rho_m \qquad \text{Eq.1.}$$

Where ρ_s = bulk density of *Sel-roti* (kg/m^3); Ws = weight of *Sel-roti*; Wm = weight of mustard seeds with the same volume as that of the *Sel-roti* (g); and ρ_m = bulk density of mustard seeds (kg/m^3). Triplicate analysis was performed.

(ii). Moisture Content: The moisture content of *Sel-roti* was determined as of AOAC official method 920.36(AOAC, 2005) and the moisture content was calculated as follows:

Percent Moisture Content = $\frac{loss\ of\ weight}{weight\ of\ smmple} X\ 100$ (Eq.2)

(iii). Fat-uptake: Fat content of *Sel-roti* was determined as per AOAC official method 920.39(AOAC, 2005) and fat content and fat-uptake were calculated as follows:

Percent Fat Content = $\frac{Weight\ of\ fat}{Weight\ of\ sample} X\ 100$ (Eq.3)

Percent Fat-uptake (Dry & fat free) = $\frac{Percent\ Fat\ Content}{100-(\%moisture\ contnt + \%\ fat)} X\ 100$ (Eq.4)

(iv). Sensory Evaluation for sensory attributes and texture profile:Sensory and texture attributes of *Sel-roti* were evaluated by a sensory panel. The descriptive panel comprised of 6 assessors (4 male amd 2 female, age 35 to 55yr).The assessors were the faculties of Food Technology Department of Central Campus of Technology, Dharan, Nepal. The assessors were trained in 7 sessions, each approximately 1 h long. The sessions included mainly group discussions and evaluation exercises, and yielded consensus of the attributes evaluated and the technique of evaluations. The assessors received feed back of their practices where their own evaluations were compared to the mean values of the whole panel. Procedures, training and profile terminology developed were followed as described by Cardello et al.,(1982), Civille and Liska(1975), Meilgaard and Others(1991), Sanchez-Brambilla et al., (2002), Mabesa, (1986), Watts et al.,(1989). Sensory and texture attributes that were developed for to evaluate in this study are presented in (table no 4.5). In this sensory study sensory quality attributes like appearance, taste, texture, & flavor; and 7 texture characteristics like smoothness, hardness, fracturability, cohesiveness, stickiness, chewiness and after taste i.e., oily mouth feel were included. Evaluations were conducted in individual panel booth with sufficient light (day light complement with tube light). Line scales with intensity value 0 (none) to 15 (high) were used to record panelist responses to each texture attribute (Sanchez-Brambilla et al., 2002; Meilgaard and others, 1999; Kim and others, 1996). The quality scoring with 1 score (not preferred) to 15 score (highly preferred) method was used to record the preference of the panelists for quality attributes like appearance, taste, texture, flavor and overall acceptability.

At each two test session (first for quality attributes and second for texture attributes), the *Sel-roti* sample at room temperature were served to each panelist in paper plates. Each sample plate was coded with 3-digit random number and order of samples by treatment

Table No 4.5. Terms used in descriptive analysis of sensory and texture profile:

Attributes	Definition
<u>Texture Attributes</u>	
Hardness [1,2]	Force to compress the sample one bite with molar teeth
Fracturabilty[2]	Extent to which sample crumbles or breaks or shatters on the first bite with molar teeth
Smoothness[3]	Degree to which the sample mass is perceived as smooth during mastication(i.e., no small gritty particle)
Cohesiveness[1]	Degree to which the sample holds together as mass one mass during mastication
Stickiness[4]	Extent to which the sample sticks to the mouth(teeth, gums and palate)
Chewiness[2]	Amount of work to chew the sample to get it ready to swallow (1chew/sec)
Oily mouth feel	After expectoration, extent to which mouth feels oily
<u>Quality Attributes:</u>	
Appearance	Judge by eye for color, shape, size, uniformity and absence of defect(ring shape, uniform size, reddish brown in color and grainy surface)
Taste	Sense of feeling by tongue stimulated by sugar and others.
Flavor	Senses perceived during mastication as a combined effect of taste and smell
Texture	Sense of feeling (by hand and mouth) as hard and soft by hand Touch and bite.

Source: 1.Sanchez-Brambilla and et al, 2002; 2.Cardello et al, 1982; 3.Civille and Liska, 1975; 4.Meilgaard and et al, 1991.

was completely randomized. Warm water was provided to each panelist for mouth cleansing in between and after taste.

Three replicate analyses were done for both sensory quality and texture profiles.

4.4 Effect of Soaking Time of Rice for the Preparation of Sel-roti

The about one year old *Kanchhi mansuli* rice was cleaned and taken into four vessels and they were soaked in portable water for two , four, six and eight hours. The soaked samples were coded with S-I, S-II, S-III and S-IV for 8, 6, 4, and 2 hr soaked rice sample respectively. After soaking, for stated time each soaked rice sample was drained, pounded into flour in *Khal-bachcha*. The flour was sieved into different particle size and mixed them in optimum ratio to get optimum particle size of flour. Then flour were mixed with sugar and ghee and kneaded well, mixed with potable water to make batter of optimum consistency. The batter was allowed to stand for about one hour and fried into hot oil of 210°C (initial temperatures) pouring to make *Sel-roti*. *Sel-roti* were prepared from each soaked rice sample following the same process. The *Sel-roti* were evaluated by panelists for sensory texture attributes and sensory attributes. The *Sel-roti* were also analyzed for their physical parameter such as moisture content, bulk density, and oil-uptake. Triplicate analysis was carried out. The obtained data were analyzed statistically. The ANOVA and LSD were carried out to test their significance ($p \leq 0.05$) and regression analysis was carried out to find out their correlation of soaking time with physical parameters.

4.5 The effect of kneading of flour and ageing time of batter

To determine the effect of kneading and ageing time of flour and batter 250g flour of optimum particle size, 52.5g sugar and 26.25g ghee were taken into each of four containers; the mixture of ingredients of two containers were prepared batter without kneading, the *Sel-roti* was prepared from one container without ageing and from another container after ageing for one hour; the mixture of ingredients of remaining two containers were kneaded for 10 min using palm and fists and prepared batter and then *Sel-roti* was prepared without ageing the batter from one container and after ageing for one hour from another container. The ageing time 1h and kneading time 10 min were chosen on the basis of the most of the respondents who had reported 1h of ageing time and 10 min of kneading time. The prepared *Sel-roti* sample were coded as A_0K_0, A_0K_1, A_1K_0 and

A_1K_1 where A_0 stands for ingredients without ageing and A_1 with ageing for one hour, K_0 for ingredient without kneading and K_1 for kneading for 10 min. The samples were analyzed for sensory attributes, sensory texture profile and physical parameters like moisture content, bulk density, and fat-uptake. The triplicate analysis was conducted and the obtained data were statistically analyzed and inferred.

Table No: 4.6 The Experimental Design

Ageing time(h)	Kneading time(min)	
	K_0(0)	K_1(10)
A_0(0h)	A_0K_0	A_0K_1
A_1(1h)	A_1K_0	A_1K_1

4.6 Effect of Kneading Time of Flour with Major Ingredients

The 250g rice flour of optimum particle size was taken in each of four containers and mixed with sugar and ghee as given in table no 4.7 and mixed well. The mixed flour and other ingredients was kneaded by rubbing between two palm and fisting for 5, 10, 15 and 20 min for content of each of four container respectively. Then batter of optimum consistency was prepared by adding water separately and allowed to stand for one hour. The *Sel-roti* were prepared from each of four batters frying in hot oil of optimum temperature for optimum time. The *Sel-roti* were analyzed for sensory attributes and sensory texture profile by trained panelists and for physical parameters like moisture, bulk density, fat-uptake. Triplicate analyses were conducted. The obtained data were analyzed for mean, standard deviation, correlation coefficient, and ANOVA. With the help of ANOVA of mean of sensory attributes and LSD the optimum kneading time was found out.

Table No 4.7 Kneading time with recipe

Sample Code	Flour(g)	Sugar(g)	Ghee(g)	Kneading Time(min)
KT-I	250	52.5	26.25	5
KT-II	250	52.5	26.25	10
KT-III	250	52.5	26.25	15
KT-IV	250	52.5	26.25	20

4.7 Effect of Ageing Time of Batter on the quality of Sel-roti

The flour and other ingredients as given in table no 4.8 were taken into each of four containers, was mixed and kneaded for 10 min each and then batter was prepared and allowed to stand for 1, 2, 3, and 4 h. After ageing respective time *Sel-roti* were prepared frying the batter into hot oil of optimum temperature. The prepared *Sel-roti* samples were coded AT_1, AT_2, AT_3 and AT_4 for sample from 1, 2, 3, and 4 h aged batter respectively. The *Sel-roti* samples were analyzed for sensory attributes and sensory texture profile by trained panelists and for physical parameters like moisture content, bulk density, and fat-uptake. Triplicate analyses were conducted. The obtained data were analyzed for mean, standard deviation, correlation coefficient, and ANOVA. With the help of ANOVA of mean of sensory attributes and LSD the optimum ageing time was found out.

Table No 4.8: Ageing time with recipe

Sample Code	Flour(g)	Sugar(g)	Ghee(g)	Ageing Time(h)
AT_1	250	52.5	26.25	1
AT_2	250	52.5	26.25	2
AT_3	250	52.5	26.25	3
AT_4	250	52.5	26.25	4

4.8 Effect of Consistency of batter on quality of Sel-roti

The flour having optimum particle size mixed with required amount of sugar and ghee, kneaded for 10min and mixed with water and batter was prepared. Four types of batter with different ratio of dry solid (DS) or matter and liquid (L) or water i.e., 2.135, 1.935, 1.765, and 1.630 was prepared (recipe in table no 4.9) and their consistency was measured in terms of volumetric flow rate i.e., cm/sec by using the flow measuring device prepared from burette in lab. The *Sel-roti* were prepared from batter having different consistency. The *Sel-roti* were analyzed for sensory quality attributes and texture profile by using panelists. Their physical parameters like bulk density, moisture and fat-uptake were also measured by using methods mentioned earlier. From the result obtained the optimum consistency and the effect of consistency on the quality of *Sel-roti* was found out.

Table No. 4.9. Recipe for consistency measurement of batter.

Sample Code	Flour(g)	Sugar(g)	Ghee(g)	Water(ml)	DS/L ratio
C-I	100	21	10.5	20	2.135
C-II	100	21	10.5	25	1.935
C-III	100	21	10.5	30	1.765
CIV	100	21	10.5	35	1.630

The amount of water added to the ingredients to make desired consistency of batter can be calculated by using the equation Eq 5.

Water to be added = $\frac{Weight\ of\ dry\ matter\ in\ ingredient}{Ratio(\frac{DS}{water})} - Water\ in\ flour$ Eq.5

Ratio (DS/L) = $\frac{Dry\ solid\ matter\ in\ ingredients}{Water\ in\ flour + Water\ added}$ Eq.6

4.9 Effect of Frying Time and Temperature on the quality of Sel-roti

After the optimization of particle size of rice flour and other parameters the frying time and temperature were optimized. In this process rice flour with proper particle size and combination of different proportion of coarse, medium and fine flour was taken and mixed with sugar and ghee (quantity given in recipe) and kneaded manually for 10 min. The batter was prepared adding with water to optimum consistency and allowed to stand for about one hour. Then the batter was poured making ring shape into hot oil in *Tai* for different time temperature combination. The initial frying temperature of oil was chosen 200°C, 210°C, 220°C and 230 °C for total time of frying 28, 33 and 38 sec with turning time(i.e., turn upside down) 15, 17 and 19 sec for each temperature. Then the prepare *Sel-roti* were evaluated by panelists for their sensory attributes and texture profile. They were also evaluated for physical parameters like bulk density, moisture content and fat uptake. The obtained data were analyzed by using mean, standard deviation and ANOVA. The means were separated by LSD for significant test ($p \leq 0.05$). On the basis of ANOVA and LSD test of sensory quality attributes the optimum frying time and temperature was found out.

Table No 4.10 The experimental design for temperature and time:

Temperature(°C)	Frying Time(sec)		
	28(ft_1)	**33(ft_2)**	**38(ft_3)**
200(T_1)	T_1ft_1	T_1ft_2	T_1ft_3
210(T_2)	T_2ft_1	T_2ft_2	T_2ft_3
220(T_3)	T_3ft_1	T_3ft_2	T_3ft_3
230(T_4)	T_4ft_1	T_4ft_2	T_4ft_3

T_1, T2& T_3 = frying temperature in °C and ft_1, ft_2& ft_3 = frying time in min.

4.10 Effect of Frying Medium on the quality of Sel-roti

The rice flour of optimum particle size mixed with sugar and ghee as given in recipe, kneaded for 10 min, and prepared batter and allowed to stand for 1 h for ageing. The *Sel-roti* were prepared from aged batter frying into different frying medium i.e. Ghee(GH), Mustard Oil (MO), Sun flower oil (SFO) and Soybean oil (SBO). The samples were evaluated for sensory attributes and texture profile by using trained panelists and analyzed for physical parameters such as moisture content, bulk density and fat-uptake. The triplicate analysis was done. The obtained data were analyzed statistically. The

Table No. 4.11: The Frying Medium and Recipe

Frying Medium	Sample Code	Flour(g)	Sugar(g)	Ghee(g)
Ghee	GH	250	52.5	26.25
Mustard Oil	MO	250	52.5	26.25
Sun Flower Oil	SFO	250	52.5	26.25
Soybean Oil	SBO	250	52.5	26.25

optimum frying medium i.e., desirable frying fat/oil was found out. The effect of frying medium on texture of *Sel-roti* and physical parameters were also found out.

4.11 Effect of age of rice and *daun* on the physical properties and sensory quality of *Sel-roti*

New and approximately one year old '*Kanchhi Mansuli*' rice (a local coarse variety of rice) were purchased from a local rice mill of Dharan, soaked overnight in water, drained and ground to flour by using mortar and pestle made of iron locally called *Khal-Bachcha* . The flour having optimal particle size were separated by using ASTM standard set of sieves with different clear openings (Pradeep Trading Co. Delhi) and mixing in definite proportion of coarse, medium and fine . The flour preparing process was same for both new and old rice.

The flour of optimum particle size of old rice was taken into two containers and sugar and ghee both collectively called "*daun*" was mixed in the flour of one container but not in other. Like wise the flour of new rice was taken into another two containers and *dawn* was mixed in the flour of one container but not in another. All together there were four samples coded as ORWD, ORWOD, NRWD and NRWOD. They were kneaded for 10min, prepared batter mixing with water and allowed to stand for one hour. *Sel-roti* were prepared and the sample *Sel-roti* were sensorially evaluated for sensory attributes and texture profile by trained panelists and analyzed for physical parameters as mentioned above. Four replicates were conducted. The obtained data were analyzed statistically.

Table No 4.12: Experimental design for age of rice and *daun*

Age of Rice	***Daun***	
	With(WD)	**Without(WOD)**
Old Rice (OR)	ORWD	ORWOD
New Rice(NR)	NRWD	NRWOD

Table No 4.13: Recipe with *daun* and without *daun*

Age of rice and *daun*	**Ingredients**		
	Flour(g)	**Sugar(g)**	**Ghee(g)**
Old Rice with *daun*(ORWD)	250	52.5	26.25
Old rice without *daun*(ORWOD)	250	--	--
New Rice with *daun*(NRWD)	250	52.5	26.25
New Rice without *daun*(NRWOD)	250	----	….

4.12 Comparision of Sel-roti prepared from traditional and optimized process

The *Sel-roti* samples prepred from traditional process were collected from three shops (GPS, KTS and SDS) and one sample was prepred from optimized process in the lab, analysed and compared for their bulk density, fat- uptake, sensory quality and texture profile. Three replicate analyses were carried out.

4.13 Physicochemical analysis of rice and Sel-roti sample

4.13.1 Physical analysis

(a) Length and breadth: The length and breadth of *Kanchhi mansuli* paddy and rice were measured with the help of vernier caliper.

(b) Bulk density: The bulk density of paddy and rice was measured by measuring the weight of material of the certain volume measured in cylinder and calculating the ratio of weight and the volume of the same material. The method of measuring bulk density of *Sel-roti* is given in section 4.2.2 b.

4.13.2 Proximate composition and chemical analysis of rice and *Sel-roti*

(a) Sample preparation: Rice and *Sel-roti* sample were ground in uniform particle size by using electric grinder and packed into polythene bag and sealed .The samples were used for proximate and other components analysis.

(b) Moisture content: The moisture content of rice and *Sel-roti* samples were determined following Ranganna (2001) and AOAC (2005) method as follows:

Five gram of well ground sample in uniform particle size was taken into cleaned, dried and tared flat bottom metallic dish. The sample in container was dried at 100± 2°C till constant weight in hot air oven. The moisture content was calculated and expressed as percentage. The triplicate analyses were carried out.

$$\text{Percent Moisture Content} = \frac{loss\ of\ weight}{weight\ of\ smmple} X\ 100 \qquad \text{(Eq.2)}$$

(c) **Crude protein content**: For crude protein estimation nitrogen content in a sample was determined by micro-Kjeldahl method following the method Ranganna (2001) and the protein was calculated by multiplying the percentage of nitrogen by a factor i.e., 5.95(AOAC, 2001).

(d) **Crude fat**: It was determined by Soxhlet extraction method using petroleum ether (boiling point, 40 – 60°C) as in AOAC (2005) and Ranganna (2001). The method is also given in section 4.2.2 (c).

(d) **Ash Content**: It was determined in muffle furnace by the method given in Ranganna (2001).

(e) **Crude fibre**: It was determined using the method given in Ranganna (2001).

(f) **Total carbohydrate**: It was determined by difference as given below:

Total carbohydrate = 100 – (C.protein + C. fat + Total ash + C.fibre).

(g) **Reducing sugar**: It was determined by Shaffer-Somogyi Micro Method described in Raganna (2001).

(h) **Total sugar**: It was determined by Lane and Enyon Method described in Ranganna (2001).

(g) **Titrable acidity**: It was determined as described in AOAC (2005).

(i) **pH**: It was determined using pH meter (Hanna) as described in AOAC (2005).

(k) **Water Activity**: The *Sel-roti* sample was ground into fine particle and was determined by using Pawkit, water activity meter(Decagon devised, Inc. version 4, 2007 and accuracy: ±0.02) which was calibrated with 6 molal NaCl, 0.760 a_w and 13.41 molal LiCaCl, 0.250a_w.

4.13.3 Mineral content

The mineral content of rice and *Sel-roti* was determined as follow:

(a) **Calcium content**: It was determined by titration method described in Ranganna (2001).

(b) **Phosphorous:** It was determined by photometric method described in AOAC (2005) and the result was expressed as total phosphate as PO_4.

(c) **Other minerals:** The rest of the minerals such Iron, Sodium, Potassium, Manganese, Cadmium, Lead, Nickel and Zinc were determined by Atomic absorption spectrometer (AAS).

Procedure for the wet sample digestion: Two to 2.5g sample was taken into a beaker and 3ml conc. HNO_3 and 2ml of conc. HCl were added and heated on hot plate very gently until the liquid become green in color. After complete digestion the solution was allowed to cool and 100ml distilled water was added and then made up the volume to 200ml and filtered through Whatman No 41 faster and then transfer to another volumetric flask.

After completion of digestion of the sample the above mentioned minerals were determined using Thermo Elemental Atomic Absorption Spectrometer (SOLLAR) made in UK, Model No 965, 2004.

The mineral contents were determined in Seam-N lab, Biratnagar.

4.13.4 Analysis of fat/oil

The Acid values, Saponification Value, Iodine value, Peroxide Value, and RM Value, were determined by titrimetic method described in AOAC (2005)) BRR, RI (by using Abbe refractometer) were determined as in Egan et al.(1981) . The analysis of fat/oils was carried out in Seam-N lab and Eastern Regional lab of DFTQC, Biratnagar, Morang, Nepal.

4.14 Statistical analysis

The data obtained from survey, sensory evaluation, and physiochemical analysis was analyzed by using ANOVA from Gen-Stat Discovery Edition 3(GenStat release 7.22 DE). The means were compared by LSD at 5% level of significance to separate them whether they were significantly different or not or which was superior or inferior among treated samples. The data were also compared by using correlation and regressions from Microsoft excel 2007.

5. Results and Discussion

5.1 Survey of *Sel-roti*

The survey work was carried out about *Sel-roti*, a traditional and indigenous food of Nepal. The one hundred twenty six household samples comprising different ethnic groups like *Brahmin*, *Chhetri, Limbu, Rai, Newar, Gurung, Kami, Damai, Sarki, Choudhary, Rajbansi* etc were studied. The sample households were distributed throughout especially Eastern Region, some parts of Middle Region and Kathmandu. The survey respondents were the house wife, some aged male who knew how to prepared *Sel-roti* and many more about *Sel-roti*. The information were collected using questionnaires prepared (given in appendices B). The outcome of the survey is as follows:

1. Respondent Profile: The respondents of the survey of *Sel-roti* consisted of different age groups, sex, and of different geographical location. The respondent profile is presented below table no 5.1:

Among 126 respondents the highest percent i.e., 52.38 were in the age group 40 – 60 years; 85.71 percent were female and 14.29 percent male; in the cast the *Brahmin and Chhetri* were highest percent(43.65) and the lowest percent(1.59) were *Rajbansi;* likewise the highest percent (69.05) were Hindu and lowest percent(0.79) were Kabir Panthi. In the geographical distribution the highest percent of respondents were from Sunsari (30.16) followed by Terthum (17.46), Dhankutta (16.67). The survey sample households covered mostly the Eastern Development Region and Kathmandu and Rupandehi of Middle Development Region.

2. Family Size: According to the response given by respondents the average family size was found to be 6.

3. Definition of *Sel-roti*: The respondents were asked what *Sel-roti* is and why is it so called? Their responses were as follows:

About 32% of the respondents said that food prepared from rice flour with sugar, ghee with or without other ingredients frying in hot oil in ring shape. They said thus produced food product i.e., roti is called *Sel-roti* because of its shape round. Some respondents replied that the roti is called *Sel-roti* because it is prepared by frying the batter of rice flour, sugar & water pouring *syalla* (a Nepali word used to indicate continuous flow of

Table No. 5.1 Respondent Profile

Demographics	Percentage	Demographics	Percentage
Age Group		Religion	
20-40	26.98	Hindu	69.05
40-60	52.38	Bauddhisth	4.76
60-80	19.84	Christian	3.18
>80	0.80	Kabir Panthi	0.79
Gender		Not mentioned	22.22
Male	14.29		
Female	85.71	Resident of:	
		Sunsari	30.16
Cast/Tribe		Terhthum	17.46
Brahmin & Chhetri	43.65	Dhankutta	16.67
Limbu,Rai&Gurung	18.25	Jhapa	13.49
Newar	11.11	Kathmandu	7.94
Magar	6.35	Taplejung	3.97
Sharki	3.97	Morang	3.97
Choudhary	3.97	Sankhuwasabha	2.38
Tamang	3.18	Panchthar	1.59
Kami	3.18	Diktel	1.59
Damai	3.18	Rupandehi	0.80
Dhimal	1.59		
Rajbansi	1.59		

Number of respondents=126.

sticky batter) in ring shape in hot oil. Some respondents replied that the ring shape *roti* is turned upside down during frying and taken out from hot oil by using *Jhir* or *Sil* (the pointed stick of iron or bamboo used to turn upside down and taken out *Sel-roti* from hot oil). So the name *Sel-roti* is derived from.

Sel-roti is a sacred food item used in different occasion and different purposes. The meaning of *Sel-roti* in different language is as follows:

Table No. 5.2. The meaning of *Sel-roti* in different language.

Language	Meaning
Sanskrit	*Sanskuli*
Limbu	*Sela*
Dhimal	*Seli*
Magar	*Roto*
Choudhary	*Ghuriyalo/Ghurmalo*
Newari	*Mari*

Some *Limbu* respondents claimed that the name of *Sel-roti* is derived from *Limbu* word *Sela* for *roti*.

Some *Magar* also claimed that ringed shaped *roti* prepared from rice flour is called *roto* in *Magar* language and hence the name *Sel-roti* is derived from the word *roto* (Personal Communication).

Especially children use to call '*Chwain roti* or *Chwain papa*' for *Sel-roti*.

About 12 to 15% respondents said that they did not know why and how the name *Sel-rot*i is given.

According to the published document, traditional processing of *Sel-roti* by Yonzan and Tamang (2009), *Sel-roti* is only the traditional food item of and popular in Nepal and Sikkim and Hills of Darjeeling of India where Gorkha people are the resident. There is some similarity in the reasons of the naming of *Sel-roti*.

4. Cereal grains used in the preparation of *Sel-roti*

The entire respondents i.e.100% said that rice is used and most of them also said old and coarse rice are used to prepare *Sel-roti*. According to respondents different varieties of rice can be used depending on the availability of rice varieties. According to them *Tauli, Atte, Dudhiya, Anadi, Pokhara* are used in mountain region and *Aumusuli (kanchhi masnsuli), Khyamti*, and B44 are mostly used in Tarai and nearby areas. Some of the respondents said that they are not specific to the particular varieties of rice. They can use any varieties of rice whatever may be available. Most of he respondents reported old rice and coarse variety of rice were good for *Sel-roti* preparation.

Wheat flour and semolina are used by some respondents especially *Sel-roti* traders (or merchants) mixing with rice flour to make the *Sel-roti* soft and brittleless. Wheat flour also assists to puff the *Sel-roti*. According to them about 250gm i.e., 1 pawa of wheat flour is mixed in 1kg rice flour. There was similarity of mixing the amount of wheat flour in rice flour in making *Sel-roti* in Sikkim and Darjeeling of India (Yonzan and Tamang, 2009 and 2010).

In addition to rice flour, maize, white millet, sorghum, buckwheat flour are also used to prepare *Sel-roti* in mountain areas where rice is scarce. But from religious view point and common sense *Sel-roti* meant the roti prepared strictly from rice flour not any other cereal or non-cereal starchy flour.

Very few respondents told that they used to add a little amount of cassava flour with rice flour to make the roti puff and soft.

5. Ingredients:

Ingredients are substances used in the preparation of *Sel-roti*. They are of two types: (a). main ingredients and (b). Optional ingredients.

(a)Main ingredients: These are basic and essential ingredients. The quality of *Sel-roti* depends on these ingredients. There are few variation and substitution in the ingredients.

(i). About 57% of the respondents used rice flour, sugar, ghee(animal ghee) and oil as main ingredients whereas (ii) about 12% of respondents used rice flour, sugar and oil as main ingredients. Being animal ghee expensive people of low income group did not use ghee, instead they used *mohi* (culture butter milk).

Some traders /merchants used vegetable ghee in place of animal ghee. The animal ghee or vegetable ghee are mixed together with sugar in flour and kneaded well.

Some respondents especially Tharu/Choudhary used jaggery in place of sugar for the purpose of sweet taste as well as good colour and flavor. In somewhere some people used honey in place of sugar as sweetener.

Oil is used for frying the *Sel-roti*. Most of the respondents said that different kind of oil such as refined oil (soybean oil), mustard oil, and sunflower oil can be used. Some people used animal ghee for frying purpose for taste and flavor. The animal ghee must be used for frying the *Sel-roti* in special occasion to offer deities, as *naibed* in *Shraddha* (yearly ritual rites for passed away people) and Prasad in Pooja. The *Sel-roti* fried in animal ghee are more tender, tasty and flavorful. Very few people used vegetable ghee for frying of *Sel-roti.* Few respondents especially *Magar, Rai* and *Limbu* used lard for frying *Sel-roti*. Some people used mutton fat for frying *Sel-roti* in winter season. Hence the main/major ingredients of *Sel-roti* were rice flour, animal ghee, sugar and oil. On the basis of the majority of the respondents the ghee and sugar together is called *daun*.

(b) Optional Ingredients: In addition to the main ingredients, the substances used to make *Sel-roti* more puffy, soft, flavorful, delicious, tasty, good appearance are called optional ingredients. The ingredients used for those purposes collectively are also called '*Daun'*. Commonly used optional ingredients or '*daun'* consists of in addition to ghee and sugar, spices, milk and milk products, some plant materials etc. The amount and components of *daun* depend on the availability of the materials, tribes, locality, economic and social status of the people. It also depends on the preference and food habits of the individual and family. The optional ingredients are categorized into the following groups depending on their functions for which they are used in the preparation of *Sel-roti*:

Table No. 5.3 Categories of optional ingredients

Categories	Ingredients
1. Puffer	soda, *chiple, gogun, kaulo, chamlayo, udal*,egg, isabgol
2. Tastier	milk, honey, coconut, banana
3. Flavorings	methi, kapur, spices (clove, cardamom, cinnamon, mace) aniseed,
4. Texture improver	*kaulo, chiple, gogun, chamlayo, udal,* butter/cream, milk,curd,isabgol,silam,methi,banana,tender root of *simal*,chamsur,egg. Sesame (*til*)

Meaning of Nepali words in English: Soda=Sodium bicarbonate; Chiple=Pouzolzia viminea; Kaulo=Persea odorafissima; udal=Steculia villosa; Methi=Fenugreek; Til=Gingelyseed or sesame; Chamsur=Garden cress seed; Simal=Bombax malabaricum; Kapur=camphor.

Some respondents used only ghee and sugar, some used in addition to ghee and sugar milk, cream, some spices, plant material such as *Kaulo, chiple, Udal*, etc as puffing agents or texture improver; some people used egg, banana or *soda*(sodium bicarbonate) for puffing purpose; and some people used different spices to make *Sel-roti* flavorful.

6. Utensils/Equipments/Vessels:

The main utensil for frying of *Sel-roti* is called '*Tai*', which is especially prepared for this purpose (Fig.5.1). It is a flat iron pan with a raised side. Most of the respondents used *Tai* however, some respondents used '*Karahi*' (a pan of iron with holding ring in either sides or a cauldron) putting a brass bowl inside the '*Karahi*'.

Other utensils used for different purposes in *Sel-roti* preparation are as follows:

'*Ari*'or '*dekchi*': It is made up of stainless steel or aluminum and used for soaking of rice; mixing of rice flour with sugar, ghee or other ingredients; rubbing or kneading; and preparing batter.

Fig.5.1 *Tai* showing frying *Sel-roti* and shaping with *Jhir*.

A Flat dish: It is made up of stainless steel and used for keeping the fried or prepared *Sel-roti* just after removing from *Tai*,

Jhir: A pointed stick made up of iron or bamboo. A bamboo pointed stick is also called '*Sinko*' or '*Sil*'. It is used to turn the *Sel-roti* upside down and to remove *Sel-roti* from hot oil of frying pan. Choudhary used '*Chimta*' (a long tong made up of thick iron stripe) in place of *Jhir*.

Nanglo: Winnowing tray made up of bamboo bands. It is used to get the flour of varried particle size.

'*Thumse*'and '*Dalo*': They are bamboo bands baskets. *Thumse* is bigger and taller than *dalo* and is narrower along bottom side, used for carrying on the back whereas *dalo* is cylindrical in size. If there were more *Sel-roti*, thumse and *dalo* are used to keep the *Sel-roti.*

Dhiki(fig.5.2A) or other flour making equipments: Leg pound made up of log of wood is used to prepared flour from soaked rice. About 63.5% of the respondents used *Dhiki* to prepare rice flour. They also used Okhli and musli (Wooden mortar and pestle of big size)(fig.5.2C).

About 21.4 per cent of the respondents used mortar and pestle made up of iron to prepare flour. About 6.4% of respondents used electric grinder to prepare flour. About 2.4% respondents used grindstone or '*silouto*' (made up of flat stone with small rolling stone). About 6.4% of respondents, especially *Sel-roti* traders of Kathmandu used ready made flour. Now there are very few mills for preparing rice flour in urban areas. According to some of the respondents, good *Sel-roti* cannot be prepared from the rice flour prepared from mill.

Fig 5.2. (A) *Dhiki*; (B) *Khal Bachcha* containing flour; and (C) *Okhli* & *Musli* - women are preparing rice flour for *Sel-roti* preparation

Yonzan and Tamang (2010) reported that the similar utensils and equipments were used in Sikkim and Darjeeling of India.

7. Fuel or heating source for *Sel-roti* preparation: About 72.2% of respondents used firewood as fuel; 23.8% of respondents used gas stove and 5% used kerosene stove for the preparation of *Sel-roti*. High heat is necessary for the preparation of good *Sel-roti*. Firewood especially of hard wood is preferred. Most of the rural people used firewood as fuel for *Sel-roti* frying because firewood is cheap and easily available in rural areas. The respondents of Terai especially *Tharu/Choudhary* used dried cow-dung and firewood together as fuel for the preparation of *Sel-roti*. In urban areas firewood is still used if large amounts of *Sel-roti* are prepared.

8. Occasion of using *Sel-roti*: *Sel-roti* is popular in almost all tribes/races or castes, religious and geographic regions. It is related to the culture of the Nepalese people. They prepared *Sel-roti* in special occasion of their own and some common. In some occasion

Sel-roti is a must e.g. *Swasthani Pooja* (worship of god Shiva) of Hindu women, *Satyanarayan Pooja*; *Maghi*, Holly and *Siruwa* of Choudhary; and *Tihar* for most of the people. The occasions when *Sel-roti* is essential among different tribes /races are given below:

Brahman and Chhetri: *Tihar, Dasain, Maghe sakranti, Pooja* (worship) especially *Satyanarayan Pooja, Swasthani pooja* (worship of lord Shiva), *Saraswati pooja* (worship of the goddess of the speech and learning); *Bratabandha*(ceremony of investiture with the sacred thread); Wedding; *Nwaran*(name giving ceremony); *Koseli*(present or offering when daughter or daughter-in-law go to their husband's house or mother's house respectively); during guest coming ; as Owen in the beginning of any kind of work especially in wedding ceremony; as '*naibed*' or '*prasad*'(article of food offered to the deities); when anybody going away from home; '*Shraddha*'(rites performed in the name of demised person in yearly basis); birthday; ceremony of the cutting the hair of the child for the first time; '*Puran'* (mythology or theology); '*Pashni*'(ceremony of feeding rice to a child for the first time); Worship of cow-shed or cow-pen(called *Gothpooja* or *Goth Dhup*); *Diwali*; funeral rites; and '*Barakhi*' (commemorate ceremony held a year after the death of a relative); *Bastu, and Ghar paincho;* when any member of the family is going away from home for lomg time. They also prepared *Sel-roti* when desired or on the request of family members and after finishing paddy planting.

Limbu, Rai & Gurung: *Dasain, Tihar; Maghe sakranti*; Wedding; during guest coming; as present/*Koseli*; *Pooja* (worship); Inauguration of the new house; *Diwali*. In rai community *Sel-roti* must be taken by bride when he goes to the bridegroom's house for the first time after marriage and by the side of bridegroom *Sel-roti* double in amount must be returned. This is their custom.

Newar: *Dasain, Tihar; Maghe sakranti*; Wedding; during guest coming; as present/Koseli; *Pooja(Satyanarayan, Swasthani* etc); *Bratabandha; matatirtha or kushe aushi; Krishnastami; Gaijatra;* Inauguration of the new house; *Belbibaha*(a special custom i.e., marriage of newari girl with bail fruit).

Magar: *Dasain*, *Tihar; Maghe sakranti*; Wedding; during guest coming; as present/*Koseli*; *Pooja (Satyanarayan, Swasthani* etc); when anybody going away from home; Puran (mythology or theology); Worship of cow-shed or cow-pen; funeral rites; '*Barakhi*' (commemorate ceremony held a year after the death of a relative. It is essential to bring *Sel-roti* by bride when he goes to the bridegroom's house for the first time after marriage, called '*duran farkaune*'.

Tamang: *Dasain; Tihar; Magheskranti*; Wedding; during guest coming; as present/*Koseli*. In Tamang during marriage Barahkori (i.e., 240) *Sel-roti* and wine must be given by the side of bride to the side of bridegroom as a custom. They prepared *Sel-roti* on desire especially in winter season.

***Kami, Damai & Sarki*:** Dasain, *Tihar*; Maghe sakranti & Shrawanesakranti; Wedding; during guest coming; as present/*Koseli*; *Pooja* (Satyanarayan, Swasthani etc); Puran; when anybody going away from home; birthday; '*Shraddha*' (rites performed in the name of demised person in yearly basis).

***Dhimal, Choudhary and Rajbansi**: Tihar*; Pooja; as present/*Koseli*; Holly or *phagu;* and *Siruwa* (a ceremony of New Year). In these communities*, Sel-roti* is essential in the occasion of holly and *Siruwa*. *Sel-roti* is important and correlated to special meaning in *Tharu* communities especially of middle and western terain. They prepare *Sel-roti* using fire producing by rubbing two dried bamboo logs together and are placed in leaf-plate. The leaf-plate with *Sel-roti* is placed on top of the '*Lohota*' (a small metal water-pot) containing full of water and is allowed to stand overnight. In next morning if the water in *Lohota* remained unchanged, they believe that there will be favorable climate for agriculture for coming season. *Sel-roti* is essential in *Maghi*, which is a religious festival of *Tharu* community.

9. Experience and frequency of *Sel-roti* preparation:

The experiences of respondents for *Sel-roti* preparation were found to be varied because there were variations in their age. The aged respondents were relatively more experienced. The experience of *Sel-roti* preparation depends on the frequecncy of preparation. The aged people especially women are more experienced. The year of experiences of respondents varies from five to 60years.There was also variation in the frequency of *Sel-roti* preparation from respondents to respondents and household to household. Almost all respondents used to prepare *Sel-roti* in *Dasain, Tihar and Maghe sakranti*. In addition to these occasion some respondents prepared *Sel-roti* in the special occasion when *Sel-roti* is essential for example, the *Sel-roti* are prepared in holly (festival of *phagu*) and *siruwa* in *Tharu, Dhimal and Rajbansi* communities. In other communities respondents replied that they prepared *Sel-roti* in their own special occasion and worship, ritual process and festival related to their culture and religious and they prepared *Sel-roti* on demand of the household members and during guest coming; and someone is going away from home for long time.

Sel-roti traders of Sunsari, Jhapa and Kathmandu prepared *Sel-roti* daily whereas traders of Dhankutta used to prepare *Sel-roti* only in weekly bazaar or market. Some traders used to prepare *Sel-roti* in winter season only because more people prefer to eat *Sel-roti* in that season.

10. Method of preparation:

According to the respondents although there are variations in addition of ingredients, soaking time of rice, coarseness of flour, some treatment procedure prior to frying, frying medium, batter consistency etc., the major steps in methodology remain the same. The flow sheet for the preparation of *Sel-roti* is given in fig. 5.3 below:

Fig.5.3: Flow-sheet for the Traditional Method of *Sel-roti* Preparation:

Rice
↓
Cleaning
↓
Soaking in clean water ---for 2 to 12 hrs
↓
Draining water
↓
Pounding (using Dhiki/*Okhli)*
↓
Flour (Coarse, medium and fine)
↓
Sugar and Ghee → Mixing and kneading well
↓
Kaulo/Chiple/Chamlayo/Udal →
Batter preparation by adding water (cold or warm)
↓
Allow to stand for ½ to 2 hrs for conditioning/Ageing
↓
Soda (Sodium bicarbonate) →
Pouring batter through hand/ladle/die in ring shape on hot oil
↓
Turning upside down with *Jhir/ sinko**

(When down side of *roti* becomes reddish brown)

↓

Frying/Cooking until whole *roti* becomes reddish brown

↓

Taking out *roti* with the help of *Jhir/sinko* and draining oil

↓

Sel-roti

**Jhir* = Pointed stick of iron; and *Sinko* =Pointed stick prepared from bamboo.

Rice and cleaning: Almost all respondents used old rice and most of them used coarse rice; very few used fine and Basmati as well. The variety of rice depends on availability of rice in that locality or even in the household. In hilly/mountain area the rice variety used for *Sel-roti* preparation were *Tauli, Atte, Dudhiya, Anadi, Pokhara* and *Aumusuli, Khyamti*, and B44 are mostly used in Tarai and nearby areas. The rice is cleaned by using *Nanglo* (winnower) or *Chalno* (bamboo seive) to remove dirt, chaps, and other kind of material other than rice. The stones, heavy materials and grains other than rice are removed by picking with hands. The rice is washed with clean water.

Soaking: The cleaned rice is dipped in water and soaked. According to the response given by respondents soaking time varies from two hours to overnight. Soaking time varies from respondent to respondents. The soaking time also depends on how fast the *Sel-roti* is prepared. Many of the respondents preferred overnight soaking. According to some respondents if rice is soaked in water just to deep after washing, the rice soaked quickly.

Pounding: The soaked rice is pounded or ground into flour by using leg-pound, wooden mortar and pestle (*okhli and musli*); iron mortar and pestle (*Khal-bachcha*); and electric grinder. Majority of the respondents preferred leg-pound. The flour for household purpose, if small amount of flour required, is prepared using *Khal-bachcha*. Some people used electric grinders if these facilities are available. Some people used *Silouto* and *lohoro* if flour is needed is small amount and there are no other facilities. The good *Sel-roti* is prepared from the flour prepared by using leg pound or Okhli or mortar and pestle. Now there are few mills available in urban areas to prepare rice flour but the flour prepared in mill is not good for *Sel-roti* preparation.The respondents of Kathmandu especially *Sel-roti* traders used prepared flour which is available for sale. '*Nanglo*' or

‘*Chalno*’/ sieve were used to get the flour having desirable coarseness or fineness or particle size. The plant materials like *kaulo, chiple, chamlayo, gogun* and *udal* used to add during pounding of soaked rice into flour.

Mixing and kneading: Sugar and ghee are mixed with flour and kneaded well. The mixing and kneading the mixture of flour, sugar and ghee is carried out by sharing the mixture between to palm of hands and fisting and rubbing.

The main purpose of kneading of the mixture of flour, sugar and ghee is to mix well the ingredients. If sugar and ghee are mixed well the good *Sel-roti* will be prepared. Over kneaded mixture causes excessive absorption of fat, crackling due to over puffing, whereas under kneaded mixture causes less puffing, more solid or raw flour inside the *Sel-roti* and not grainy appearance on the surface of the *Sel-roti*. Some respondents especially some traders of Sunsari used vegetable ghee for kneading the flour. Choudhary respondents used jaggery instead of sugar for good color and flavor and they also used curd. Some people used cream instead of ghee. Experienced people knew kneading was optimum by smelling; looking the color of the kneaded flour with ghee and sugar; by observing pearly or grainy appearance of kneaded flour with sugar and ghee; by hearing the sound when the kneaded mixture was thrown into the flame of fire wood.

Batter preparing: The batter is prepared by adding water to the already kneaded flour. The optional ingredients such as spices, soda, and powder form of puffing, texture improving agents are added to batter and mixed well. Some respondents used to add warm water to prepare batter. They prepare batter of proper consistency.

The sensory quality of *Sel-roti* depends on batter consistency. Because according to the respondents the *Sel-roti* prepared from thick batter contains wale of flour whereas roti prepared from very thin batter the roti puffed very much and burst as well as become hollow and brittle on cooling. The consumers do not like the *Sel-roti* prepared from both types of batter. The batter should be of proper consistency i.e., batter should flow continuously when poured from hand or ladle. In other word the batter should be glutinous or viscous or sticky and should flow in a way of flowing a sticky fluid. Thus, prepared batter is allowed to stand for ½ hr to 2 hrs. According to some respondents holding of batter for some time helps in puffing of roti. Some respondents especially of Rai said the batter is allowed to stand overnight.

Frying: The oil or ghee or other form of fat used to fry *Sel-roti* is heated in *Tai* or *Karahi*. When smoke comes out of the surface of oil or it is tested by placing a little batter by *jhir* or *sinko* into hot oil if batter puffed well producing a sound, now it is ready for frying the *Sel-roti*. Then prepared batter is poured in ring shape into hot oil and cooked until the lower side of roti becomes slight reddish brown and then the roti is turned upside down with the help of *jhir* or *sinko* and again cooked until the whole *Sel-roti* become reddish brown. The cooked *Sel-roti* is taken out from hot oil with the help of *jhir* or *sinko* and piled on dish and allowed to cool. Most of the respondents used refine oil for frying of *Sel-roti*. Some of the respondents used vegetable ghee and few respondents said they used lard too. The *Sel-roti* prepared for pooja, or as *naibed* offering to the deities and other religious and ritual performance, animal ghee is used as frying medium. The *Sel-roti* fried in animal ghee are more tender, tasty and flavorful.

Maize
↓
Cleaning
↓
Husking - to remove the pericarp
↓
Dry millimg Grind stone
↓
Grits
↓
Soaking in water for 3 days
↓
Kaulo → Grinding or wet milling
↓
Mixing with sugar and water
↓
Allow to stand for 10hrs
↓
Frying in hot oil and cooked well as in *Sel-roti* preparation from rice flour
↓
Maize *Sel-roti*

In mountainous areas where maize is abundant and rice is relatively scarce, some people use to prepare *Sel-roti* from maize only for consumption.

Fig.5.4. Flow sheet for Sel-roti preparation from maize.

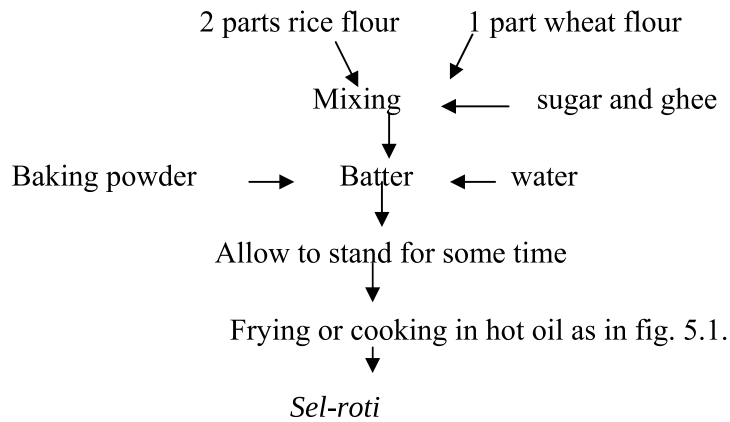


Fig.5.5. Flow sheet for the preparation of *Sel-roti* by traders in Kathmandu

Although there were variation in types and quantity of ingredients used, processing parameters the traditional processing methods were almost same in different geographical location and among different casts and tribes. The traditional processing methods given by respondents in survey were similar to the traditional processing method reported by Yonzan and Tamang (2010). The uses of ingredients were found similar to that of reported by Yonzan and Tamang (2010). The traditional processing methods given by respondents are given in fig. 5.3.

11. Method of flour preparation from rice:

The rice is cleaned and soaked in water for about two to eight hour or overnight. After draining, the rice is converted into flour by using different types of equipment based on availability in those areas. According to the response of the respondents, most of them prefer to use *Dhiki* i.e., leg pound followed by wooden mortar and pestle, iron mortar and pestle, grinder, grindstone and silouto. Now there are rice flour making mills are available in some urban areas. Most of the respondents said the flour prepared from mill is not suitable for *Sel-roti* preparation because the good *Sel-roti* cannot be prepared from such flour. This might be due to the flour having more or less similar particle size and another reason might be due to damage of starch by flour milling mills as reported by Matz (1996) and Kharel et al, (2010). The respondents of Kathmandu especially *Sel-roti* traders used prepared flour, which is available for sale.

12. The factors influencing the quality of *Sel-roti*:

On the response of the questions posed to the respondents about the factors influencing the quality of *Sel-roti* the result is as follows:

(a).Puffing:

According to the response of the respondents, the factors influencing the puffing of *Sel-roti* and their percentage are given in table no. 5.4.

Few respondents mentioned isabgol (Crude fibre), conditioning time i.e, ageing of batter, consistency of batter, particle size etc which influence puffing of *Sel-roti*.

For the different factors mentioned by respondents in table no 5.4, all most all respondents reported coarse and old rice was responsible for puffing, so therefore, coarse varieties and old i.e, aged rice was used to prepared *Sel-roti* and followed by others factors as reported by respondents like needing, heating i.e., frying temperature, soda, kaulo, ghee, wheat flour, chipple, udal and eggs. Kneeding contributes to mix evenly all ingredients and make matrix of starch and fat or protein which help to puff by retaining vapor during initial phage of frying into hot oil. High frying temperature above 200°C(initial frying temperature) contributes to generate vapor inside and make the surface case hardening which help to retain vapor and puff *Sel-roti*. Soda generates

Table No. 5.4. Factors influencing the puffing of *Sel-roti*

Particular	Percentage of respondent
Coarse and old rice	100
kneading	32.54
Heat of oil or fire	31.75
Sodium bicarbonate	26.19
Kaulo	11.91
Ghee	10.32
Wheat flour	8.73
Chiple	7.94
Udal	4.76
Egg	3.97

N=126. Respondents were allowed multiple responses, percentages may exceed 100%.

carbon dioxide gas during frying; kaulo, chiple and udal because of containing gum and mucilages make batter thick and slippery and help to retain gas or vapor; wheat flour contains gluten and gliadin protein ; egg especially eggwhite acts as whipping agent in batter, so all contribute puffing of *Sel-roti*.

(b) Mouth feel**:** According to the response of the respondents, the factors influencing the mouthfeel of *Sel-roti* and their percentage are given in table no 5.5 below:

Table No. 5.5. Factors influencing the mouth feel

Particular	**Percentage of respondents**
Ghee and sugar	50.00
Daun	19.84
Spices	12.70
Methi (Fenugreek seed)	11.11
Camphur	1.58
Not known	7.94

N=126. Respondents were allowed multiple responses, percentages may exceed 100%.

About 50% of respondents reported ghee and sugar provide taste and make tender and likewise *daun* means cream or dahi or milk, they all contribute the mouthfeel i.e., good sensation in the mouth due to the combined effect of taste, texture and flavor of *Sel-roti*. Spices and camphor provides flavor.

(c) Taste: According to the response of the respondents, the factors influencing the taste of *Sel-roti* and their percentage are given in table no 5.6. Almost all respondents reported sugar gives taste for *Sel-roti* that may be due to people think sweet is the taste and sugar provides sweetness to the products. Sugar is followed by ghee and sugar combined as taste giving factor. *Daun* (mainly cream, *dahi*, milk, butter, etc), milk, jaggery,coconut, honey, banana etc contributed their own taste to the *Sel-roti* and moreover, their tastes might enhanced during frying and heat brought some chemical changes such as caramelization of sugar, millard reaction and also produced some burnt flavor. Therefore they all contribute taste to the *Sel-roti*. Hence *Sel-roti* has piculier and unique taste and flavor.

Table No. 5.6. The factors influencing the taste of *Sel-roti*

Particular	Percentage of respondent
Sugar	100.00
Ghee& sugar	71.10
Daun	9.52
Milk	3.97
Spice	3.18
Jaggery	1.59
Coconut	1.59
Honey	0.79
Banana	0.79

N=126. Respondents were allowed multiple responses, percentages may exceed 100%.

(d) Texture: According to the response of the respondents, the factors influencing the texture of *Sel-roti* and their percentage are given in table no 5.7.

More than twenty percent of respondents reported that ghee and cream improve the texture of *Sel-roti* and other in decreasing order are *kaulo, daun , chiple*, kneading, milk,

Table No.5.7. Factors influencing texture of *Sel-roti*

Particular	Percentage
Ghee and cream	20.64
Kaulo	11.91
Daun	9.52
Chiple	7.94
Rubbing	7.94
Milk	7.14
Banana	6.35
Chamlayo	5.55
Curd	5.55
Old rice	3.97
Udal	3.18
Fenugreek seed	2.38

N=126. Respondents were allowed multiple responses, percentages may exceed 100%.

banana, *chamlayo*, curd, old rice,fenugreek. Most of them contribute to tenderness; some help to absorb more oil; some help to puff well, those in turn contribute to texture of the *Sel-roti*.

Very few respondents said that garden cress, egg, isabgol, *silam*, wheat flour can be used as texture improver for good texture of *Sel-roti*.

(e) Shelf life**:** Substances or factors influencing the shelf life of *Sel-roti* are as follows:
(i) Help to increase shelf life: Ghee, sugar, well frying, dry and cold environment.

(ii) Shorten or decrease shelf life: Banana, Eggs, Curd, *soda, Kaulo, chiple, udal*.

13. Desirable Characteristic

According to the responses (i.e., liked by highest percentage on particular characteristic) given by the respondents the *Sel-roti* should have the following characteristics:

a.. Appearance: ring/round shape, puffed, reddish brown, spongy inside, grainy appearance on the surface.

b. Taste: Sweet

c. Texture: neither so hard and nor so Soft but in between and, crispy/crumby.

d. Flavor: good, slightly sweetish and fried or slightly burnt sugar.

e. Eating quality: Oily/fatty and crumby.

14. Storage of *Sel-roti*

Normally *Sel-roti* can be stored for 1 week. Shelf life or storage life of *Sel-roti* depends on (i) ingredients used for example banana, curd, soda, plant bark etc., decrease shelf life whereas ghee, sugars increase, (ii) frying condition, (iii) storage condition.

Sel-roti containing rice flour, ghee, and sugar; well fried; stored at dry and cold condition will have comparatively long self/ storage life.

About 42% of respondents accept that the good *Sel-roti* preparation is an art and about 35% of respondents replied that it depends on skill and practice. Some respondents said they don’t know.

15. Quantity of *Sel-roti* prepared in terms of rice:

In the question asked how much quantity of *Sel-roti* do you prepared, respondents whether they prepared for the family or for sale replied the quantity in term of rice but not in term of *Sel-roti*. On the basis of the response given by respondents in survey there were about 84% of respondents who used to prepare the *Sel-roti* for their own consumption and household purposes and about 16% of respondents used to prepare *Sel-roti* for sale i.e., commercial purposes.

According to them in an average 26.4kg rice/year/family was used to prepared *Sel-roti* for household purpose whereas about 4.12kg rice/day/trader was used to prepare *Sel-roti* for sale. Among total quantity of rice used about 8.07% rice was used to prepare *Sel-roti* for household purposes and 91.93% rice was used to prepare *Sel-roti* for commercial purpose. If we considered the family numbers in Nepal is 44.67 Lacks, then the total quantity of rice used for *Sel-roti* preparation would be 12.18 lacks metric tons whose 91.93% is used to prepare *Sel-roti* for commercial purpose. According to the traders of Sunsari they prepared *Sel-roti* in regular basis for sale as well as on demand in special occasions and to send abroad to the relatives as well as family members by *lahure* families.

Table No. 5.8. Quantity of rice used to prepare *Sel-roti* for different purposes

Purposes	**% of respondent**	**Average Quantity of rice**	**Total Quantity of rice(Lacks metric tone**
Household	84	26.4kg/yr/family	0.98(8.07% of total)
Commercial	16	1504kg/yr/trader	11.20(91.93% of total)

According to the traders of the *Sel-roti* the price of *Sel-roti* was Rs.3 to Rs.5 per piece. The profits made by different traders were varied from Rs.100 to Rs.400 per day. Now the price of Sel-roti has increased. Respondents said that more Sel-roti were sold in winter than summer because people prefer to eat more *Sel-roti* in winter. Likewise more *Sel-roti* were sold during festival like *Tihar* etc. According to Yonzan and Tamang (2010) the cost per plate containing 4 Sel-roti was Rs.10 in Sikkim.

The sizes of the *Sel-roti* prepared from different persons vary and the numbers depend on the size. There is no standard equipment for the preparation of *Sel-roti* so that the standard sized *Sel-roti* could be prepared. Some people used hand and some used ladle or some brass bowl with small hole at the button. According to the respondents the numbers of *Sel-roti* prepare from 1kg rice was 26±8.

On the basis of the above data there is a good scope to commercialize the *Sel-roti* as indigenous food of Nepal. For this there is a need to improve the quality as well as shelf life of *Sel-roti*. This will be the area for further R and D work.

The shelf life study of sel-roti is needed for commercialization.this will be also proper area of R & D work.

The *Sel-roti* prepared for household purpose includes consumed by family, sent as *Koseli*, given to the guests, distributed as *Prasad* etc.

16. Recipe of *Sel-roti*:

There were variations in the recipe of *Sel-roti* depending on casts/tribes, availability of ingredients, culture and economic conditions of the family etc.

TableNo. 5.9: General and commercial recipe of *Sel-roti*

Recipe	Rice	Sugar	Ghee	Vegetable ghee	Soda	Oil/fat
Recipe I	1 kg	125 g				375ml
Recipe II	1 kg	125g	62.5 g			350ml
Recipe III	1 kg	125 g	125 g			400ml
Recipe IV	1 kg	250 g	125g			500ml
Commercial I	1 kg	125 g	42 g	83 g	1.5 g	
Commercial II	1 kg	100 g	100 g			

Table No.5.9 is the general and commercial recipe of *Sel-roti*. Although there are many variations in the use of optional ingredients, the use of main ingredient remains almost the same. Some *Mongolian* community use eggs. Some use vegetable ghee instead of ghee. Some use *chiple*, *chamlayo*, *Kaulo* and *udal* to make the product soft. *Kaulo* gum, its dried bark's powder and *udal* gum are generally used at the rate of 100-200, 50-100 and 20-50 gm/ kg rice respectively. Commercially, soda is used at the rate of about 1.5g /kg rice for puffing. Some people also use different types of spices e.g., fenugreek, cinnamon bark, clove etc., milk, *curd, til, silam,* banana. Different type of oil/fats can be used for frying of *Sel-roti* e.g., refined oil, soybean oil, sunflower oil, mustard oil, animal ghee, vegetable ghee. Some Mongolian use lard and some higher cast people use mutton tallow for frying purpose.

The furtheer research work can be done on optional ingredients such as chiple, chamlayo, kaulo and uddal; different spices especially on their functional characteristics and effect on human health.

17. Liking of *Sel-roti*

The response on the question who most likes *Sel-roti* in the family is given in the table no.5.10.

According to the response given by respondents children were first then followed by old, adult whereas very old people are least liker of sel-roti, this might be due to differet diseases in which fatty foods are restrited.

Table No.5.10: Member who likes to consume more *Sel-roti* in the family.

Particular	Percent of Respondents
Children	46
Old	30
Adult	29
Adolescent	21
All members	14
Very old	5

N=126. Respondents were allowed multiple responses, percentages may exceed 100%.

5.2 Recipe Optimization

Among the various recipes collected from the survey five most common recipes i.e., more respondents used to make *Sel-roti* in their house or shop or restaurant were selected. They are given in method section. According to the recipes *Sel-roti* were prepared. The *Sel-roti* were evaluated sensorially by consumer panelists (who were known Sel-roti and used to eat frequently) by using 7-point hedonic rating. The scores were analyzed and mean scores are given in the table no. 5.11.

The ANOVA of the mean scores showed that A got lowest score in all attributes and significantly different (p≤0.05) from others and the scores are in increasing order up to D then scores decreased. In all attributes C, D and E are not significantly different (p>0.05). D got highest value for all sensory attributes like appearance, flavor, taste and texture except overall acceptance for which E got slightly higher score than B. Although C, D and E were not significantly different (p>0.05), however, D is superior to others. For more clearer the hedonic mean scores were converted to rank given in table no.5.12.

Comparing with the tabulated value for 5 responses and 5 treatments from the table 19-5b at 5% level (Ranganna, 2001) D is significantly superior at 5% level. Hence recipe D was selected for *Sel-roti* preparation and the recipe D which consisted 1kg rice, 250g sugar, 125g ghee and 300 ± 9.6g water which is equivalent to 100g rice flour(wet weight basis), 21g sugar, 10.5g ghee and 25 ml water. This recipe was used throughout the research work.

Table No 5.11: Mean score of the sensory evaluation

Attribute	**Treatments**				
	A	**B**	**C**	**D**	**E**
Appearance	4.47±(1.42)^{a}	4.87±(1.36)^{ab}	5.18±(1.47)^{bc}	5.71±(1.47)^{c}	5.60±(0.91)^{c}
Flavor	4.13±(1.56)	4.95±(1.41)^{a}	5.18±(1.14)^{ab}	5.64±(1.16)^{b}	5.51±(1.16)^{b}
Taste	3.96± (1.51)	5.00±(1.46)^{a}	5.13±(1.32)^{ab}	5.67±(1.31)^{bc}	5.47±(1.42)^{abc}
Texture	3.31±(1.58)	4.91±(1.57)^{a}	5.02±(1.51)^{a}	5.44±(1.30)^{a}	5.24±(1.48)^{a}
Overall Acceptance	3.61±(1.30)	4.94±(1.15)^{a}	5.27±(1.26)^{ab}	5.60±(1.14)^{b}	5.61±(1.14)^{b}

Mean of 45 panelists. The mean ± standard deviation. The similar alphabets in row indicates not significant different (p>0.05) by LSD.Recipe ratio of flour in kg, sugar, ghee and water in g:A= 1:125:0:300(9.6); B = 1:125:62.5:300(9.6); C = 1:125:125:300(9.6); D = 1:250:125:300(9.6) and E = 1:250:250:300(9.6).

Tabl No 5.12. Conversion of Hedonic Scale to Rank

Attributes	Treatments				
	A	B	C	D	E
Appearance	5	4	3	1	2
Flavor	5	4	3	1	2
Taste	5	4	3	1	2
Texture	5	4	3	1	2
Overall acceptance	5	4	3	2	1
Total	25	20	15	6	9

If proper ingredients are mixed in correct proportion the good products result. In case of sel-roti flour from 1kg rice, 250g sugar, 125g ghee and 300ml water gives good sel-roti. The optimum ratio of ingredients wee obtained from recipe optimization. The correct proportion of ingredients must be forgood doughnut product (Lawson, 1997).

5.3 Particle size distribution of rice flour

The flour samples from different *Sel-roti* traders of Dharan, Tarahar, household of Dharan, Biratanagar and one lab prepared were collected. The flour samples except Biranagar were prepared by using *Okhli-musli* and *Khal-bachcha*. The flour sample from Biratnagar was prepared from milling machine. The all samples were analyzed for their particle size distribution by using standard set of sieves and the particle size distribution curve is given in fig 5.6 (a). The mean particle size of the samples SD, GD, KD, PD, TT, BRT and EXP were 772± 33, 629±58, 549±74, 705±15, 582±17, 394, and 516±7 respectively. The sample SD had largest mean particle size whereas sample BRT had smallest mean particle size among the collected samples. The curve SD, PD and GD are shifted right, curve BRT is shifted left and curve SD and EXP are in between. The position of the curve in the graph indicates the mean particle size of the flour and also the quality of the *Sel-roti* provided other things remain same.

The rice flour of formulation 1 and formulation 2 were analyzed for their particle size distribution by using standard set of sieves and their frequency distribution are given in fig. 5.6 b & c. The frequency distribution of rice flour in fig. 5.6 a & c show similar pattern. In fig.5.6 b all curves except curve **d** are broken because curve **d** includes coarse, medium and fine particles. The mean particle size of the samples a, b, c, d, e, f, and g were 91±2, 227±6, 383±7, 495±8, 615±4, 752±9,and 1133±14 respectively. The *Sel-roti* prepared from the mixture of coarse, medium and fine flour was found to be preferred by panelists in formulation F1. On the basis of the panelists result the formulation F2 was prepared and the frequency particle distribution curve of formulation F2 is given in fig.5.6 c which shows that Curve G, F, E have high pick shifted to the right, curve A, B, & C to the left and curve D (bold one) in between.The mean particle size in micron of the samples A, B, C, D, E, F, and G were 359±4, 425±6, 465±6, 520±6, 614±8, 652±8 and 746±10 respectively. The curve D whose mean particle diameter is 520±6μ resembles to more or less normal distribution, the *Sel-roti* prepared from which was preferred most by panelists. Again on this basis the formulation F3 was prepared and the frequency particle distribution curve of this formulation is given in fig.5.6 d. The mean particle size in micron of samples D, H and I were 520±6, 566±4 and 552±3 respectively. The Sel-roti prepared from sample D whose mean particle size was 520±6μ and the frequency distribution curve is given in fig.5.6e were most preferred by panelists and was selected as optimum particle size i.e., 520±6μ for good *Sel-roti* preparation. The rice flour having this mean particle size was used throughout the research work.

The mechanical means or the sophisticated milling machines are not developed in our country Nepal to produce flour having a mixture of different particle size. There are some milling machines seen in urban areas but the *Sel-roti* prepared from the flour produced from such mill is not of good quality because the flour has more or less similar particle size and also may be the starch damage created by rigorous action of such mill. In other countries roller, burr and pin mill used to produce rice flour which can produce a loaf but fine hammer and turbo milled flour can't because of heavy starch damage created by rigorous action of two mills (Martz,1996).

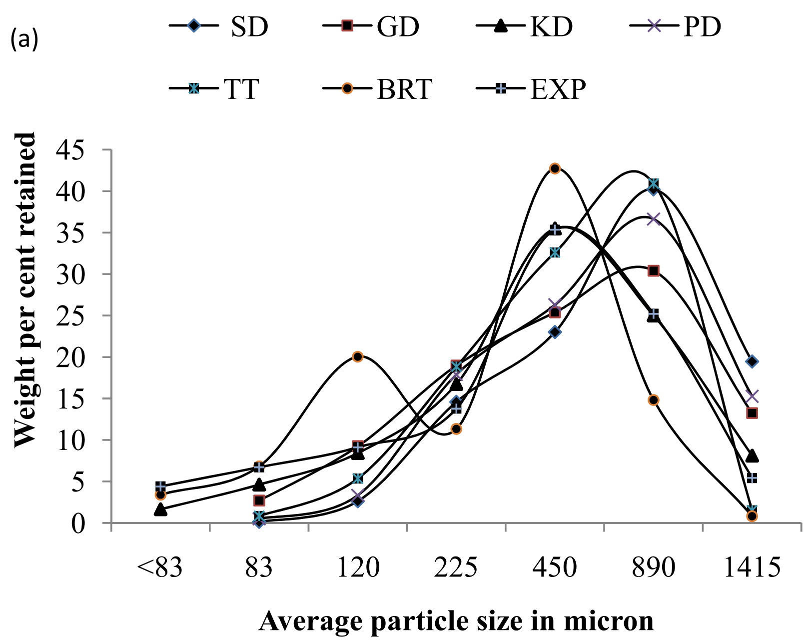


Fig.5.6(a) Particle size distribution of market, household and lab sample of rice flour

SD, GD, KD … represent the rice flour sample collected from different locations

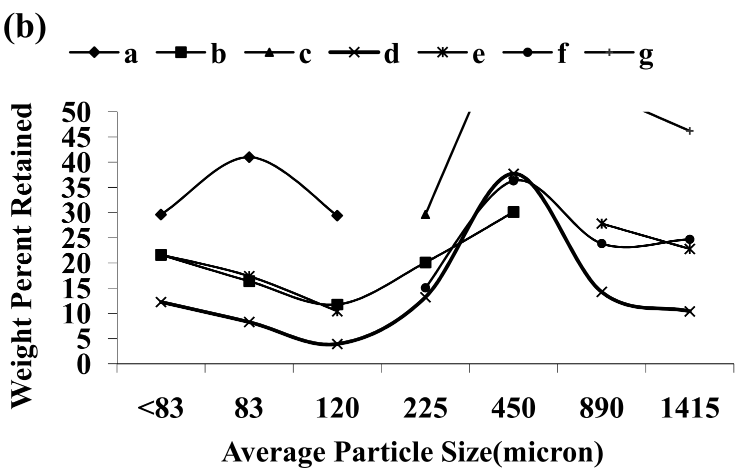


Fig. 5.6 (b) Particle Size Distribution of Rice Flour- Formulation 1(F1)

In fig 5.6 (b) a,b,c,….g represent lab prepared rice flour samples containing different proportion of course, medium and fine as of formulation F1 and

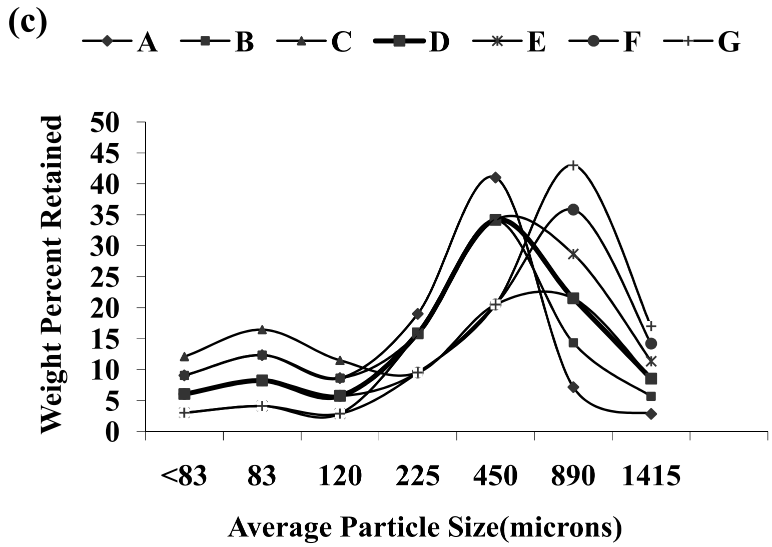


Fig.5.6(c) Particle Size Distribution of Rice flour – Formulation 2(F2).

In fig 5.6 (c) A,B,C, …….G represent the rice flour samples containing different proportion of course, medium and fine as of formulation F2.

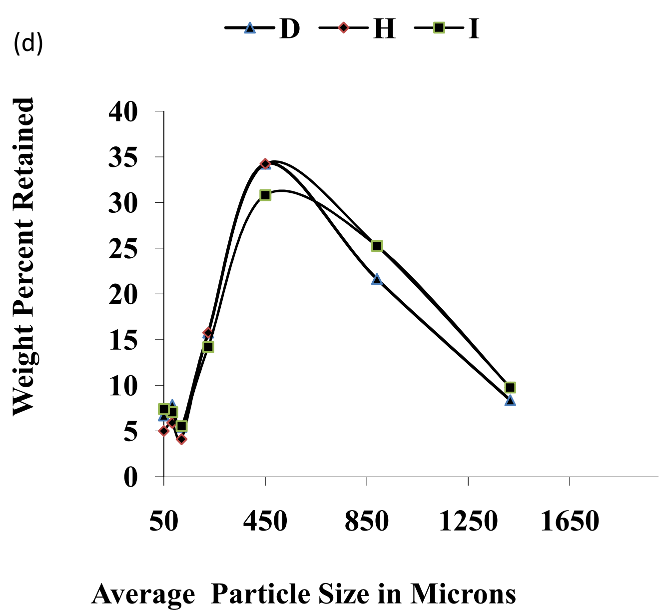


Fig5.6 (d) Particle Size Distribution of Rice Flour – Formulation 3(F3)

In fig. 4.6 (d) D, H& I represent the rice flour samples containing different proportion of coarse, medium and fine as of formulation F3.

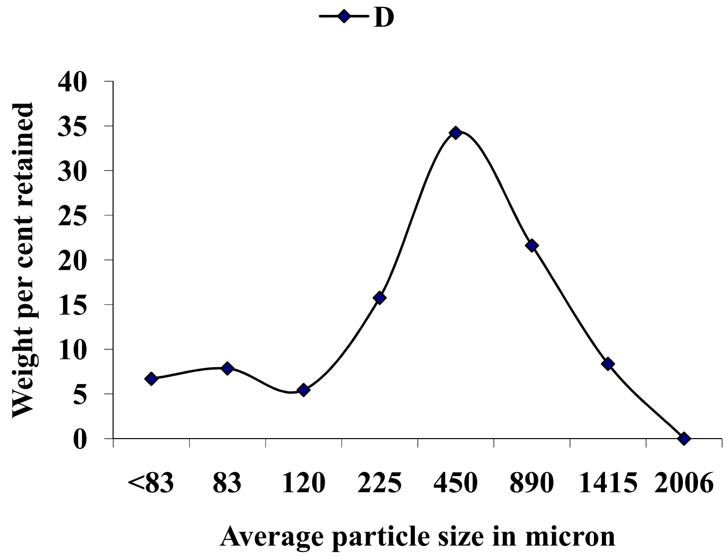


Fig. 5.6 (e) Particle Size Distribution of Rice Flour of Optimized Particle Size

The flours having required particle distribution can be obtained by blending the flour in different proportion of different particle size separating by using standard sieves/screens from the flour obtained by grinding or pounding with *Dhikki* or *Okhli*.

Baked products are inherently complex systems because they involved a large number of ingredients. During cooking (baking) of cake batter and bread dough, heat induces physical and chemical changes in the contents of batter or dough system. These heat-induced changes yield a stable structure with subsequently desirable flavor, aroma and texture characteristics. The texture in bread and cake is to a large extent, a function of the rheological properties of the material making up the gas cell walls. Some of the other factors affecting the texture of breads and cakes, as perceived in the mouth, are the shape, size, and size distribution of the gas cells (Taranto, 1983). Processing brings about changes in chemical and physical properties that make the end product more attractive and useful as a food (DeMan, 1983). The above mentioned phenomenon are applicable for *Sel-roti* because *Sel-roti* is prepared from the batter prepared from rice flour, sugar and ghee frying in very hot oil. The particle size distribution of flour is very important factor to influence the texture and sensory quality of *Sel-roti* provided that ingredients and processing conditions remain constant.

5.4 Effect of Particle Size on physical and sensory quality of *Sel-roti*

(a) Effect of particle size on Bulk Density: The bulk density of *Sel-roti* as effected by paricle size is given in fig. 5.7 a, b, and c. The regression and correlation analysis showed that there was good positive correlation of mean particle size of flour with bulk density of *Sel-roti* prepared from market sample ($r=0.96$, $p\leq0.05$), formulation F1($r=.98$, $p\leq0.05$) and formulation F2($r=0.97$, $p\leq0.05$) as shown in fig.5.7 a, b and c. In figure 5.7 a, b and c trends show similar pattern that means as the mean particle size increased the bulk density also increased provided that all other conditions remained same. In other way the bulk density of the *Sel-roti* was found to be directly proportional to the mean particle size of the rice flour from which the *Sel-roti* was prepared. Because the appearance of the *Sel-roti* including inside structure showed that as the mean particle size of flour increases the puffiness decreases and the solid proportion increases. The flour having fine particle size produced *Sel-roti* with puffy and hollow inside; medium particle size flour produced puffy and spongy inside; and coarse particle sized flour produced very less or no puffy

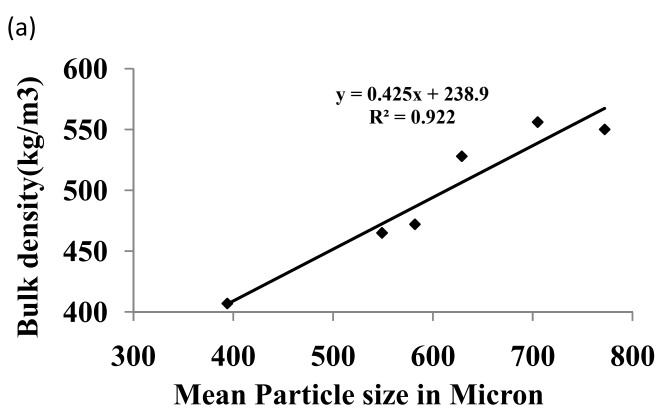
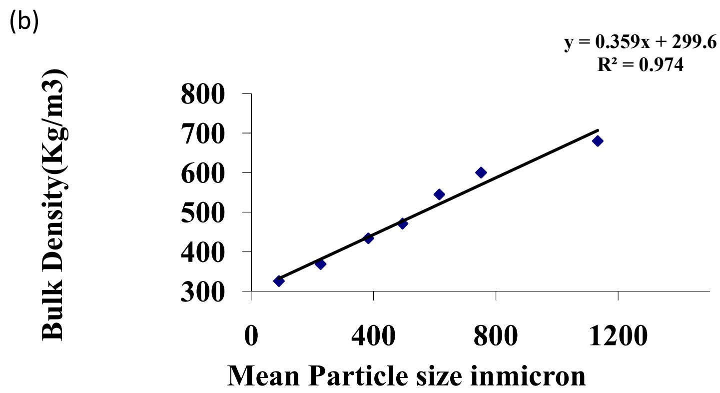


Fig.5.7a. Mean particle size and bulk density of (a). Market samples



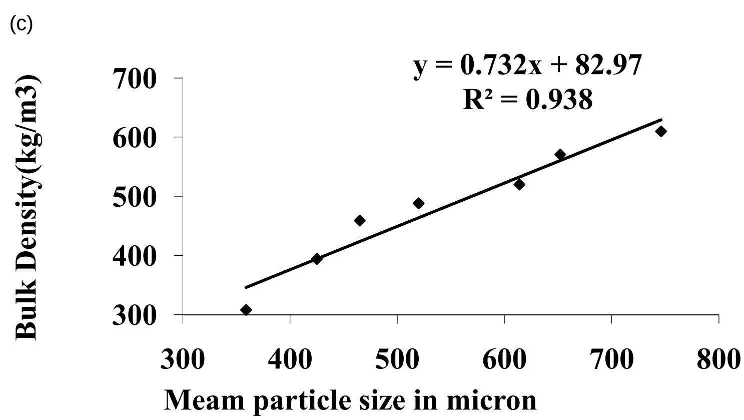


Fig.5.7b&c. Mean particle size and bulk density of (b) Formulation F1 and (c). Formulation F2

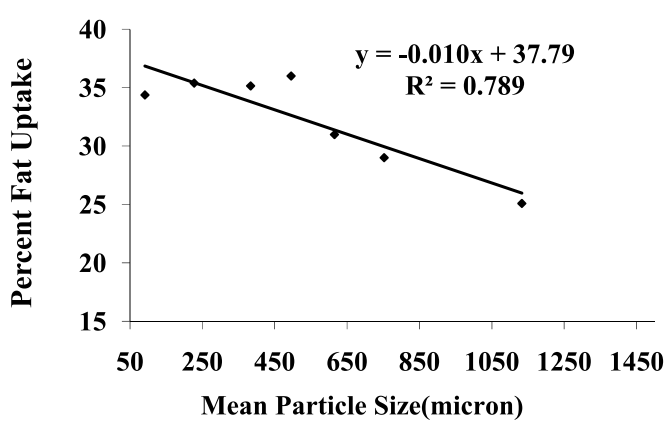
Sel-roti with solid mass inside. Therefore, puffy *Sel-roti* with hollow inside gave low bulk density; puffy *Sel-roti* with spongy inside gave medium bulk density, and less or no puffy *Sel-roti* with solid inside gave high bulk density. The spongy mass was found in the *Sel-roti* prepared from the flour having mid mean particle size. In the experiments the highly preferred *Sel-roti* by panelists (the result of the sensory attributes is given in table 5.14) was prepared from the rice flour having mean particle size 520±6 μ and the bulk density of that *Sel-roti* was found to be 488±7 kg/m3. Hence the selection of the particle size of the flour is important for the good quality of the *Sel-roti*.

(b) Effect of particle size on Fat-uptake: The fat uptake of *Sel-roti* as efected by particle size is given in fig. 5.8 a & b. The regression and correlation analysis of mean particle size and fat-uptake showed that the good negative correlation of mean particle size of flour was found with the fat-uptake of *Sel-roti* prepared from formulation F1(r= -0.89 p≤0.05) and formulation F2(r= -0.90 p≤0.05).

In the figure 5.8 a & b the both trend lines show similar pattern that means the fat-uptake of *Sel-roti* decreased with increase in mean particle size of the rice flour. This might be due to larger surface area exposed, which absorbed more fat and also more hydrophobic groups exposed which take more fat when particle size become smaller and smaller. Hence the fat-uptake of *Sel-roti* was found to be depended on particle size of the rice flour from which the *Sel-roti* was prepared. The fat-uptake of the *Sel-roti* is important parameter to judge the quality of *Sel-roti*. Since most of the consumers prefer the oily/fatty *Sel-roti* but not having excessive fat. It was revealed by the score given by the consumer panels on testing the *Sel-roti* containing different proportion of fat for the optimization of recipe; and written answer for the question asked for preferring *Sel-roti* having low or high fat/oil content.

The fat-uptake of *Sel-roti* prepared from the rice flour having mean particle size 520±6 μ which was most preferred by the panelists was found to be 35.3±2.01 percent on dry and fat free basis.

a



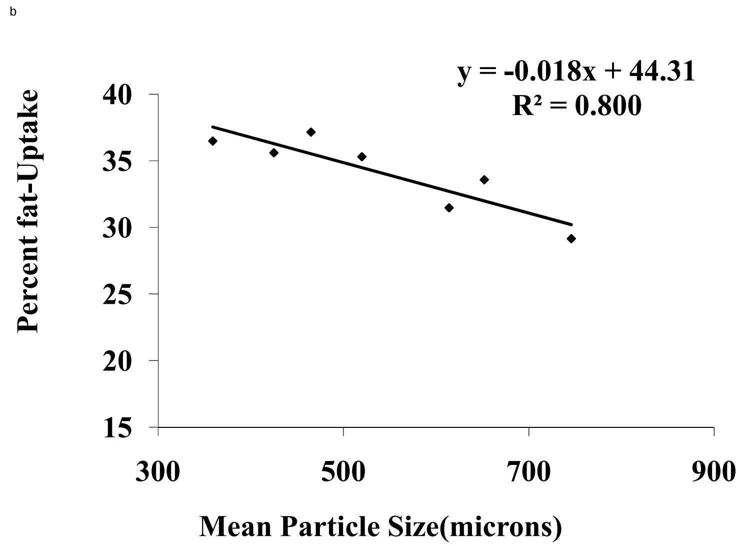


Fig.5.8Mean Particle Size and Fat Uptake (a) Formulation F1 and (b) Formulation F2

(c) Effect of particle size on Sensory attributes: The mean score of the sensory attributes given by the panelists to the *Sel-roti* prepared from different mean particle sized rice flour in formulation F1 is given in table no 5.13. The ANOVA of panel scores for sensory attributes of *Sel-roti* prepared from formulation F1 (table no 5.13) revealed that in appearance *Sel-roti* samples **g**, **f**, **b** and **a** got low score and were significantly different ($p \leq 0.05$) whereas *Sel-roti* samples **c**, **d** and **e** got high score and were not significantly different ($p > 0.05$) to each other but significantly different from others. In case of taste the *Sel-roti* sample **a** got lowest mean score and was significantly different ($p \leq 0.05$) from other; **g**, **f** an **b** were not significantly different ($p > 0.05$) but they were significantly different from other; **c**, **d** and **e** were not significantly different and got high mean score than others. In case of texture sample **a** and **g** got low mean score and were not significantly different but they were significantly different from other, sample **d** and **e** got high mean score and were not significantly different ($p > 0.05$) but were significantly different ($p \leq 0.05$) from others. In case of flavor sample **a** got lowest mean score and **d** & **e** got high score and are not significantly different but significantly different from other. In case of overall acceptability sample **g** got lowest score and followed by **a**, **b**, **c** and **f** and they were significantly different from **e** and **d** which got higher score. From the above discussion there was effect of particle size of rice flour on the preference of sensory attributes of *Sel-roti*. In all attributes samples **d** and **e** are not significantly different but sample **d** got highest mean scores in all attributes. Hence *Sel-roti* sample **d** whose mean particle size was 495(8) μ was preferred in the formulation F1. It also revealed that the *Sel-roti* prepared from the rice flour containing a mixture of all particle size was found to be good. The *Sel-roti* samples **a**, **b**, **f** and **g** corresponding mean particle size were 91, 227, 752 and 1133 μ got lower mean score for appearance, texture and overall acceptability that means they were not preferred by panelists. The preparation of *Sel-roti* was not technically feasible from the rice flour having mean particle size less that 120 μ and more than 890 μ such *Sel-roti* were not organoleptically preferred because *Sel-roti* prepared from the flour having mean particle size less than 120 μ puffed excessive during frying but collapse on cooling and became leathery in texture, whereas the batter from the flour of more that 890 μ could not flow continuously and could not take ring shape, did not puff and became solid and excessive grainy and hard in texture.

When rice flour having mean particle size 495μ which was the mixture of 25% coarse, 50% medium and 25% fine flour being selected, to optimize the different proportions of flour of different sizes formulation F2 containing different proportions of coarse, medium and fine flour was made and the *Sel-roti* were prepared and presented to the panelists for evaluation of sensory attributes and texture profiles. The ANOVA of sensory attributes were carried out and the result is given in table no 5.14. The analysis of the panel score revealed that in case of appearance sample G got lowest mean score and significantly

Table No 5.13. Mean Score of the Sensory Attributes of *Sel-roti* of Formulation F1.

Sensory Attributes	Treatments[1]						
	a	b	c	d	e	f	g
Appearance	6.90(3.2)	8.40(2.9)	11.33(2.4)^{a}	12.47(1.7)^{a}	12.36(1.7)^{a}	9.70(3.3)	4.07(1.2)
Taste	8.20(2.7)	10.27(1.4)^{a}	11.93(0.9)^{b}	12.67(1.3)^{b}	12.40(0.7)^{b}	11.07(1.4)^{a}	10.67(1.9)^{a}
Texture	4.93(2.8)^{a}	6.72(3.1)^{c}	8.33(2.4)^{b}	11.27(1.9)^{d}	11.00(3.3)^{d}	7.20(3.0)^{bc}	3.73(1.5)^{a}
Flavour	8.30(2.9)	9.90(2.3)^{b}	11.60(1.1)^{c}	12.40(1.4)^{d}	12.10(1.4)^{cd}	11.00(1.9)^{a}	10.50(2.1)^{ab}
Overall Acceptability	6.93(1.4)	8.60(1.6)	11.10(1.3)	12.53(1.2)^{a}	12.13(1.6)^{a}	9.70(2.5)	4.80(1.7)

N=18(6 panelists x 3 replicates). The values are mean score of triplicate analysis and the figures in parentheses are standard deviation. The values were recorded in 15point scale on the preference basis. A, b, c, d same alphabet in row indicates no significant difference ($p>0.05$) as determined by LSD.1, mean particle size (in micron) of flour, a=91(2), b=227(6), c=383(7), d=495(8), e=615(4), f=752(9) & g=1133(14).

Table No 5.14. Mean score of the sensory attributes of Sel-roti of Formulation F2.

Sensory Attributes	Treatment[1] A	B	C	D	E	F	G
Appearance	11.39(1.5)[a]	10.72(1.5)[b]	10.5(2.1)[bc]	12.22(1.4)	10.22(2.4)[bc]	10.94(1.7)[abc]	6.56(3.3)
Taste	11.66(1.3)[a]	10.61(2.2)[b]	10.72(1.6)[b]	12.61(1.0)	11.00(2.1)[c]	11.5(1.2)[ac]	10.00(2.7)
Texture	11.11(1.6)[a]	10.11(2.5)[b]	10.94(2.0)[a]	12.18(1.3)	9.61(2.5)[bc]	9.78(2.7)[bc]	6.78(3.4)
Flavour	10.94(1.6)[a]	10.72(1.6)[a]	10.56(1.6)[a]	12.00(1.6)	10.61(1.9)[a]	10.61(2.0)[a]	9.83(2.5)
Overall Aceptability	10.94(1.3)[a]	10.22(1.8)[b]	10.39(1.2)[abc]	12.39(1.2)	9.78(2.2)[b]	10.28(1.8)[bc]	7.67(2.6)

N=18(6 panelists x 3 replicates). The values are mean score of triplicate analysis and figures in parentheses are standard deviation. The values were recorded in 15point scale on preference basis. a,b,c,d same alphabet in row indicates no significant difference (p>0.05) as determined by LSD. 1-mean particlesize(micron):A=359(4), B=425(6),C=465(6), D=520(6), E=614(8), F=652(8) &G=746(10).

different (p≤0, 05) from others. Sample A and sample F were not significantly different (p>0.05), likewise sample C and sample E were not significantly different; and sample D got highest score and was found to be superior. In case of taste similar type of result was found as in appearance i.e., sample G got lowest score and D got highest score and both were significantly different (p≤0.05) to one another and from other. Likewise in case of texture G got lowest score and was significantly different from other; A and C were not significantly different (p>0.05); B, E and F were not significantly different; and D got highest score and was significantly different (p≤0.05) from others. In case of flavor G got lowest score; A, B, C, E and F were not significantly different (p>0.05) and D got highest score and was significantly different (p≤0.05) from other. In case of overall acceptability G got lowest score and was significantly different from other, score followed by E, B, F and C were not significantly different ; A and C were also not significantly different, and D got highest score and was significantly different from other. Mean score of the panel for each type of *Sel-roti* revealed that in each sensory quality attribute the score increased with increasing particle size up to 520±6 μ and then decreased. The *Sel-roti* prepared from the flour of mean particle size 520±6μ was found to be superior in each quality attribute so formulation D i.e., 520±6μ flour consisting 30, 50 & 20 part of coarse, medium and fine respectively was selected. Again the formulation F3 of D, I and H containing different proportion of coarse, medium and fine flour was prepared and the *Sel-roti* prepare from that flour were evaluated sensorially by panelists and the ANOVA result is given in table no 5.15. The result shows there is no significant different ($p>0.05$) but among the formulation D got highest sensory score in all the sensory attributes. From the ANOVA of all the formulation D i.e., 520±6μm was found to be superior for quality attributes. Thus optimized particle size of flour i.e., 520±6μm was recommended and was used for further investigation.

The analysis of panel score of quality attributes for first and second formulation of particle size revealed that relatively rice flour having low mean particle and high mean particle size as well as more or less similar particles are not fit for good quality *Sel-roti*. It

Table No 5.15. Mean score of the sensory attributes of *Sel-roti* of Formulation F3

Sensory Attributes	Treatment[1] D	I	H
Appearance	12.40(1.12)	11.87(1.51)	11.50(1.57)
Taste	12.47(0.83)	11.67(1.11)	11.80(1.15)
Texture	11.27(1.05)	11.13(1.70)	10.33(1.09)
Flavor	12.27(1.10)	11.93(1.44)	12.27(1.39)
Overall Acceptability	12.33(0.98)	11.67(1.11)	11.33(1.19)

N=18(6 panelists x 3 replicates). The values are mean score of triplicate analysis and figures in parentheses are standard deviation. The values were recorded in 15point scale on preference basis. 1-mean particle size (micron): D = 520(6); I = 552(3) and H = 566(4).

also revealed that good quality *Sel-roti* can be prepared from the rice flour containing different particle size distributed in different proportion of coarse, medium and fine. Because coarse particle contributes to grainy appearance, medium particle give main body and fine particle acts as filler and the batter from combined particle in optimum proportion with other ingredients i.e., ghee and sugar in a optimum consistency become slippery and flow continuously and that can be poured into ring shape into hot oil and puffed well giving spongy mass inside, which all give good appearance and texture as well to the *Sel-roti*.

(d) Sensory Texture Profile of *Sel-roti*: The trained panelists' mean scores of sensory texture profile of *Sel-roti* of formulation F1, F2 and F3 are shown in table no 5.16, 5.17 and 5.18 respectively. The regression and correlation analysis of mean particle size of rice flour and sensory texture profile of *Sel-roti* showed the good positive correlation of mean particle size of flour with sensory texture attributes like hardness(r=0.91, p≤0.05), fracturability(r=0.91, p≤0.05); and good negative correlation with smoothness(r=-0.96, p≤0.05), stickiness(r=-98, p≤0.05), and cohesiveness(r=-0.84, p≤0.05); fair positive

Table No.5.16.Mean score given by panels for sensory texture profile formulation F1

Texture	Treatments[1]						
Attributes	a	b	c	d	e	f	g
Smoothness	12.07(0.88)	9.93(2.4)	8.13(1.6)^{a}	8.13(1.7)^{a}	8.70(2.4)^{a}	6.27(2.3)	3.80(1.01)
Hardness	3.70(1.2)	5.70(1.2)^{a}	7.20(1.7)	5.40(0.88)	6.50(1.9)^{a}	9.00(2.2)^{b}	10.40(2.3)^{b}
Fracturability	2.93(1.3)	4.53(1.5)^{a}	5.80(2.4)	4.07(1.2)	5.13(2.2)^{ab}	8.07(2.8)^{bc}	9.73(2.3)^{c}
Cohesiveness	6.00(2.8)^{ab}	6.10(2.8)^{b}	5.13(2.7)^{a}	5.30(3.0)^{ab}	5.40(1.9)^{ab}	3.27(1.0)^{c}	3.93(1.1)^{c}
Stickiness	5.93(3.0)^{a}	5.40(3.5)^{ac}	4.73(3.0)^{a}	4.60(2.9)^{ac}	4.07(2.2)^{ab}	3.47(1.7)^{bc}	2.93(1.5)^{b}
Oily mouth feel	8.53 (2.6)^{ab}	8.07(2.7)^{a}	8.20(2.6)^{ab}	8.27(2.7)^{ab}	9.27(2.1)^{b}	8.00(1.2)^{a}	6.40(1.8)
Chewiness	14.00(4)^{a}	15.00(2.6)^{ab}	14.00(2.8)^{a}	14.00(2.0)^{a}	14.00(4.0)^{a}	16.00(2.0)^{b}	15.00(2.0)^{b}

N=18(6 panelists x 3 replicates). The values are mean score of triplicate analysis and figures in parentheses are standard deviation. The values were recorded in 15cm intensity scale except chewiness which is the numbers of chew per second. a,b,c,d same alphabet in row indicates no significant difference (p>0.05) as determined by LSD. 1, mean particle size (micron) of flour, a=91, b=227, c=383, d=495, e=615, f=752 & g=1133.

relation with chewiness(r=0.67, p>0.05) and fair negative relation with oily mouth feel(r=-0.63, p>0.05). Similarly in formulation F2 (table no.5.17) the analysis showed the good positive correlation of mean particle size with sensory texture attributes like hardness(r=0.99, p≤0.05), fracturability(r=0.96, p≤0.05); good negative correlation with smoothness(r=-0.97, p≤0.05), cohesiveness(r=-92, p≤0.05), stickiness(r=-0.76, p≤0.05), and oily mouth feel($r=-0.85$, $p\leq0.05$); and fair positive relation with chewiness($r=0.65$, $p>0.05$). In both formulations similar results were obtained i.e., the trends were similar except in oily mouth feel since the correlation of mean particle size was significant with oily mouth feel in formulation F2 whereas it was not significant in formulation F1.That might be due to the effect of difference in proportion of different particle and their distribution in both formulations. The Pearson moment correlation coefficient analysis showed that hardness and fracturabiliy were positively correlated($r=0.99$, $p\leq0.05$) but

Table No.5.17. Mean score given by panels for sensory texture profile F2

Texture	Treatments[1]						
Attributes	A	B	C	D	E	F	G
Smoothness	10.13(1.9)^{a}	9.40(1.8)^{ab}	10.07(2.3)^{a}	8.33(2.2)^{b}	7.40(2.4)^{c}	6.53(1.6)^{c}	4.73(1.7)
Hardness	5.47(1.4)^{a}	5.60(1.3)^{a}	6.20(1.4)^{b}	6.60(1.8)^{b}	8.00(2.3)^{c}	8.33(2.3)^{c}	9.73(2.3)
Fracturability	5.33(1.8)^{a}	6.00(2.1)^{ab}	5.33(2.0)^{a}	6.67(2.1)^{b}	8.20(2.2)^{c}	8.60(2.6)^{cd}	9.27(2.7)^{d}
Cohesiveness	6.60(1.9)^{a}	7.07(2.6)^{a}	6.00(2.8)^{b}	6.07(2.2)^{b}	5.80(2.2)^{b}	5.07(2.1)^{c}	4.67(1.7)^{c}
Stickiness	5.80(2.3)^{ad}	6.60(1.8)	5.93(2.2)^{ab}	5.27(2.1)^{ad}	5.20(1.8)^{ad}	5.67(2.1)^{ab}	4.60(1.6)^{c}
Oily mouth feel	9.67(2.0)^{a}	8.93(2.1)^{ab}	8.60(1.6)^{ab}	9.00(1.4)^{ab}	8.00(1.4)	8.87(0.8)^{b}	6.80(1.2)
Chewiness	14.00(2.0)^{a}	15.00(3.0)^{b}	14.00(3.0)^{abc}	15.00(3.0)^{b}	14.00(4.0)^{bc}	15.00(3.1)^{abc}	16.00(3.0)^{bc}

N=18(6 panelists x 3 replicates). The values are mean score of triplicate analysis and figures in parentheses are standard deviation. The values were recorded in 15cm intensity scale except chewiness which is the numbers of chew per second.a,b,c,d same alphabet in row indicates no significant difference ($p>0.05$)as determined by LSD.1-mean particle size (micron): A=395,B=425,C=465,D=520,E=614,F=652 & G=746.

hardness and smoothness were negatively correlated($r=-0.95$, $p\leq0.05$). The analysis result also showed that the hardness, fracturability and chewiness were found to be increased with increase in mean particle size whereas smoothness, cohesiveness, stickiness and oily mouth feel were found to be decreased with increase in mean particle size. Hence there was profound effect of particle size of rice flour on the textural profiles of *Sel-roti*.

On the basis of ANOVA of mean score of panelists on sensory attributes the optimum mean particle size of rice flour selected for good *Sel-roti* preparation was 520±6μ which consisted coarse (30%), medium (50%) and fine (20%) whose frequency distribution curve (fig.5.6c) resembles more or less normal distribution. The values of sensory texture attributes of good *Sel-roti* of optimum mean particle size i.e., 520±6μ rice flour were found to be 8.83, 6.60, 6.70, 5.80, 5.37, 9.00 and 15 for smoothness, hardness, fracturability, cohesiveness, stickiness oily mouth feel and chewiness respectively on 15 point scale except for chewiness which is the number chew at the rate of I chew per second.

Table No.5.18 .Mean score given by panels for sensory texture profile formulation F3

Texture	Treatments[1]		
Attributes	D	I	H
Smoothness	8.20±1.6	7.67±1.4	7.67± 2.6
Hardness	6.87±1.4^{a}	7.00±1.4^{a}	8.07± 2.5^{b}
Fracturability	8.53±1.6^{a}	6.73±1.1^{b}	9.67± 2.8^{c}
Cohesiveness	7.53±1.5^{a}	8.00± 3.3^{ab}	7.15± 3.0^{ac}
Stickiness	5.70±1.5^{a}	6.40± 3.0^{b}	5.33± 2.4^{a}
Oily mouth feel	9.47±1.6	9.13±2.5	8.70± 1.8
Chewiness	15.00±3.0	15.00±4.0	15.00± 4.0

N=18(6 panelists x 3 replicates). The mean ± Standard deviation. The values are mean score of triplicate analysis. The values were recorded in 15cm intensity scale except chewiness which is the numbers of chew per second.a,b,c,d same alphabet in row indicates no significant difference (p>0.05)as determined by LSD. 1-Mean particle size (micron): D=520,I=552, & H= 566.

5.5 Effect of soaking of rice on the quality of *Sel-roti*

(a) The effect on Bulk density: The bar diagram of the bulk density of the *Sel-roti* prepared from the soaked rice are given in fig 5.9. The ANOVA and LSD of the data revealed that the bulk density of the *Sel-roti* prepared from rice soaked for different time were not significantly different ($p>0.05$).

(b) The effect on fat-uptake: The fat uptake of the *Sel-roti* prepared from the rice flour from soaked rice in water for different time are given in fig. 5.10. The ANOVA and LSD of data obtained reveled that there was no significantly different ($p>0.05$) in bulk density of *Sel-roti* of different rice sample soaked for different times. Hence soaking time did not effect on the fat-uptake of the *Sel-roti*.

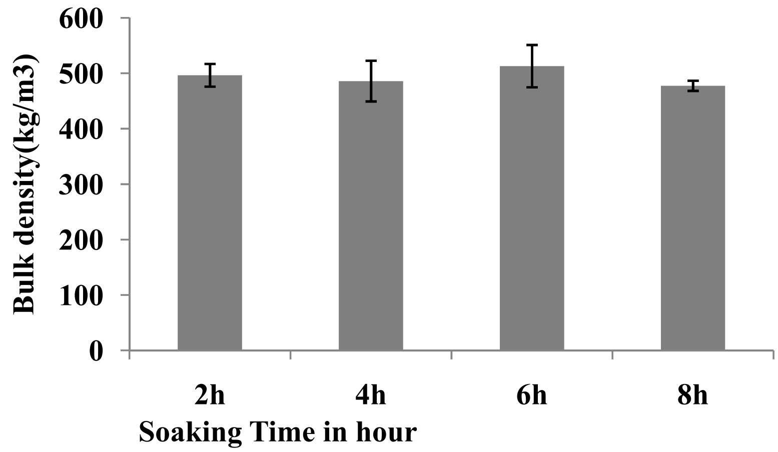


Fig No. 5.9 The effect of soaking time on bulk density of samples for different times i.e., 2, 4, 6, and 8 hour.

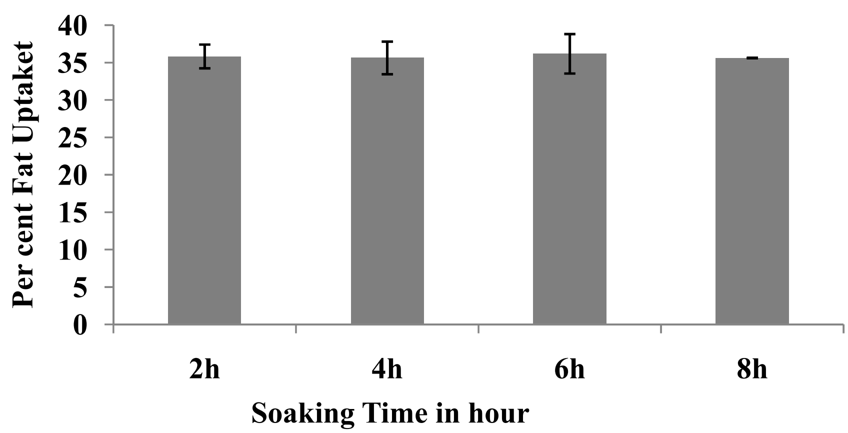


Fig.5.10 The effect of soaking time on fat- uptake of samples for different times i.e., 2, 4, 6, and 8 hour

(c) The effect on sensory quality: The bar diagram of the effect of soaking time of rice on the sensory quality of *Sel-roti* is given in fig.5.11.

The ANOVA and LSD analysis revealed that the sensory quality of the *Sel-roti* prepared from the flour of rice soaked in different times were found not to be significantly different ($p>0.05$) except for appearance in which the panel score of *Sel-roti* prepared from the flour of rice soaked for 2h was lowest and was significantly different ($p \leq 0.05$) from others. This result suggests that the minimum soaking time for rice to prepare *Sel-roti* should be 2h and longer the time of soaking better is the result.The soaked rice should contain about 35% moisture. In this moisture content grinding or pounding is easy and less damage to starch which gives good result in making *Sel-roti*. Hence minimum of 2h of soaking time of rice is recommended and used throughout the work for *Sel-roti* preparation. This soaking time consides with time reported by Tarino and Loza (1984) who reported the soaking time of 2h at 30° C.

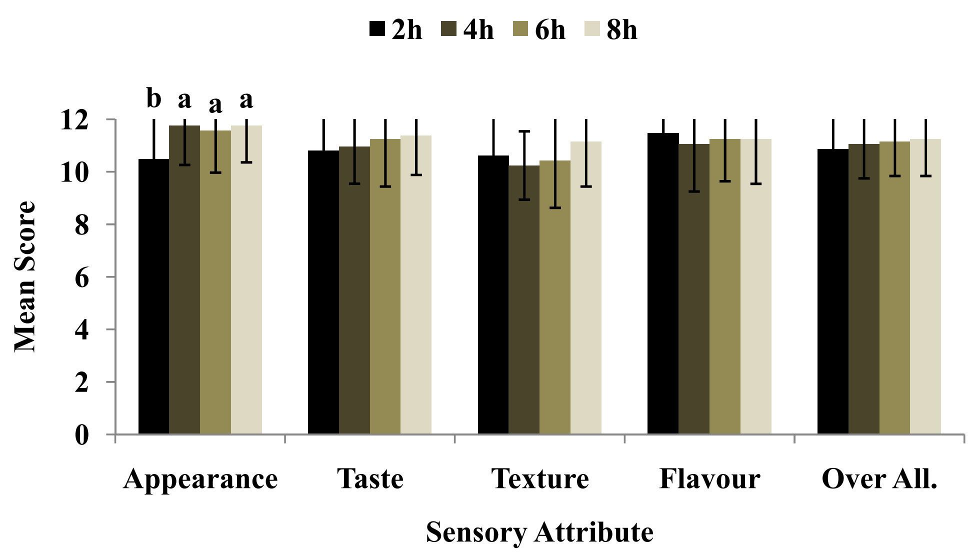


Fig.5.11. The Sensory Attributes of *Sel-roti* as affected by soaking time of rice. The similar alphabets above the bar diagram indicate not significantly different (p>0.05). The error bars show the variation of three replicates (i.e., 6x3=18) in terms of standard deviation.

(d)The effect of soaking time of rice on texture profile of *Sel-roti*: The mean scores for texture attributes of *Sel-roti* prepared from the flour of soaked rice for different times given by panelists are given in table no 5.19.

Table No.5.19 Mean sensory score of texture profile of *Sel-roti* as affected by soaking time

Texture Attribute	Soaking Time (h)			
	2	4	6	8
Smoothness	7.52±1.2	7.24±1.5	7.24±1.3	6.71±1.0
Hardness	7.10±1.5	6.76±1.3	7.10±1.0	6.52±1.4
Fracturability	7.19±1.1	6.81±1.6	7.43±1.6	6.95±1.2
Cohesiveness	6.20±1.5	6.00±1.6	6.90±1.5	6.71±1.1
Stickiness	6.33±1.5	6.24±1.1	5.86±1.5	5.67±1.0
Oily Moth feel	8.81±1.4	8.71±1.1	8.52±1.1	8.48±1.3
Chewiness	$15.00±3.0^{ab}$	$16.00±4.0^{b}$	$15.00±4.0^{ab}$	$14.00±3.0^{a}$

N=18(6x3), the mean values ± standard deviation. The similar alphabet in row indicate no significant different (p>0.05).

The regression and correlation analysis of soaking time and the texture profile revealed that there was good negative correlation of soaking time with smoothness(r = -0.93, p>0.05), Stickiness(r =-0.97, p≤0.05), and oily mouth feel(r =-0.97, p≤0.05), fair negative relation exist between hardness (r = -64), chewiness (r = -0.63) and there was fair positive relation of soaking time with cohesiveness (r = 0.74). The result also showed very poor relation of soaking time with fracturability.The ANOVA and LSD analysis reveled that increased soaking time had no significance effect on textural attributes of *Sel-roti* and also suggested that the minimum soaking time of rice for *Sel-roti* preparation was 2h at room temperature i.e., 25 to 30°C.

5.6 The combined effect of kneading of flour and ageing of batter on

(a) The bulk density: The bulk density of *Sel-roti* prepared from the batter treated for different kneading time and ageing time (combined) is given in fig.5.12 (a). The bulk density of A1K1, A1K2, A2K1 and A2K2 were found to be 570±14.8, 538±20.5, 563±19.8 and 532±14.8 respectively. The ANOVA and LSD analysis showed the bulk density of A1K1, A2K1 were not significantly different (p>0.05) but they were significantly different (p≤0.05) with A2K1 and A2K2 which were themselves were significantly different (p≤0.05). The sample A1K1 had highest value whereas A2K2 had lowest. The kneading of flour with *daun* had significant effect on bulk density. Likewise the ageing had also effect on bulk density. A1K1sample *Sel-roti* was prepared from the non-kneaded ingredient mixture and non aged batter whereas A2K2 sample was the *Sel-roti* prepared from ingredient mixture kneaded for 10min and the batter aged for 1h at room temperature. That is probably due to the proper mixing of *dawn* and flour which helped to puff well and give spongy inside structure which gave low bulk density.

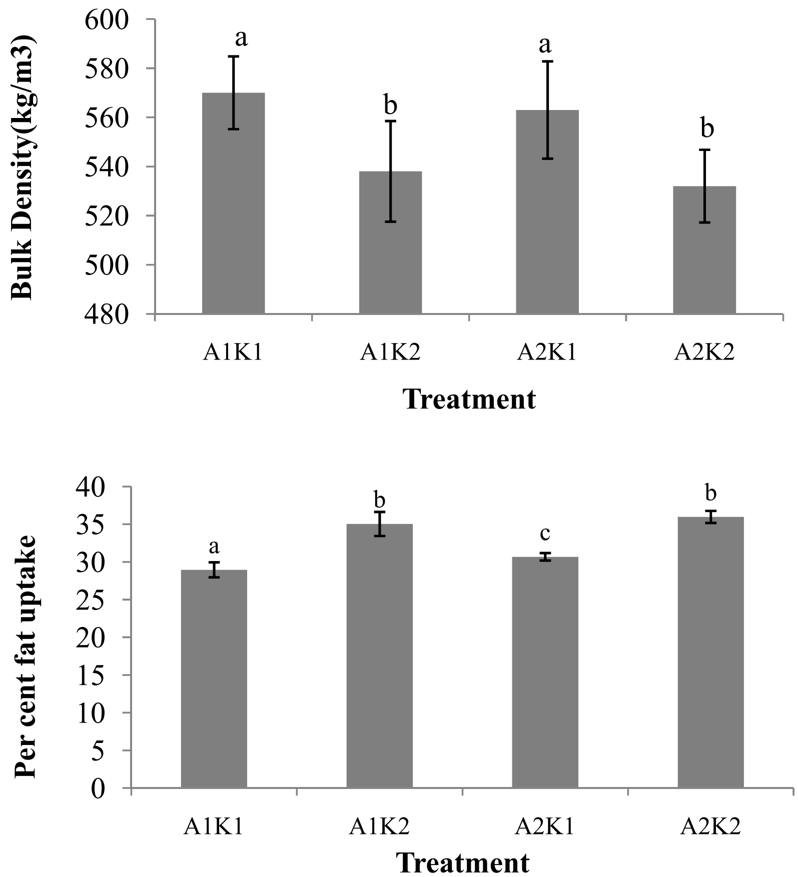


Fig.5.12.(a) Bulk density and (b) Fat uptake of *Sel-roti* as effected by Kneading time of flour and ageing time of batter. The similar alphabets indicate not significant difference (p>0.05). A1K1= No kneading and no ageing; A1K2= 10min kneading and no ageing; A2K1=No kneading and 1h ageing; and A2K2= 10 min kneading and 1h ageing.

(b) The fat uptake: The fat uptake of *Sel-roti* prepared from the batter treated for different kneading time and ageing time (combined) is given in fig.5.12 (b).

The fat uptake of A1K1, A1K2, A2K1 and A2K2 were found to be 28.95±1.0, 35.04±1.6, 30.68±0.52 and 35.97±0.8 respectively. The ANOVA and LSD of mean score showed that A1K1 sample had lowest fat-uptake and significantly different ($p \le 0.05$) from others whereas A2K2 sample had highest fat-uptake and significantly different (p≤0.05) from the fat-uptake of A1K1and A2K1 and not significantly different (p>0.05) with A1K2 sample. The result revealed that kneading had significant effect on fat uptake of *Sel-roti* likewise ageing had also effect on fat uptake of *Sel-roti*.

(c) The sensory quality: The sensory attributes of *Sel-roti* as affected by kneading time of flour and ageing time of batter are shown in fig. 5.13.

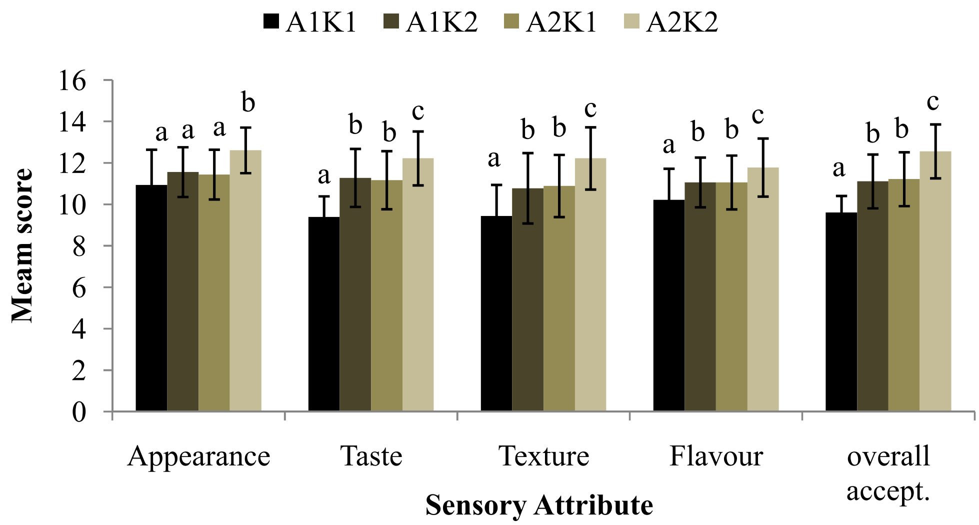


Fig.5.13. Mean sensory score of Sel-roti as effected by kneading and ageing time. A1K1= No kneading and no ageing; A1K2= 10min kneading and no ageing; A2K1=no kneading and 1h ageing; and A2K2= 10 min kneading and 1h ageing.

The ANOVA and LSD of sensory scores revealed that the *Sel-roti* sample A1K1got lowest score for all sensory attributes and were significantly different (p≤0.05) from others. The sample A2K2 got highest value for all sensory attributes and was significantly different (p≤0.05) from others. The scores for A1K2 and A2K1 were not significantly different (p>0.05) for all sensory attributes. The panelists preferred A2K2 Sel-roti sample which was prepared from the mixture of ingredients kneaded for 10 min and the batter aged for 1h. Hence the result revealed that kneading and ageing had significant effect on the sensory quality of *Sel-roti* and are important processing steps for good *Sel-roti* preparation. The aged batter prepared from kneaded flour and other ingredients resulted puffed product having spongy structure inside.

(d) The texture profile: The sensory texture attributes of Sel-*roti* as affected by kneading times of flour and ageing time of batter is given in table no 5.20. The ANOVA and LSD of mean score for sensory texture attributes showed that there were significant difference ($p \leq 0.05$) among the samples A1K1, A1K2, A2K1 and A2K2 for smoothness, fracturability, cohesiveness, whereas hardness, stickiness, oily mouth feel and chewiness were not significantly different($p > 0.05$). The hardness of the sample A1K1 was more than the sample A2K2, again the oil-uptake of the sample A2K2 was higher than the fat-uptake of other samples. Hence the kneading of ingredients and ageing of batter had effect on the texture attributes of *Sel-roti*.

Table No. 5.20 The mean sensory scores of *Sel-roti* for texture attribute as effected by kneading and ageing.

Texture Attribute	A1K1	A1K2	A2K1	A2K2
Smoothness	6.39 ± 1.5^{a}	7.06 ± 1.7^{b}	6.39 ± 1.3^{a}	6.89 ± 1.4^{ab}
Hardness	6.83±1.4	6.61±1.3	6.78±1.2	6.67±1.2
Fractuability	6.50 ± 1.6^{ab}	7.22 ± 1.4^{a}	5.94 ± 1.3^{b}	6.00 ± 1.0^{b}
Cohesiveness	6.78 ± 1.4^{a}	6.39 ± 1.5^{b}	5.78 ± 1.2^{a}	5.78 ± 1.7^{a}
Stickiness	5.94±1.3	5.78±1.3	5.78±1.7	5.61±1.3
Oily mouth feel	7.50±1.2	7.54±1.1	7.44±1.2	7.61±1.7
Chewiness	14.00±4.0	15.00±3.0	16.00±4.0	15.00±2.0

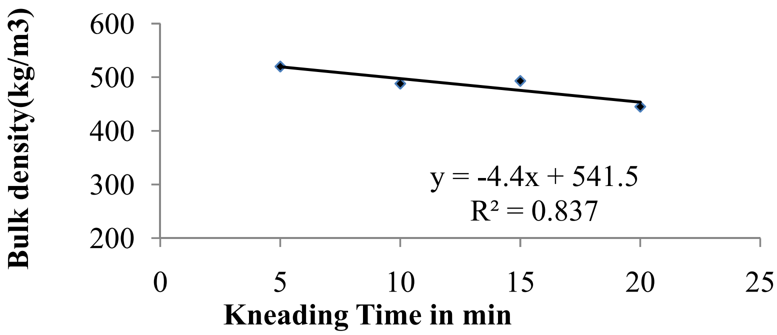
N=21(7x3), the mean values ± standard deviation. The similar alphabet in row indicate no significant different ($p > 0.05$). A1K1= No kneading and no ageing; A1K2= 10min kneading and no ageing; A2K1=no kneading and 1h ageing; and A2K2= 10 min kneading and 1h ageing.

5.6.1. Effect of kneading time on

(a) The bulk density: The bulk density of *Sel-roti* as affected by kneading time is given in fig.5.14 (a). The bulk densities were found to be 520±17, 488±6, 492±2 and 445±13 for kneading time 5, 10, 15 and 20 min. respectively. The regression analysis of bulk densities showed the negative relation of kneading time with densities($r = -0.915$, $p > 0.05$) i.e., the densities decreased with increasing kneading time.

(b) The fat-uptake: The fat uptake of *Sel-roti* as affected by kneading time is given in fig 5.14(b). The per cent of fat uptake of *Sel-roti* were found to be 34.82±2.1, 36.82±3.5, 36.22±2.7 and 37.05±2.4 for kneading time of 5, 10, 15, and 20 min respectively.

(a)



(b)

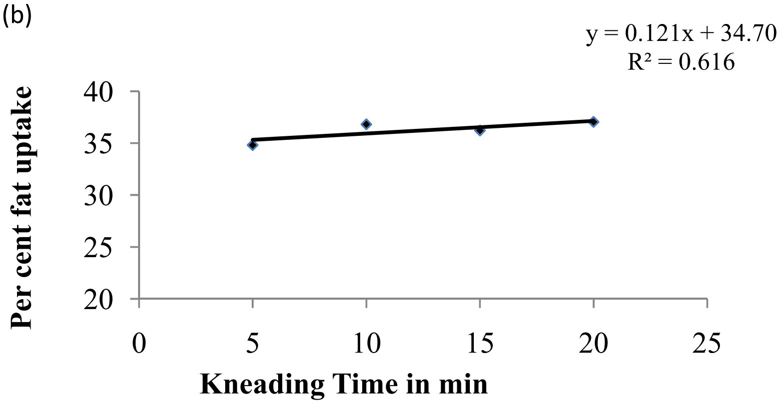


Fig. 5.14 (a) Bulk density and (b) fat-uptake of *Sel-roti* as effected by kneading time of ingredients.

The regression analysis showed the positive relation of kneading time with fat uptake ($r = 0.785$, $p>0.05$) i.e., the fat uptake by *Sel-roti* increased with the increase in kneading

time if other things remain constant.

(c) The sensory quality: The mean sensory score given by panelists for each sensory attribute i.e., appearance, taste, texture, flavor and overall acceptance are given in fig.5.15. The standard deviations are presented as error bar and the differences of mean by LSD are also presented as alphabets.

In case of appearance the mean scores were found to be 11.33±1.6, 12.20 ±1.7, 12.20± 0.8 and 12.20±1.4 for 5, 10, 15 and 20 min respectively. The sample KT1 (5 min kneaded) got lowest score and was significantly different ($p \le 0.05$) from other samples. The samples KT2, KT3 and KT4 got same scores. The similar trend were followed in scoring by panelists for other sensory attributes i.e., taste, texture, and overall acceptance except flavor in which Sel-*roti* prepared from 5min kneaded ingredient got lowest score and *Sel-roti* sample from 20 min kneaded ingredient got highest score and other two samples 10 and 15 min kneaded got score in between, which were not significantly difference themselves but significantly different with 20 min kneaded sample. That result

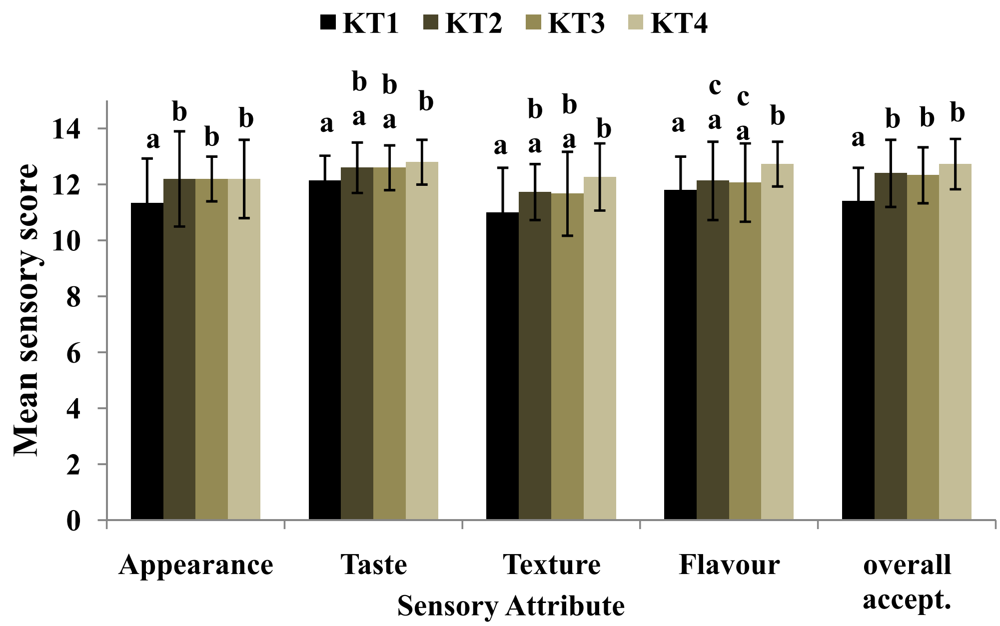


Fig 5.15. Mean sensory score of *Sel-roti* as affected by kneading time of ingredients. The similar alphabet above the bars of each sensory attribute indicate no significant difference ($p>0.05$). KT1= 5 min, KT2= 10 min, KT3 = 15 min and KT4= 20 min.

showed that the minimum time for kneading of ingredients was 10 min for the given quantity of ingredient. However, the ingredients were kneaded manually and the optimum kneading time may also depend on the quantity of ingredients.

(d)The texture profile: The sensory score for texture attributes i.e., smoothness, hardness, fracturability, cohesiveness, stickiness, oily mouth feel and chewiness are given in table no.5.21. The correlation and regression analysis revealed that the fair negative relation was found out between kneading time of ingredients and the texture attributes of *Sel-roti* like hardness($r = -0.7912$, $p>0.05$), fracturability($r =-0.7060$, $p>0.05$), and chewiness($r=-0.7745$, $p\leq0.05$); fair positive relation with cohesiveness($r= 0.6609$, $p>0.05$); and the poor relation with stickiness and smoothness. The ANOVA and LSD of scores also showed the significance difference of sensory mean scores of smoothness, hardness, cohesiveness, stickiness except oily mouth feel and chewiness for different kneading time. Hence kneading time had effect on the texture attributes of *Sel-roti*.

Table No.5.21 The mean sensory scores of *Sel-roti* for texture attribute as effected by kneading and ageing

Texture Profile	Treatment (kneading time in min)			
	5	10	15	20
Smoothness	7.60 ± 1.4^{a}	6.00 ± 1.1^{b}	7.13 ± 1.4^{a}	6.33 ± 1.7^{b}
Hardness	7.93 ± 1.2^{a}	6.07 ± 1.8^{b}	6.87 ± 1.1^{c}	5.53 ± 1.2^{b}
Fracturability	7.80 ± 1.7^{a}	6.53 ± 1.1^{b}	7.33 ± 1.6^{ab}	6.20 ± 1.4^{b}
Cohesiveness	5.33 ± 1.3^{a}	6.53 ± 1.2^{b}	6.07 ± 1.8^{b}	6.47 ± 1.3^{b}
Stickiness	5.67 ± 1.3^{ab}	5.80 ± 1.3^{ab}	6.13 ± 1.6^{a}	5.27 ± 1.3^{bc}
Oily mouth feel	8.60±1.7	8.07±1.3	8.13±1.3	8.20±1.6
Chewiness	16.00±4.0	16.00±2.0	16.00±3.0	15.00±1.0

N=18(6x3). Mean sensory score ± standard deviation, the similar superscript alphabets in row indicate not significant difference ($p>0.050$).

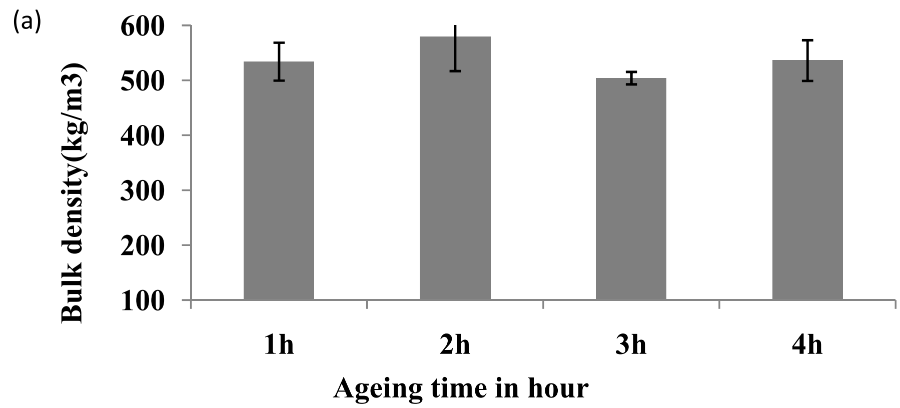
From the above result and discussion the kneading of ingredients is necessary operation

for good *Sel-roti* preparation however, it does not mean that over kneading gives better products.The similar result was reported for by Lawson,1997.

5.6.2 Effect of ageing time of batter on:

(a)The bulk density: The bulk densities of *Sel-roti* prepared from batter aged for different time (i.e., 1, 2, 3 and 4h) are given in fig. 5.16a. The bulk densities of *Sel-roti* were found to be 535±34, 579 ±32, 504±11 and 536 ± 27 for 1, 2, 3 and 4h ageing time of batter respectively. The ANOVA and LSD of densities data showed that these data were found to be not significant difference (p>0.05). Hence ageing time had no significant effect on bulk density in a given experimental ageing time of batter.

(b) **The fat-uptake**: The fat uptakes of *Sel-roti* prepared from batter aged for different time (i.e., 1, 2, 3 and 4h) are given in figure 5.16b.



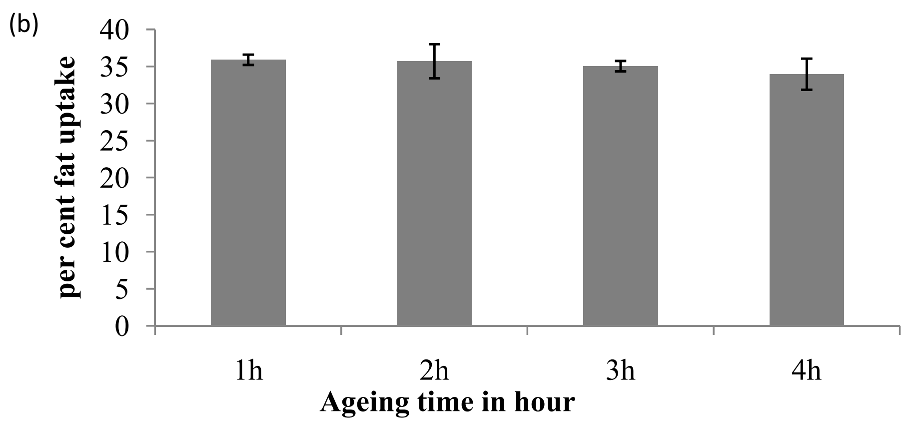


Fig.5.16.(a) Bulk density and (b) fat uptake of *Sel-roti* as effected by Ageing time of ingredients.

The fat uptake of Sel-*roti* was found to be 535± 34, 579 ± 32, 504±11 and 536 ± 27 for 1, 2, 3 and 4h ageing time of batter respectively.

The ANOVA and LSD of fat uptake data showed that these data were found to be not significant difference (p>0.05). Hence ageing time had no significant effect on fat uptake in a given experimental ageing time of batter.

(c) The sensory quality: The bar diagram of mean sensory score for different sensory attributes (i.e., appearance, taste, texture, flavor and overall acceptance) is given in figure 5.17. The standard deviations are presented as error bar.

The mean sensory scores given by panelist for appearance were 12.00±1.6, 12.00±1.6, 12.53±1.5, and 12.33±1.2 for ageing time of 1, 2, 3 and 4h respectively. Likewise for taste the mean score were 12.13±1.6, 12.40±1.2, 12.20 ±1.5 and 12.20 ±1.3; for texture the mean scores were 11.60±1.6, 11.73±1.3, 11.67±1.7 and 11.13± 2.0; for flavor the scores were 11.80±1.2, 12.20±1.2, 11.93±1.3 and 11.87±1.5; and for overall acceptance the scores were11.60±1.4, 12.27±1.1, 11.93±1.4 and 12.00±1.4.

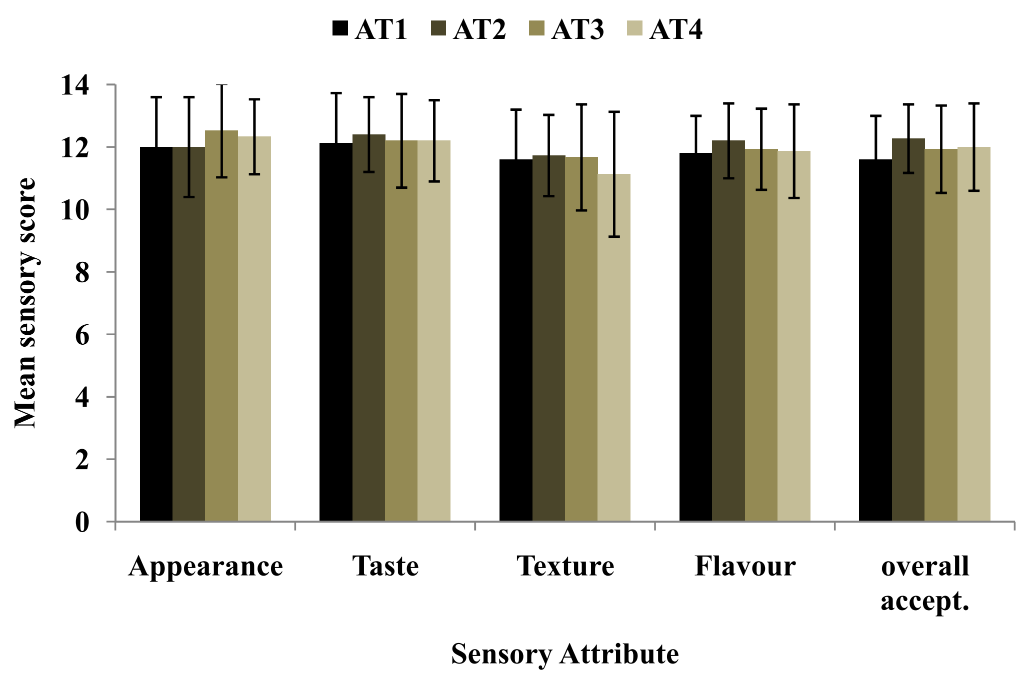


Fig 5.17. Mean sensory score of *Sel-roti* as affected by kneading time of ingredients. The similar alphabet above the bars of each sensory attribute indicate no significant difference ($p>0.05$). AT1= 1h, AT2= 2h, AT3 = 3h and AT4= 4h

The ANOVA and LSD of mean scores (Fig 5.17), showed that the significance different ($p\leq0.05$) did not found between mean scores and ageing times in each sensory attribute. Although *Sel-roti* sample prepared from 2h aged batter got high score for quality attributes except appearance but the scores were not significant to others. The ageing of batter is necessary for good *Sel-roti*, which was revealed from earlier experiment i.e., the effect of kneading of ingredients and ageing of batter. Therefore the minimum ageing time of batter should be one hour at room temperature for good *Sel-roti* preparation provided that other conditions remain same. That ageing time was used throughout the experiment.

(d) The texture profile: The mean sensory scores for texture attributes *Sel-roti* as effected by ageing time of batter are given in table no 5.22.

The ANOVA and LSD of mean scores revealed that there were no significant difference (p>0.05) between mean scores of different texture attributes (except hardness and stickiness) on different designed experimental ageing time.

Table No.5.22 The mean sensory scores of *Sel-roti* for texture attribute

Texture Profile	Treatment (Ageing time in hour)			
	1	**2**	**3**	**4**
Smoothness	6.72±1.2	6.33±1.4	7.06±1.6	6.22±1.2
Hardness	$5.94±1.4^{a}$	$6.11±1.6^{a}$	$7.00±1.7^{b}$	$6.33±1.1^{ab}$
Fracturability	7.50±1.3	6.89±1.4	7.17±1.3	6.56±1.7
Cohesiveness	6.00±1.3	6.06±1.3	6.06±1.4	5.67±1.5
Stickiness	$5.44±1.3^{a}$	$5.78±1.2^{ab}$	$5.83±1.3^{b}$	$5.11±0.8^{a}$
Oily mouth feel	8.44±1.4	7.67±1.3	7.89±1.7	7.89±1.5
Chewiness	16.00±2.0	17.00±3.0	16.00±3.0	16.00±3.0

N=18(6x3). Mean sensory score ± standard deviation, the similar superscript alphabets in row indicate not significant difference (p>0.050).

Only proper ageing resulted quality sel-roti with good appearance, proper expansion and spongy inside. This is similar to resting period for daoghnut (Lawson, 1997).

5.7 The effect of consistency of batter on

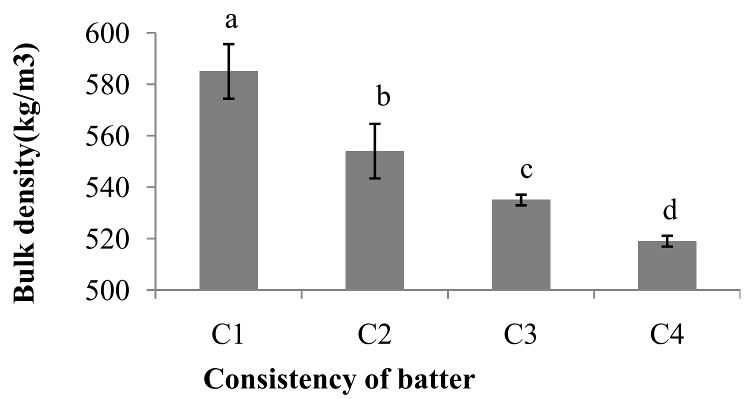
Four samples of batter having different consistency i.e., C1, C2, C3 and C4 whose values were 2.135, 1.935, 1.765 and 1.630 respectively in term of the ratio of dry solid (DS) or dry matter and liquid (L) or amount of water and their corresponding values in term of velocity flow rate were 0.664, 2.301, 5.466 and 12.466 cm/s respectively were taken and *Sel-roti* were prepared and analyzed and their results and discussion are given as follow:

(a) The bulk density: The bulk densities of samples of *Sel-roti* prepared from the batter with consistencies, C1, C2, C3, and C4 were found to be 585, 554, 535, and 519 kg /m^3 respectively and are given in fig 5.18(a). The ANOVA and LSD analysis revealed that the bulk densities were significantly different ($p \leq 0.05$) to each other. The regression analysis also showed that there were good positive relation between consistencies i.e., DS/L ratio and bulk densities($r = 0.9968$, $p \leq 0.05$). The highest bulk density of sample C1 might be due to less puffy and more solid content of *Sel-roti* produced from thick batter with high consistency whereas lowest density of sample C4 among the samples might be due to more puffy and less solid content of *Sel-roti* prepared from comparatively thin or lowest consistency of batter. It was difficult to prepare Sel-roti from the batter of higher consistency than C1 and lower consistency than C4.

(b) The fat-uptake: The per cent fat uptake of *Sel-roti* prepared from the batter with consistencies C1, C2, C3 and C4 were found to be 31.50 ± 1.4, 35.82 ± 0.8, 33.54 ± 0.1 and 31.80 ±1.0 respectively and are given in fig. 5.18 (b). The ANOVA and LSD analysis showed that the fat uptake of samples C1 and C4 were not significantly different ($p > 0.05$) each other but significantly different ($p \leq 0.05$) with others i.e., C2 and C3 likewise the samples C2 and C3 were not significantly different each other but significantly different with other i.e., C1 and C4. The Sel-roti sample prepared from the batter with consistency of 1.935DS/L had highest fat-uptake among the samples and the batter with consistency of 2.135DS/L had lowest fat-uptake. The correlation and regression analysis of fat-uptake and consistency of batter did not show any relation between them.

(c)The sensory quality: The sensory mean scores of *Sel-roti* as effected by the consistency of batter (expressed as DS/L i.e., the ratio of dry solid /matter and liquid/water) are given in table No 5.19. The mean scores of sensory attributes of *Sel-roti* for different consistency i.e., C1, C2, C3, and C4 were found to be as 11.3±1.2, 12.27±0.9, 7.73±1.3 and 6.93±1.5 respectively for appearance; 10.53±1.4, 10.80±1.7, 9.80±0.9, and 9.67±1.5 for taste; 9.93±1.7, 11.13±2.0, 8.60±1.6 and 7.40 ±2.2 for texture; 9.67±2.1, 10.80±1.9, 8.93±1.2 and 8.93±1.2 for flavor: and 10.27±1.4, 11.73±1.2, 8.47±1.6 and 8.47 respectively for overall acceptability.

(a)



(b)

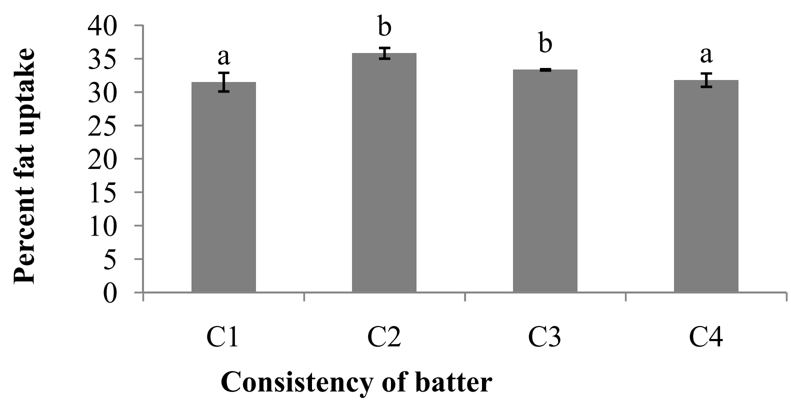


Fig.5.18 (a) Bulk density and (b) fat uptake of *Sel-roti* as effected by Consistency of batter. The similar alphabets above the bar indicate not significantly different ($p>0.05$). C1 = 2.135, C2 = 1.935, C3 = 1.765 and C4 = 1.630 DS/L.

The ANOVA and LSD analysis of mean scores reveled that the sensory scores of *Sel-roti* samples prepared from the batter of different consistency were significantly different ($p\leq0.05$) from each other and *Sel-roti* sample from C2 got highest score in appearance; the mean score of sample of *Sel-roti* prepare from the batter with consistency C1 was not significantly different ($p>0.05$) from the mean score of the sample from C2 and C3 but significantly different($p\leq0.05$) from the sample from C4 and the sample from C3 and C4 were similar statistically in taste; the mean scores of the samples from the batter with different consistency were significantly different($p\leq0.05$) from each other and sample from C2 got highest score in texture; the mean score of the samples except from C2 were not significantly different($p>0.05$) but the sample from C2 got highest score and significantly different($p \le 0.05$) from others in flavour; and the mean scores from C1 and C2 were significantly different($p \le 0.05$) from each other and also with C3 and C4, and mean scores of the samples from C3 and C4 were not significantly different($p > 0.05$) but significantly different($p \le 0.05$) from other two, C1 and C2 in overall acceptance. In all

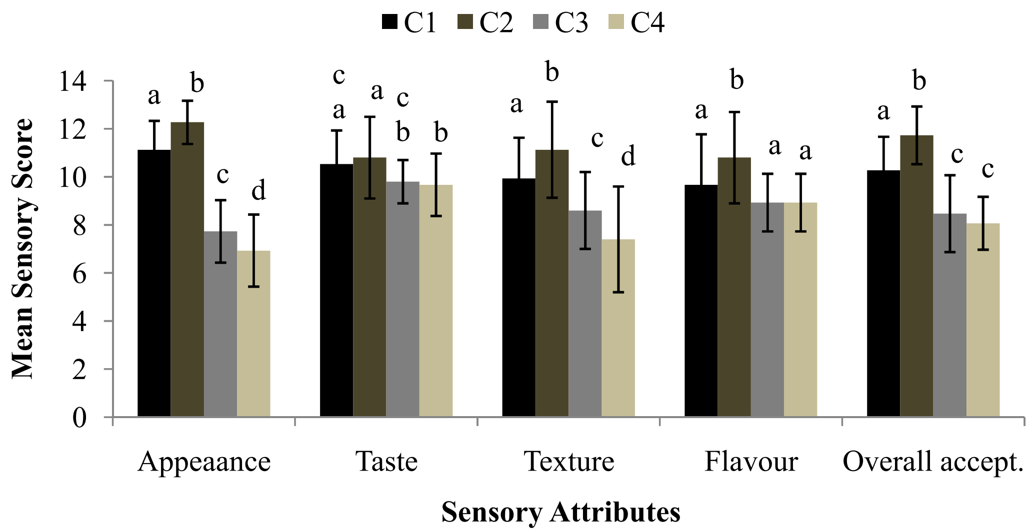


Fig. 5.19. Mean sensory score of *Sel-roti* as effected by consistency of batter. The similar alphabet above the bars of each sensory attribute indicate no significant difference (p>0.05). C1 = 2.135, C2 = 1.935, C3 = 1.765 and C4 = 1.630 DS/L.

quality attributes sample from C2 got highest score and in most cases was significantly different ($p \le 0.05$) from others i.e., most of the panelists preferred the *Sel-roti* sample prepared from the batter having consistency C2 i.e., 1.935 DS/L whose corresponding velocity flow rate was 2.301cm/s. That consistency of batter was selected as optimum consistency for good *Sel-roti* preparation and used throughout the research work.

The consistency of batter depends on the ratio of dry solid/matter and liquid i.e., water. The proper quantity of water is of utmost importance in obtaining proper batter consistency and ultimate product quality. If the too much water is used the product have a distorted appearance, excessive absorption, hollow inside and poor expansion. If less water is used the products have a rough, broken surface on one side, excessive absorption (in cracks, etc), thick crust, cracks developing during frying, poor expansion and more solid inside (Lawson, 1997).

(d) The texture profile: The mean scores for texture attributes of *Sel-roti* as effected by the consistency of batter are given in table No.5.23.

Table No.5.23 The mean sensory scores of *Sel-roti* for texture attribute as effected by consistency of batter.

Texture Profile	Treatment (Consistency in DS/L)			
	C1	C2	C3	C4
Smoothness	7.93±1.4^{a}	7.40±1.0^{a}	6.27±1.2^{b}	5.80±1.3^{b}
Hardness	8.07±1.5^{a}	7.60±1.1^{a}	5.60±1.4^{b}	5.47±1.1^{b}
Fracturability	9.40±2.0^{a}	8.13±1.1^{a}	5.73±1.2^{b}	5.27±1.4^{b}
Cohesiveness	5.20±1.2^{a}	6.53±1.0^{b}	6.60±1.4^{b}	7.00±1.4^{b}
Stickiness	4.67±1.2^{a}	5.87±1.5^{b}	6.93±1.4^{c}	7.13±1.2c
Oily mouth feel	7.73±1.4	7.67±1.1	7.80±1.3	7.80±1.1
Chewiness	13.00±4.0	14.00±3.0	14.00±4.0	14.00±4.0

N=18(6x3). Mean sensory score ± standard deviation, the similar superscript alphabets in row indicate not significant difference (p>0.050). C1 = 2.135, C2 = 1.935, C3 = 1.765 and C4 = 1.630 DS/L

The correlation and regression analysis of mean scores(table no 5.23) of *Sel-roti* with consistency of batter revealed that there was good positive relation of consistency of batter with smoothness(r = 0.9844, p≤0.05), hardness(r = 0.9, p≤0.05), and fracturability(r= 0.9794, p≤0.05); good negative with stickiness(r = -0.982, p≤0.05); fair negative relation with chewiness(r= -0.821, p>0.05), and oily mouth feel(r = - 0.6755, p>0.05) and poor negative with cohesiveness(r = -0.768, p>0,05). There was good positive relation of hardness with fracturability(r = 0.9907, p≤0.050) and smoothness(r = 9844, p≤0.05) and good negative with stickiness (r= -0.9532, p≤0.05).

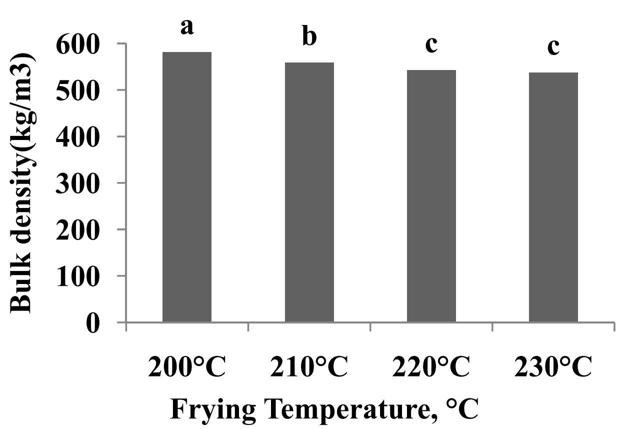
The ANOVA and LSD analysis of mean scores showed that the mean scores of sample *Sel-roti* from C1 and C2 were not significantly different (p>0.05) in smoothness, hardness and fracturability and significantly different (p≤0.05) to each other in cohesiveness and stickiness and similarly with C3 and C4. The mean scores for oily mouth feel and chewiness were not significantly different (p>0.05). The above result showed the consistency of batter had effect on the texture attributes of *Sel-roti*. Therefore, proper addition of water to prepare batter play important role in the quality of *Sel-roti*.

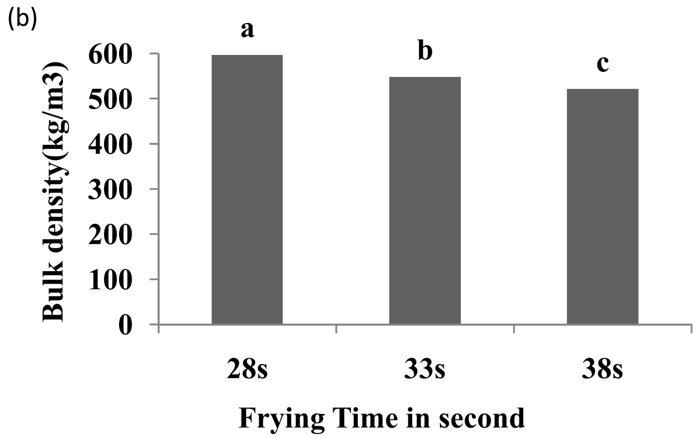
5.8 Effect of frying Temperature and Time on

(a) The bulk density: The bulk densities of *Sel-roti* fried at different temperature for different times are given in figure.5.20 (a), (b) and (c). The fig.5.20. (a) shows the effect of frying temperature.

The ANOVA and LSD of mean value showed that the bulk densities of *Sel-roti* sample fried at 200°C was found to be significantly different ($p \leq 0.05$) from other samples fried at other temperatures. Likewise the bulk densities of *Sel-roti* samples fried at 210°C were also significantly different ($p \leq 0.05$) from other samples, but the bulk densities of the *Sel-roti* fried at 220°C and 230°C were not significantly different($p. > 0.05$) each other and were significantly different($p \leq 0.05$) with *Sel-roti* fried at 200°C and 210°C. The fig.5.20 (b) shows the effect of frying time on the bulk densities. The ANOVA and LSD showed that the bulk densities of *Sel-roti* fried at different times were found to be significantly different ($p \leq 0.05$) from each others. The correlation and regression of data showed that the frying temperature had good negative relation with bulk densities ($r = -0.9646$, $p \leq 0.05$) likewise frying time had also good relation with bulk densities ($r = -0.9863$, $p \leq 0.05$). The densities were found to be decreased with frying temperature and time of *Sel-roti* and were also significantly different at all temperature and time except the bulk density of *Sel-roti* samples fried at 210°C, 220°C and 230°C for 33 and 38 second. The

(a)





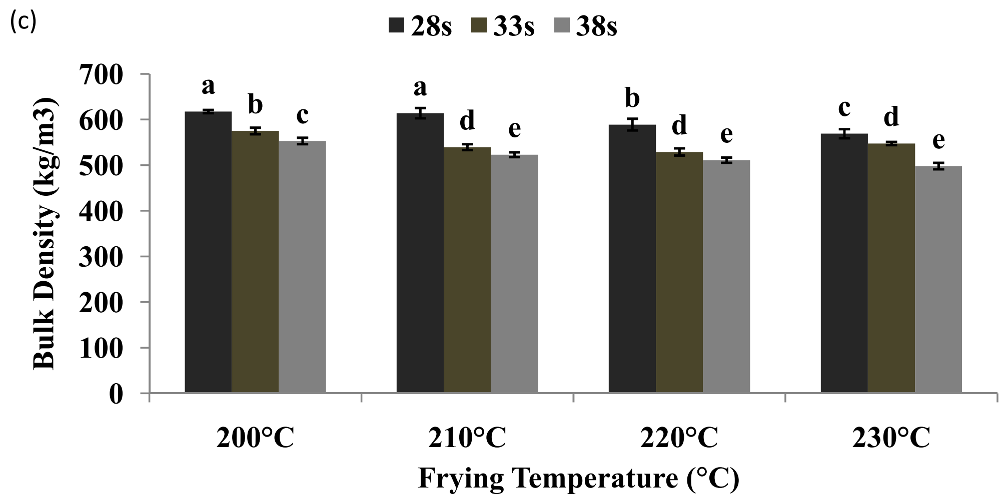


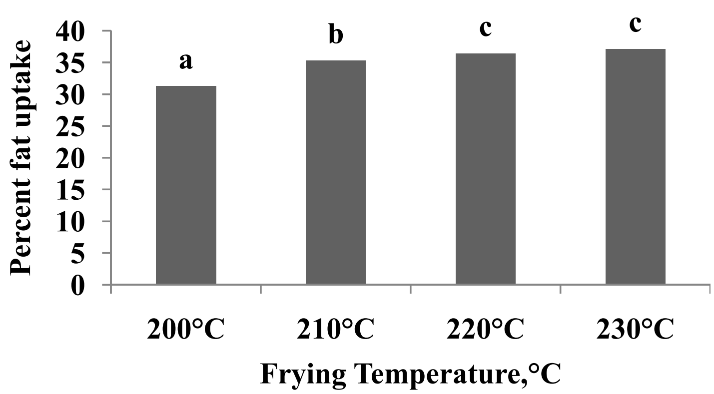
Fig. 5.20 the effect of (a) temperature on bulk density, (b) time on bulk density and (c) temperature and time on bulk density of *Sel-roti*. The similar alphabets above the bar diagram indicate not significantly different ($p>0.05$).The figure.5.20.(c) shows the combined effect of frying temperature and time on bulk densities of *Sel-roti*.

result might be due to comparatively more puffing at higher temperature and drying out in longer time of frying.

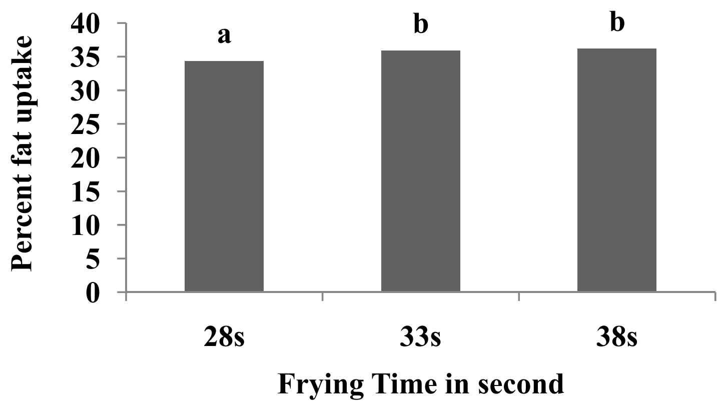
(b)The fat-uptake: The percent fat uptake of *Sel-roti* as affected by frying temperature and time are given in figure. 5.21(a), (b) & (c). The fig.5.21(a) showed the effect of frying temperature on percent fat-uptake; fig.5.21 (b) effect of frying time on fat- uptake;and fig.5.21(c) the frying temperature and time on fat-uptake by *Sel-roti*. In all cases the ANOVA and LSD showed there were significantly different fat-uptake values at all temperature and times except 220°C and 230°C for 33 and 38 second. The correlation and regression of data showed there was good positive relation of frying temperature and time with fat-uptake of *Sel-roti* that means the percent fat-uptake increased with increased frying temperature and time, that may be due to more absorption of more fat at high temperature and longer time of frying of *Sel-roti*. The similar result was reported by Lawson (1997) on frying of donought.

© **The sensory quality:** The sensory mean scores of quality attributes such as appearance, taste, texture, flavor and overall acceptance as effected by frying temperature and time are given in fig.5.22. The ANOVA and LSD of mean scores of quality attributes of *Sel-roti* fried at different temperature for different times revealed that as given in fig.5.22 sample **e (**i.e., *Sel-roti* sample fried at 210°C for 33 second) got highest score in all quality attributes and was significantly different ($p \leq 0.05$) with other in appearance, overall acceptance and not significantly different ($p > 0.05$) with sample **f** in taste, sample **c**, **d**, and **f** in texture and **f**, and **g** in flavor and significantly different with others in all quality attributes. The samples **h** and **I** got low scores because these were fried at 230°C for longer time so that these were burnt outside but not well cooked inside and were not liked by panels. Similarly samples **a** and **b** got relatively low scores because these samples were not developed for good color and not well cooked because of low heat and less frying time. Hence the result revealed that the sample **e** was liked by most of the panelists and then the frying temperature and time (i., e., 210°C and 33S of sample **e** was selected and recommended for the preparation of good *Sel-roti*.

(a)



(b)



(c)

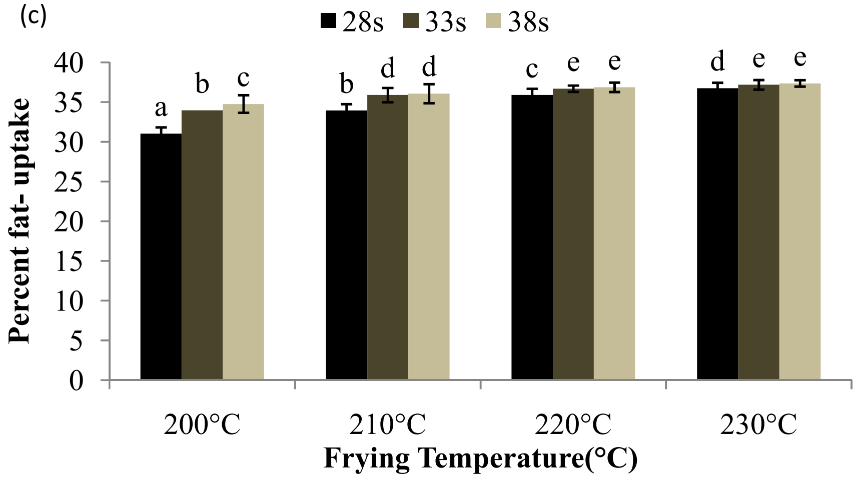


Fig.5.21 Effect of (a) frying temperature on fat-uptake, (b) frying time on fat- uptake and (c) frying temperature and time on fat uptake of *Sel-roti*. Similar alphabets above the bars indicate not significantly different (p>0.05).

The sensory evaluation result shows that proper combination of frying temperatureand time is utmost impoetance for good quality sel-roti. Low frying temperature resulted not well puffed, not grained surface and of not good appearance sel-roti. Frying took longer time and the product remained linger in oil. High frying temperature prevented proper expansion; also burnt surface gave black color. Likewise short frying time resulted uncooked product, under developed color and long frying time resulted burnt product. The similar result was observed in frying of doughnut product (Lawson, 1997).

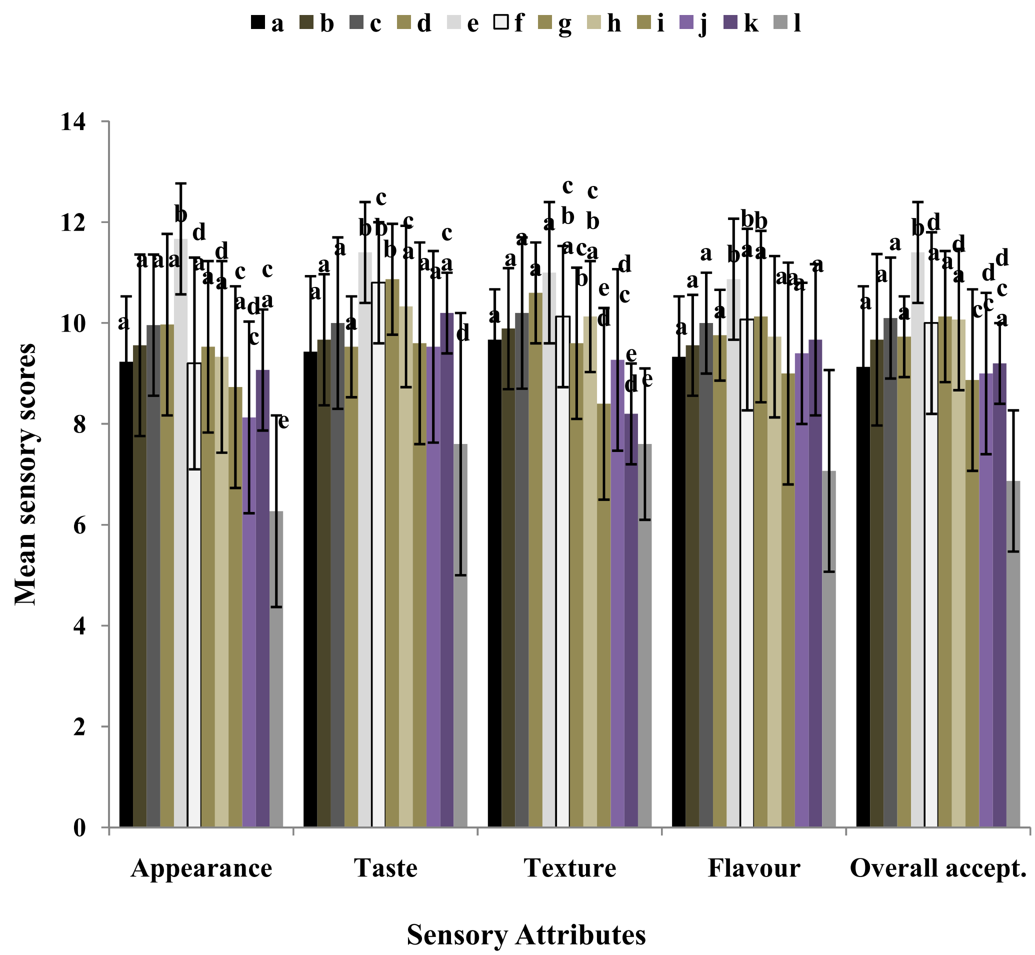


Fig.5.22 Sensory mean score for quality attributes of *Sel-roti* as effected by frying temperature and time. a= 200°C for 28s; b= 200°C for 33s; c=200°C for 38s, d=210°Cfor28s; e=210°C for 33s; f= 210°C for 38s; g= 220°C for 28s; h= 220°C for 33s; i = 220°C for 38s; j= 230°C for 28s; k= 230°C for 33s and l = 230 °C for 38s.

(d) The texture profile: The mean sensory scores of texture attributes of *Sel-roti* fried atdifferent temperatures for different time are given in table no.5.24. The ANOVA and LSD of mean scores showed the significance effect of frying temperature and time on texture attributes of *Sel-roti*. At 200°C frying temperature there was no significant effect of time on texture attributes but these values were significantly different from others in most cases, however, these were not significantly different to some value .

Table No.5.24. The mean sensory scores of texture attributes of *Sel-roti* fried at different temperatures for different time.

Treatment	Smooth.	Hardness	Fractur.	Cohesive.	Stickiness	Oilym.feel	chewiness
a	9.90±1.7^{a}	5.30±1.0^{a}	4.60±1.1^{a}	7.60±1.4^{a}	6.50±1.2^{a}	8.60±1.6^{a}	14±4.0^{a}
b	9.65±1.8^{a}	5.70±1.0^{a}	4.90±1.0^{a}	7.10±1.5^{a}	6.20±1. 7^{a}	8.80±1.6^{a}	13±2.0^{a}
c	8.8± 1.7^{a}	5.90±1.0^{a}	5.0±1.1^{a}	6.70±1.2^{a}	6.80±1.3^{a}	8.5±1.4^{a}	13±3.0^{a}
d	8.98±1.6^{a}	6.20±1.4 ^{a}	5.07±1.2^{a}	7.28±1.4 ^{a}	6.60±1.3^{a}	8.40±1.6^{a}	13±3.0^{a}
e	8.53±1.5^{ad}	6.73±1.3^{a}	6.13±1.2^{bc}	6.67±1.3^{ab}	6.13±1.4^{b}	8.33±1.5^{a}	13±3.0^{a}
f	7.13±1.4^{b}	7.40±1.3^{b}	6.53±1.2^{b}	6.53±1.1^{ab}	5.87±1.2^{b}	8.,07±1.6^{a}	13±4.0^{a}
g	7.40±1.5^{b}	6.73±1.2^{a}	6,07±1.2^{bc}	6.40±0.9^{ab}	6.07±1.4^{bc}	7.93±1.3^{ab}	14±3.0^{bc}
h	7.57±1.7^{bd}	7.60±1.6^{b}	6.93±1.8^{ab}	6.80±1.3^{ab}	6.33±1.2^{ab}	7.87±1.4^{ab}	15±4.0^{b}
i	7.13±1.1^{b}	7.93±1.4^{b}	6.93±1.5^{bd}	6.33±1.2^{b}	6.13±1.4^{abc}	7.33±1.7^{b}	15±3.0^{b}
j	7.53±1.6^{b}	7.27±1.3^{b}	5.47±1.3^{ac}	7.07±1.7^{a}	6.67±1.3^{ac}	7.67±1.2^{ab}	14±2.0^{abc}
k	6.13±1.4^{c}	7.93±1.6^{b}	6.27±1.3^{bc}	6.80±1.2^{ab}	6.07±1.1^{bc}	7.87±1.6^{ab}	14±2.0^{b}
l	6.07±1.4^{c}	8.33±1.4^{ab}	7.47±1.7^{d}	6.07±1.2^{b}	5.73±1.1^{bc}	7.27±1.5^{b}	14±3.0^{b}

N=18(6x3). Mean sensory score ± standard deviation, the similar superscript alphabets in column indicate not significant difference (p>0.050). a= 200°C for 28s; b= 200°C for 33s; c=200°C for 38s, d=210°C for28s; e=210°C for 33s; f= 210°C for 38s; g= 220°C for 28s; h= 220°C for 33s; i = 220°C for 38s; j= 230°C for 28s; k= 230°C for 33s and l = 230° C for 38s.

5.9 Effect of frying medium on

(a) The bulk density: The bulk density of *Sel-roti* fried in Ghee, mustard oil (MO), Soybean Oil (SBO) and Sunflower Oil (SFO) are presented in fig.5.23.The ANOVA and LSD of mean scores revealed that though the bulk density of Gh sample was lowest but was not significantly different from samples SBO and SFO whereas was significantly different with sample MO. The high bulk density of MO meant less puffy than others.

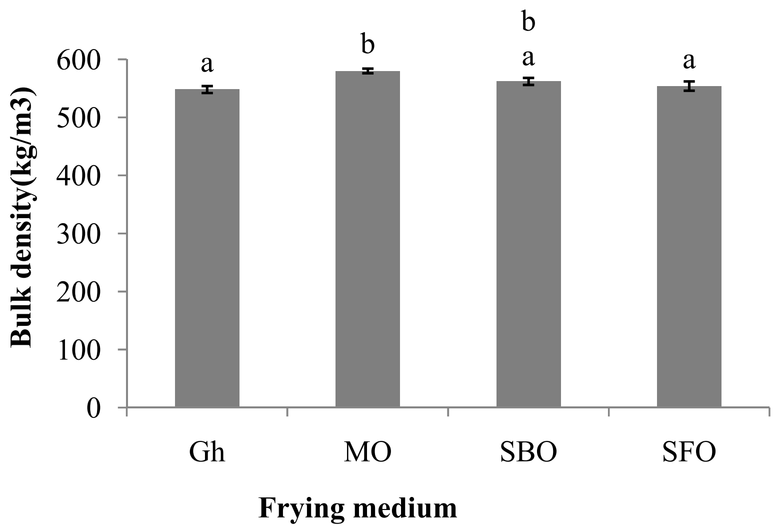


Fig.5.23 The effect of frying medium of *Sel-roti* on the bulk density. The similar alphabets above the bar diagram indicate not significantly different (p>0.05). Gh = Ghee, MO = Mustard Oil, SBO = Soybean oil, and SFO = Sunflower oil.

(b) **The fat-uptake**: The percent fat-uptake of *Sel-roti* as effected by the frying medium i.e., Ghee, Mustard oil, Soybean oil and Sunflower oil are presented in fig. 5.24.

The ANOVA and LSD of mean scores revealed that the fat-uptake of Gh sample was highest and significantly different from other samples. Similarly fat- uptake by MO sample was second highest and was significantly different to others, likewise, the fat -uptake of SBO and SFO were not significantly different ($p>0.05$) to each other but were significantly different ($p\leq0.05$) from others.

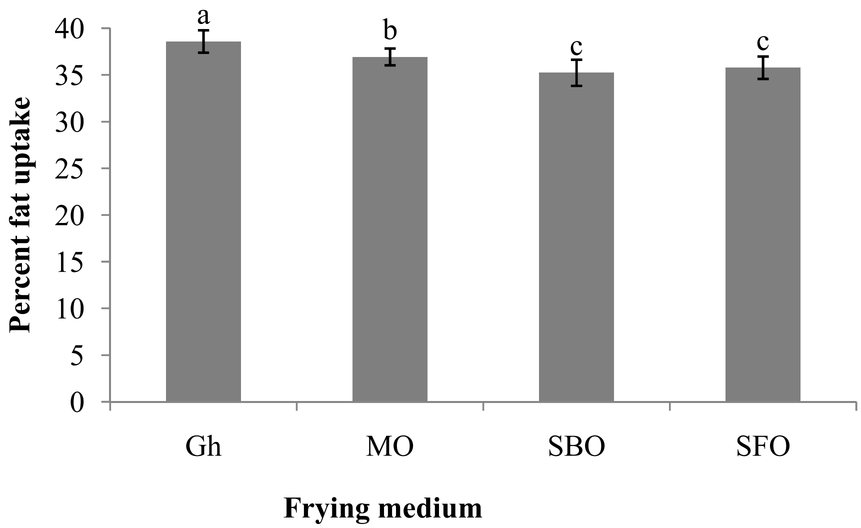


Fig.5.24. The effect of frying medium on the fat-uptake of selroti. The similar alphabets above the bar diagram indicate not significantly different (p>0.05). Gh = Ghee, MO =Mustard Oil, SBO = Soybean oil, and SFO = Sunflower oil.

(c) **The sensory quality**: The mean scores of *Sel-roti* simples like Gh, MO, SBO and SFO are presented in fig.5.25.

The ANOVA and LSD of mean scores of sensory attributes of *Sel-roti* showed that the mean scores of MO sample were lower for all attributes and were significantly different except for appearance. The mean scores of *Sel-roti* sample Gh were not significantly different with mean score of MO, SBO and SFO in appearance; taste; texture and overall acceptance respectively but significantly different with the scores of SBO and SFO, SFO, and SBO in appearance and flavor; taste; and overall acceptance respectively. The above discussion revealed that there was the effect of frying medium on the sensory quality of Sel-roti. According to the score given by panels the sample Gh got higher scores in taste, flavor and overall acceptance than SBO and SFO but significantly different and ghee is more expensive and less available; the SBO sample got highest score in texture, taste, and flavor than SFO and nutritionally sound than SFO due to containing appropriate proportion of linolenic acid (essential fatty acid) (Gunstone, 2004). Hence SBO i.e., soybean oil was selected for preparation of good *Sel-roti*.

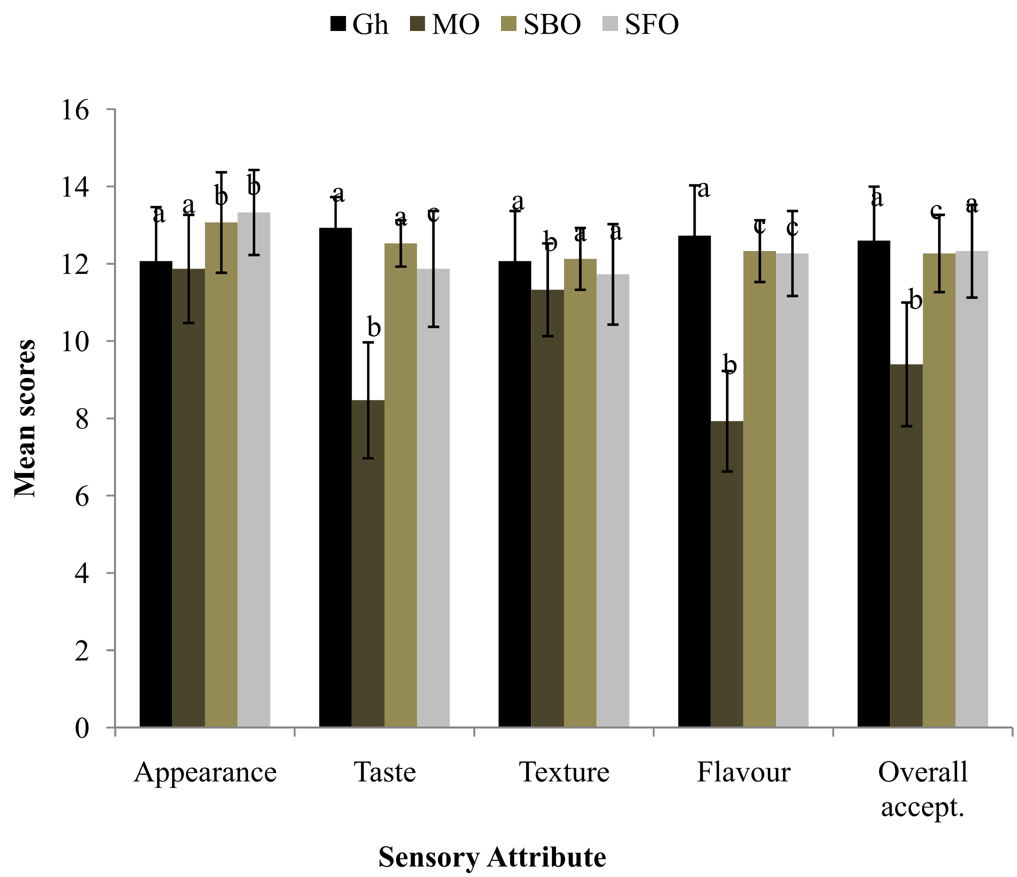


Fig.5.25 Mean scores of sensory attributes of Sel-roti as effected by frying medium. The similar alphabets above the bar diagram indicate not significantly different (p>0.05). Gh = Ghee, MO = Mustard Oil, SBO = Soybean oil, and SFO = Sunflower oil.

(d) **The texture profile:** The sensory scores given by the panelists to the texture attributes of Sel-roti fried in different medium of fat/oils are given in table no. 5.25. The ANOVA and LSD of mean scores showed that there was no significant different in scores between samples, Gh, MO, SBO and SFO in smoothness, stickiness and chewiness. Hardness of SFO was lowest among the samples and significantly different ($p \leq 0.05$). The fracturability of Gh sample was not significantly different with MO but significantly

Table No 5.25. The mean scores of texture attribute of Sel-roti as effected by frying medium

Parameter	Gh	MO	SBO	SFO
Smoothness	8.13±1.5	8.13±1.4	8.27±1.5	8.47±1.4
Hardness	7.80±1.3[a]	7.13±1.2[a]	7.13±.1.1[a]	6.93±1.2
Fracturability	8.47±1.2[a]	7.67±1.4[ab]	7.60±1.3[b]	6.87±1.0[b]
Cohesiveness	6.00±1.3[a]	7.13±1.5[b]	6.20±1.2[a]	6.20±1.2[a]
Stickiness	6.06±1.1	6.53±1.2	6.47±1.3	6.47±1.0
Oily mouth feel	8.93±1.5[a]	10.53±1.6[b]	8.93±1.3[a]	8.53±1.4[a]
Chewiness	15.00±3.0	16.00±4.0	15.00±4.0	15.00±3.0

N=18(6x3). Mean sensory score ± standard deviation, the similar superscript alphabets in rows indicate not significant difference (p>0.050). Gh = ghee (animal), MO = Mustard oil, SBO = Soybean Oil, SFO = Sunflower Oil.

different ($p \leq 0.05$) with SBO and SFO. The cohesiveness of Gh was not significantly different ($p \leq 0.05$) with SBO and SFO but significantly different with MO. The similar result was obtained in oily mouth feel as well.

5.10. Effect of age of rice and "*daun*" on physical and sensory quality of *Sel-roti*

(a) The bulk density: The bulk density of *Sel-roti* prepared from the new and old rice flour with and without *daun* is given in figure 5.26. The ANOVA and LSD analysis revealed that the value of bulk density of *Sel-roti* prepared from both new and old rice flour with *daun*; and without *daun* were not significantly different ($p > 0.05$) but significantly different ($p \leq 0.05$) between *Sel-roti* prepared with *daun* and without *daun*. Therefore, *daun* significantly affected the bulk density of *Sel-roti* i.e., the *Sel-roti* prepared from both new and old rice flour with *daun* puffed well. The puffed (*Sel-roti* with lower bulk density) *Sel-roti* are liked by the consumers.

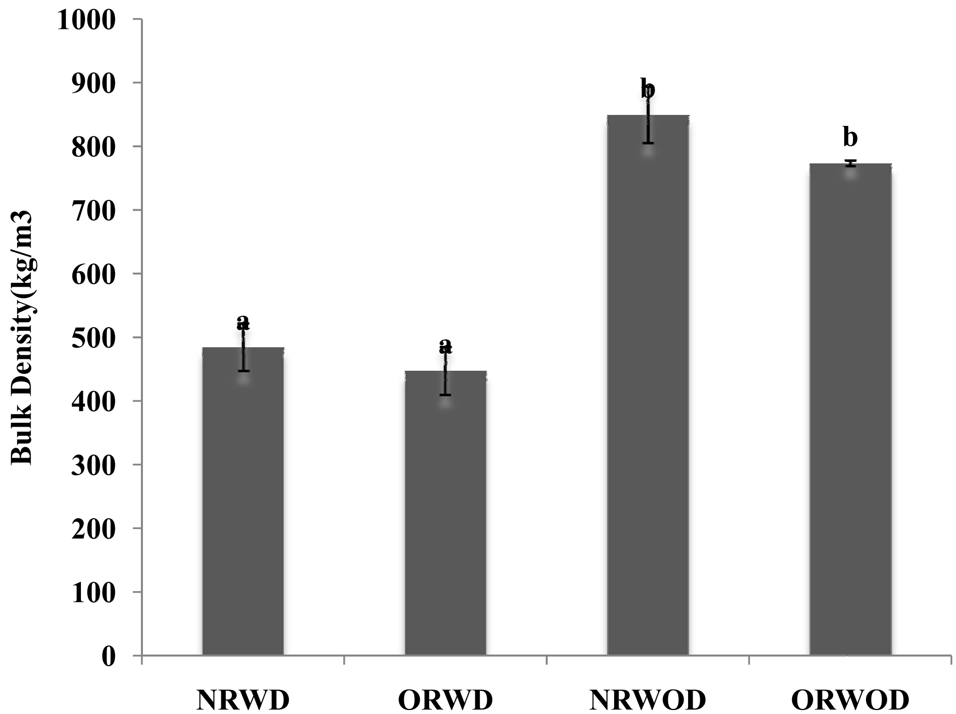


Fig.5.26. The bulk density of *Sel-roti* as affected by age of rice and *daun*. NRWD= New rice with *daun*; ORWD= old rice with *daun*; NRWOD= New rice without *daun*; and ORWOD = Old rice without *daun*. The similar alphabets above the bar diagram indicate not significantly different (p>0.05). The error bars show the variation of three determinations in terms of standard deviation.

(b) The fat-uptake by *Sel-roti*: The fat uptake by *Sel-roti* prepared from new and old rice flour with and without daun is given in fig. 5.27. The ANOVA and the LSD analysis revealed that the values of fat-uptake by *Sel-roti* prepared from the new and old rice flour without *daun* were not significantly different ($p \leq .05$) but were significantly different ($p \leq .05$) between new and old rice flour with daun; and both new and old rice flour

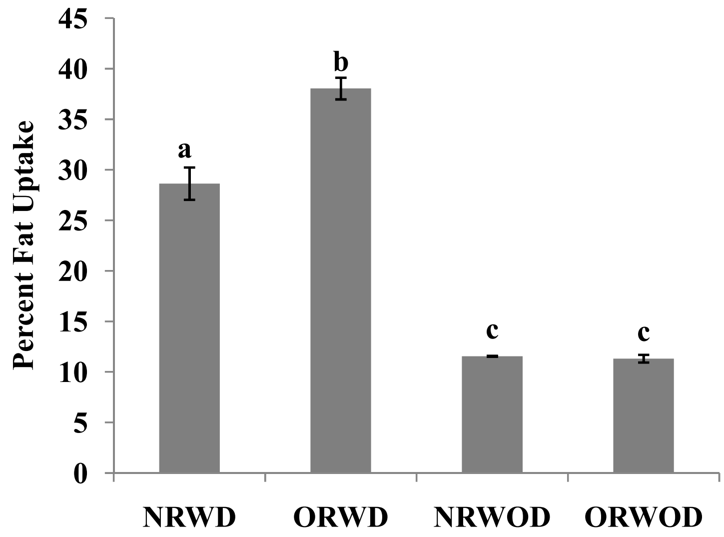


Fig.5.27: The fat-uptake by *Sel-roti* as affected by age of rice and *daun*. NRWD= New rice with *daun*; ORWD= old rice with *daun*; NRWOD= New rice without *daun*; and ORWOD = Old rice without *daun*. The similar letters above the bar diagram indicate not significantly different (p>0.05). The error bars show the variation of three determinations in terms of standard deviation.

with *daun* and without the *daun*, that means the age of rice did not affect the fat-uptake whereas daun significantly affected the fat-uptake by the *Sel-roti*. *The Sel-roti* prepared from the old rice flour with *daun* absorbs more fat than new rice flour with daun.

(c) Sensory Attributes: The sensory attributes of *Sel-roti* prepared from New and old rice with and without *daun* are given as bar diagram in fig.5.28. The ANOVA and LSD of mean score for sensory attributes revealed that all quality parameters of *Sel-roti* prepared from both new and old rice flour with *daun* were not significantly different (p>0.05), likewise the quality attributes of *Sel-roti* prepared from both new and old rice flour were also not significantly different (p>0.05). But the quality attributes of *Sel-roti* prepared from old and New rice flour with *daun* were significantly different (p<0.05) from the quality attributes of ole rice and new rice flour without *daun*. Hence the age of rice did not effect on the sensory quality of *Sel-roti*, provided other conditions remain same whereas *daun* had profound effect on the quality of *Sel-roti*.

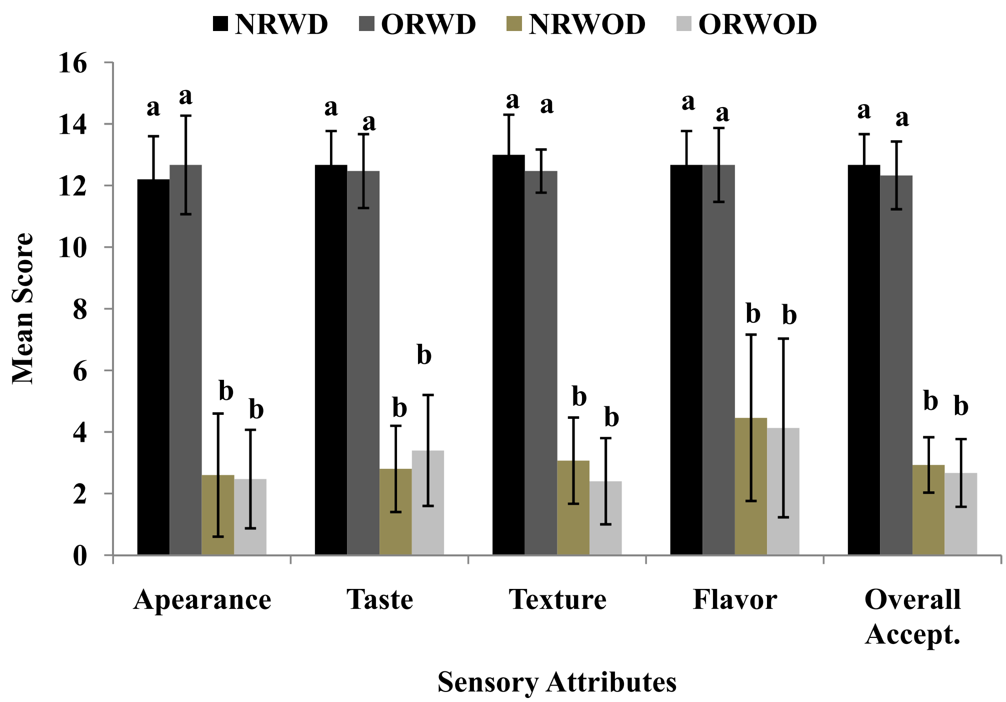


Fig.5.28. The Sensory Attributes of *Sel-roti* as affected by age of rice and *daun*. NRWD= New rice with *daun*; ORWD= old rice with *daun*; NRWOD= New rice without *daun*; and ORWOD = Old rice without *daun*. The similar alphabets above the bar diagram indicate not significantly different (p>0.05). The error bars show the variation of three determinations in terms of standard deviation.

(d) The texture profile. The mean score given by the panelist for texture profile of the *Sel-roti* prepared from new and old rice flour with and without *daun* is gives in table no. 5.26.

The ANOVA and LSD analysis revealed that there was no significant different (p>0.05) between each and every texture attribute of the *Sel-roti* prepared from both new and old rice flour with and without '*daun'* but the values of the different textural attributes of *Sel-roti* prepared from new and old rice flour with *daun* were significantly different from the values of *Sel-roti* prepared from the new and old rice flour without *daun*. According to the result given in table no 5.26 the higher values of smoothness of *Sel-roti* indicates the less grainy appearance on the surface of the *Sel-roti*; the lower values of hardness of *Sel-roti* indicate softer; the high value of oily mouth feel indicate high uptake of fat/oil by *Sel-roti*; and lower value of chewiness indicate easy to eat the *Sel-roti* prepared from the flour with *daun* than *Sel-roti* from the flour without *daun*.

The physical and sensory properties of *Sel-roti* such as light to reddish brown and grainy appearance, ring-shape, puffed and spongy nature, integrity, sweet taste, soft and crumbly texture and good eating quality, which are the most important and indispensable characteristics for those the consumer eats the *Sel-roti* can be obtained in the *Sel-roti* prepared from the rice flour with *daun*. The *Sel-roti* having such characteristics cannot be prepared without the *daun*.

TableNo.5.26. Mean Sensory texture profile of *Sel-roti* as influenced by age of rice and *Daun.*

Texture Attribute	NRWD	ORWD	NRWOD	ORWOD
Smoothness	8.15±1.5[a]	8.25±1.3[a]	5.60±1.6[b]	5.80±1.4[b]
Hardness	5.30±1.5[a]	5.70±1.4[a]	9.25±1.4[b]	10.25±1.4[b]
Fracturability	7.65±1.3[a]	8.05±1.4[a]	4.00±1.6[b]	3.60±1.4[b]
Cohesiveness	7.15±1.4[a]	7.05±1.7[a]	6.35±1.4[b]	6.25±1.5[b]
Stickiness	5.60±1.7[a]	5.60±1.3[a]	7.45±1.6[b]	7.40±1.5[b]
Oily mouth feel	7.85±1.2[a]	7.75±1.5[a]	3.15±1.7[b]	2.95±1.5[b]
Chewiness	15.00±3.0[a]	16.00±3.0[a]	20.00±3.0[b]	21.00±4.0[b]

N=20(5x4), the mean values± standard deviation. The similar alphabet in row indicate no significant different (p>0.05). NRWD= New rice with *daun*; ORWD= old rice with daun; NRWOD= New rice without daun; and ORWOD = Old rice without *daun*.

The age of rice showed very less or no effect on the fat-uptake, bulk density, Sensory attributes and texture of the *Sel-roti* whereas *daun* showed pronounced effect on the fat-uptake, bulk density, sensory attributes and texture of the *Sel-roti*. Hence, *daun* play a very important or indispensable role for the preparation of good quality *Sel-roti*.

5.11 Comparision of Sel-roti prepared from Traditional Process and Optimized Process.

(a) Bulk density: The bulk densities of traditionally processed *Sel-roti* samples, GPS, KTS and SDS and optimized processed *Sel-roti* sample, OPS were found to be 528 ± 3.0, 523 ± 3.5, 567 ± 4.0 and 512 ± 2.0 respectively and is presented in fig. 5.29.

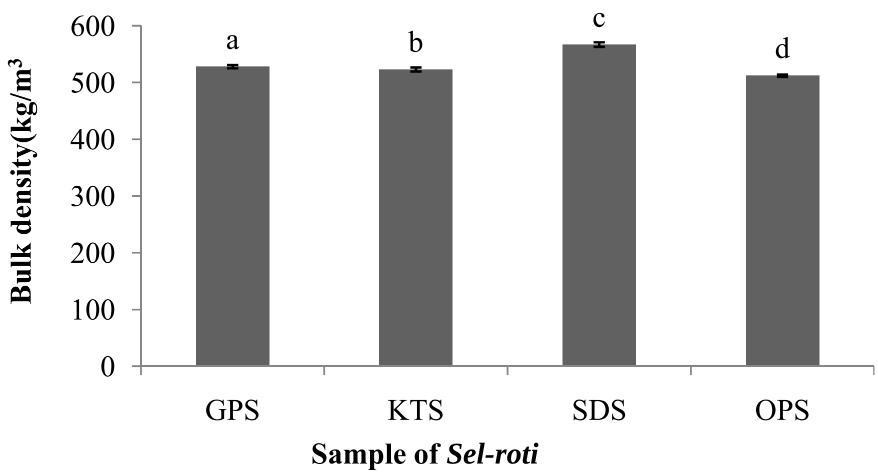


Fig. 5.29. Bulk density of Sel-roti prepared from traditional and optimized process

The similar alphabets above the bar diagram indicate not significantly different (p>0.05). The error bars show the variation of three determinations in terms of standard deviation. GPS = *Sel-roti* from Gurung shop, KTS = *Sel-roti* from K.Thapa shop, SDS = *Sel-roti* from Shrestha shop and OPS =*Sel-roti* from Optimized process.

The OPS smple had lowest bulk density among the samples and the ANOVA and LSD of mean value showed the density values were significantly different ($p \leq 0.05$) each other.

(b) **Fat-uptake**: The fat-uptake of *Sel-roti* samples, GPS, KTS, SDS and OPS were found to be 29 ± 1.4, 31 ± 1.5, 27 ± 1.4 and 35 ± 1.5 respectively. They are given in fig. 5.30. The ANOVA and LSD of mean value of fat-uptake revealed that the fat-uptake of the samples were found to be significantly different ($p \leq 0.05$) and the sample OPS had highest fat-uptake among the tested samples. Hence the *Sel-roti* prepared from optimized process and recipe was found to be superior because panelists liked *Sel-roti* containing high fat-uptake. This is true for most of the consumers who prefere high fat containing *Sel-roti*. *Sel-roti* gives high calorie due to high fat content.

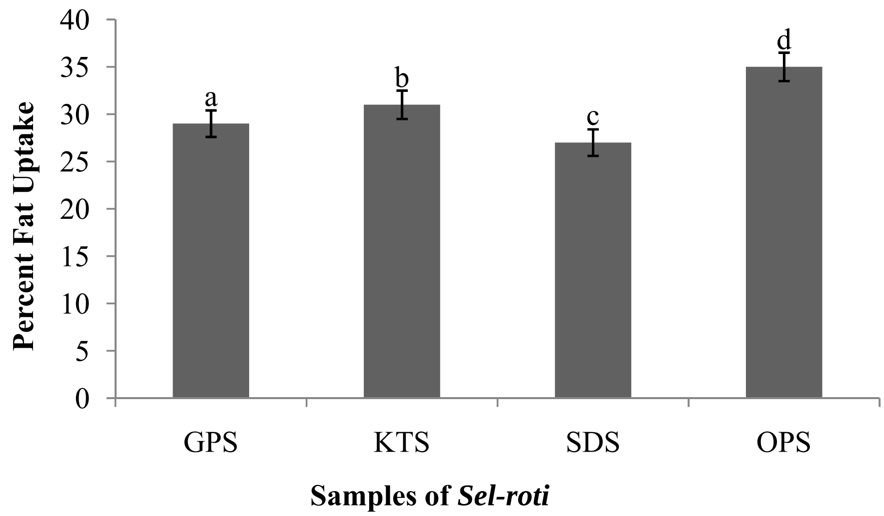


Fig. 5.30. Fat uptake of Sel-roti prepared from traditional and optimized process.

The similar alphabets above the bar diagram indicate not significantly different (p>0.05). The error bars show the variation of three determinations in terms of standard deviation. GPS = *Sel-roti* from Gurung shop, KTS = *Sel-roti* from K.Thapa shop, SDS = *Sel-roti* from Shrestha shop and OPS*Sel-roti* from Optimized process.

(c) Sensory Quality: The mean score given by panelists for appearance were 11.58±1.6, 12.33±1.5, 10.92±1.6, and 13.5±1.4; for taste 12.0±1.3, 12.83±1.2, 11.08±1.4, and 14.0±1.3; for texture 11.33±1.6, 12.18±1.5, 10.42±1.4, and 13.78; for flavor 12.17±1.5, 12.33±1.6, 11.58±1.5 and 13.67±1.2; and for ovrall acceptance 12.0±1.4, 12.38±1.6, 11.08±1.4, and 13.83±1.2 for Sel-roti samples GDS, KTS, SDS and OPS respectively. The result is shown in figure 5.31.

The ANOVA and LSD of sensory scores of *Sel-roti* samples prepared from traditional process and optimized process revealed that the mean scores of samples GDS, KTS, SDS and OPS were significantly different ($p \leq 0.05$) from each other for appearance; likewise the mean scores of all samples for taste, texture, flavor and overall acceptance were found to be significantly different($p \leq 0.05$) from each other except scores of GDS and KTS were not significantly differen ($p > 0.05$) for taste and flavor; and sample OPS got highest scores for all quality attributes. Hence, OPS i.e., *Sel-roti* prepared from optimized process was found to be superior. The significantly different sensory scores of different

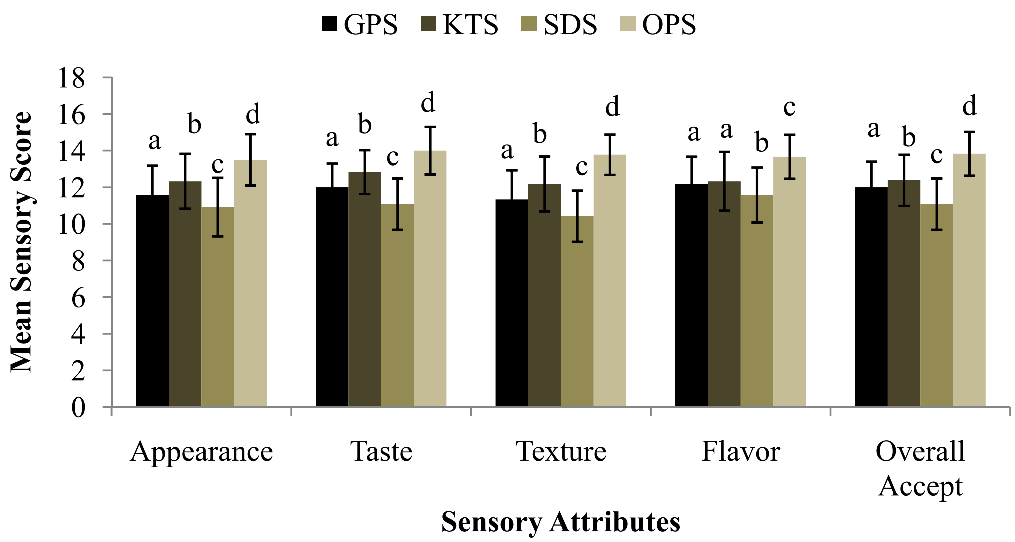


Fig. 5.31. Mean sensory score of Sel-roti pepared from Traditional and Optimized process.

The similar alphabets above the bars of each sensory attribute indicate no significance difference ($p>0.05$). The sample GDS, KTS, and SDS are prepared from traditional process in shop or restaurant and OPS is prepared from optimized process.

samples showed that there were variation in the quality of *Sel-roti* prepared from different persons and places due to the affect of variation in recipe, and processing parameter. This result supports that there is need for optimization of recipe and processing parameters and justifies the work carried out on optimization of recipe and processing parameters as well.

(d) Texture profile: The mean sensory scores for texture profile is given in table no. 5.27.

The ANOVA and LSD of panelists' scores of texture attributes of *Sel-roti* samples prepared from traditional and optimized process revealed that the sample OPS got lowest mean score for smoothness and was found to be significantly different ($p\leq0.05$) from samples GDS, KTS and SDS which were not significantly different ($p>0.05$); sample OPS got lowest score for hardness, highest score for fracturability and oily mouth feel and was significantly different ($p\leq0.05$) from others; the sample SDS got highest score for chewiness and was significantly different ($p\leq0.05$) from others which were not

Table No.5.27. Mean sensory profile of *Sel-roti* prepared from traditional and optimized process.

Texture Attribute	GDS	KTS	SDS	OPS
Smoothness	8.0±1.1^{a}	7.83±1.3^{a}	8.25±1.5^{a}	7.08±1.1^{b}
Hardness	8.08±1.2^{a}	7.75±1.4^{a}	9.33±1.5^{b}	5. 75±1.2^{c}
Fracturability	6.33±1.3^{ab}	6.50±1.3^{a}	5.75±1.4^{b}	8.75±1.1^{c}
Cohesivness	4.33±1.0	4.33±1.0	3.81±1.1	4.33±1.0
Stickiness	4.33±1.1^{a}	4.18±1.2^{ab}	3.67±1.0^{b}	4.75±1.0^{a}
Oily mouth feel	8.58±1.4^{a}	9.33±1.3^{b}	8.25±1.5^{a}	10.42±1.2^{c}
Chewiness	15.00±2.0^{a}	15.00±2.0^{a}	17.00±3.0^{b}	15.00±1.0^{a}

N=18(6x3), the mean value ±standard deviation. The similar alphabets in row indicate no significant difference (p>0.05). The sample GDS, KTS, and SDS are prepared from traditional process in shop or restaurant and OPS is prepared from optimized process.

significantly different (p>0.05) from each other; and the mean scores of all samples for cohesiveness were not significantly different (p>0.05). The lowest mean score of sample OPS for smoothness revealed that the sample OPS had grainy surface; the lowesr score of OPS for hardness and highest score for fracturability showed that OPS had comparatively soft and crunchy texture amomg the tested samples. Likewise the highest score of sample OPS oily mouthfeel revealed that it contained high fat. The above result and discussion showed that the panelists found the desirable characteristics of *Sel-roti* in the sample OPS than others

5.12 The biochemical changes in ageing of batter for *Sel-roti* preparation

Lactic acid bacteria grow during ageing of batter and fermentation takes place and some biochemical changes occurs. The extent of changes depends on the temperature and time of ageing. The result and discussion for the same experiment is given as follow:

(a) The changes in pH of batter: The pH of the batter during ageing at different temperatures i.e., 30°C, 40°C and 50°C and four times i.e., 0, 3, 6, and 9h for each temperature are presented in fig.5.32.The ANOVA and LSD of mean values revealed that the pH changes was found to be decreased at 40°C than 30°C and the decrease was significant (p≤0.05). The pH of the batter was decreased as the ageing time increased and the changes were significant.

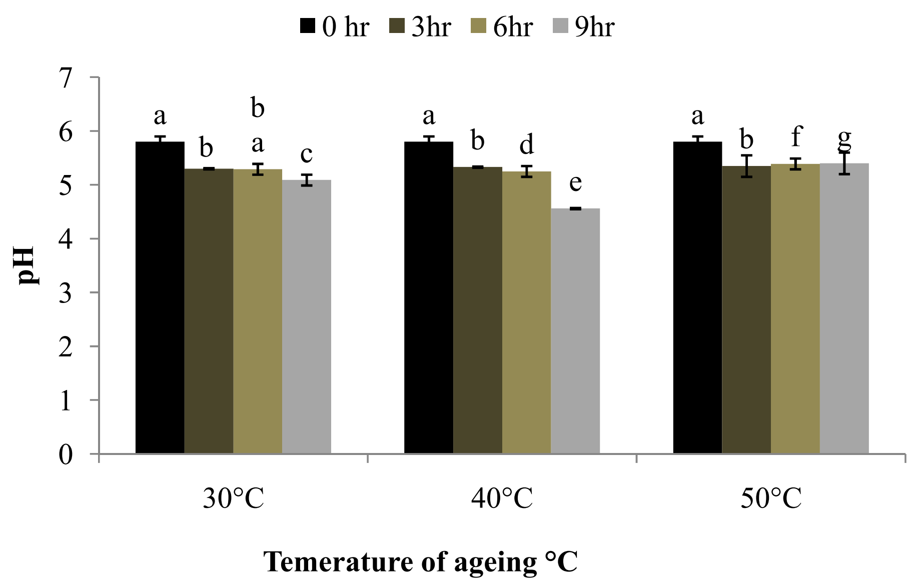


Fig. 5.32 pH of the batter during ageing at different temperature and time. The similar alphabets above the bar indicate not significantly different (p≤0.05).

(b)The changes of acidity of batter: The acidity of batter during at different temperature and time are presented in fig 5.33. The ANOVA and LSD of mean values showed that acidity was found to be increased as the temperatures as well as time of ageing were increased and the increased acidity was significant (p≤0.05). The highest acidity was found to be at 40°C for 9h of ageing of batter that may be due to the comparatively favorable growth of lactic acid bacteria and more production of acid in longer period of time.

(c)The changes of reducing sugar during ageing of batter: The reducing sugar content of the batter during ageing at different temperature and time are given in fig.5.34.

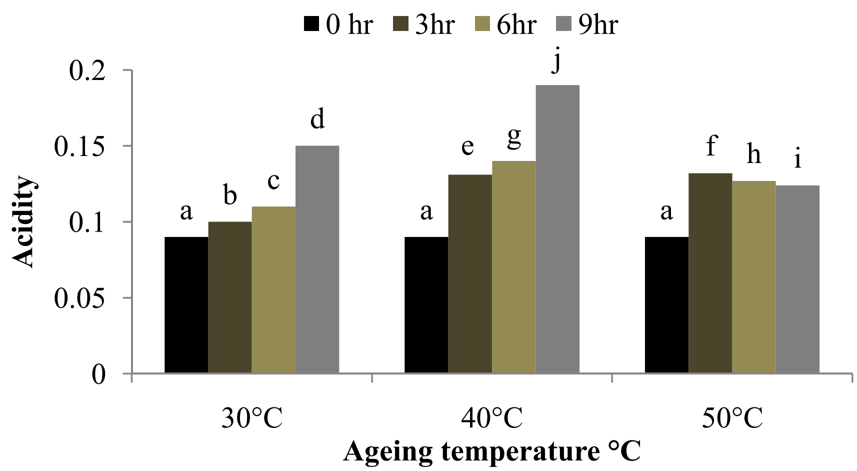


Fig.5.33 The acidity of batter during ageing at different temperature and time. The similar alphabets above the bar indicate not significantly different (p≤0.05).

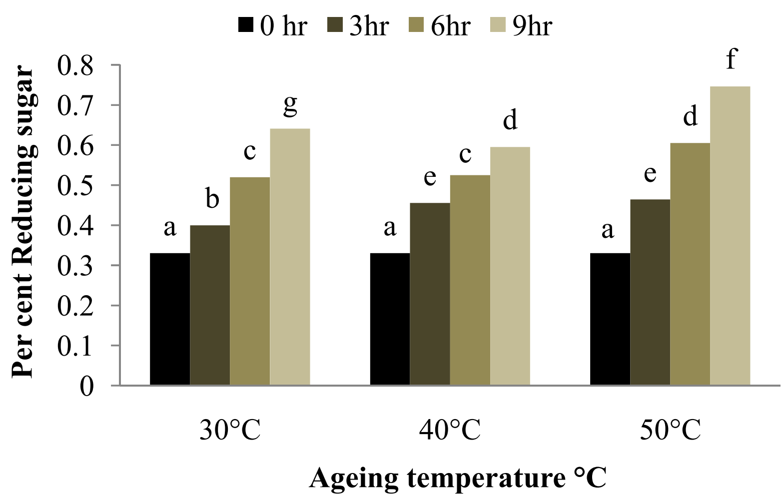


Fig.5.34.The reducing sugar content of batter during ageing at different temperature and time. The similar alphabets above the bar indicate not significantly different (p≤0.05).

The ANOVA and LSD of mean values of reducing sugar showed that the reducing sugar content was found to be increased as the temperature as well as time of ageing was increased. The effect of temperature and time were significant. The increased reducing sugar was more pronounced with increases in temperature than time of ageing of batter. That might be due to conversion of more sugar into reducing sugar in higher temperature.

(d) The changes of total sugar during ageing of batter: The total sugar content of Batter during ageing at different temperature and time is presented in fig.5.35. The ANOVA and LSD of mean values showed that the effect of time of ageing of batter was found significant than temperature in changing the sugar content of batter. The highest amount of total sugar was found at 50°C and 6h of ageing of batter.

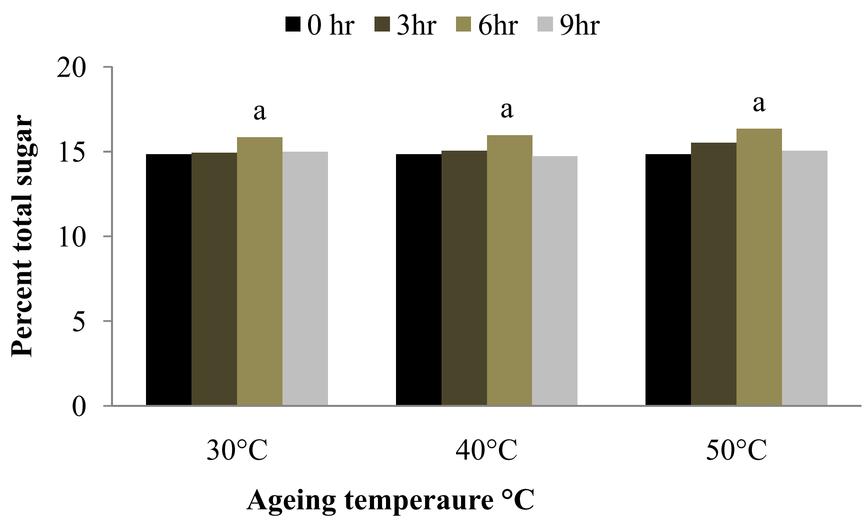


Fig.5.35 The total sugar content of batter during ageing at different temperature and time. The similar alphabets above the bar indicate not significantly different ($p \leq 0.05$).

(e) The changes in the proximate composition of batter: The proximate composition of batter during ageing at different temperature and time is given in table no.5.28.There were slight changes in proximate composition but not significant changes. The temperature and time within which the effect was carried out did not show any effect on the proximate composition in the batter. The initial pH, acidity, reducing sugar as dextrose, protein content of *Sel-roti* batter were found to be comparable but high in fat content, low in total sugar and carbohydrate content with the values reported by Yonzan and Tamang(2010).

5.13 Physicochemical and sensory characteristic of *Sel-roti*

5.13.1 Physical properties

The some of the physical parameters which are very important for their identification or classification or to handle or to prepare the product are given in table No.5.29.

Some of the physical parameters are useful in the classification, identification of materials; some provides the useful information about storage, handling and preparation of the materials.

Table No.5.28 The proximate composition of batter during ageing at different temperature and time (Dry basis).

Sample code	Protein	C.Fat	Total Ash	C.Fibre	Carbohydrate
A	5.44±0.30	10.66±0.6 0	0.70±0.0	0.16±0.03	82.86±0.20
B	5.43±0.41	10.66±0.41	0.70±0.03	0.16±0.02	82.85±0.32
C	5.43±0.32	10.59±0.36	0.70±0.03	0.16±0.02	82.92±0.35
D	5.43±0.31	10.63±0.33	0.71±0.02	0.16±0.01	82.87±0.25
E	5.43±0.25	10.63±0.31	0.72±0.02	0.16±0.02	82.90±0.26
F	5.43±0.24	10.64±0.25	0.70±0.02	0.16±0.03	82.86±0.36
G	5.43+0.26	10.64±0.27	0.69±0.03	0.16±0.01	82.88±0.27
H	5.43±0.28	10.64±0.24	0.71±0.02	0.16±0.02	82.86±0.28
I	5.43±0.22	10.60±0.32	0.70±0.03	0.16±0.0 1	82.92±0.29
J	5.43±0.24	10.65±0.25	0.70±0.02	0.16±0.02	82.86±0.30

Mean±standard deviation of triplicate sample. Time and temperature combination A= (30C, 0h), B= (30°C, 3h), C=(30°C, 6h), D=(30°C,9h), E= (40°C,3h), F= (40°C,6h), G= (40°C,9h), H= (50°C,3h), I= (50°C,6h) and J= (50°C,9h).

5.13.2 Chemical composition of *Sel-roti*

The chemical composition of *Sel-roti* is given in table no 5.30. This table includes the proximate composition, sugar and energy value of *Sel-roti*. The table no 5.31 contains major and trace elements.

Table no.5.30 shows the proximate composition, sugar and energy value of rice and *Sel-roti*. The rice is the good source of carbohydrate whereas *Sel-roti* is the good source of carbohydrate and fat but poor source of protein. It can supply high calorie i.e., 532Kcal/100g *Sel-roti* on dry basis. This may be the reason many people like to have *Sel-roti* more in winter than summer. The protein and fat content of rice were higher than the

Table No.5.29. The physical properties of rice (*Kanchchi mansuli*) and *Sel-roti*

Particular	Paddy	Rice	Sel-roti
Length (mm)	8.40±0.30	5.32±0.01	
Breadth (mm)	2.59±0.01	2.13±0.90	
Weight of 1,000 kernel (g)	19.60±0.60	13.8±0.80	
Hectoliter weight (kg)	54.21	86.25	
Bulk density (kg/m^3)	542±0.10	862±0.20	542±6.0
Color	Golden	White	Reddish brown
Taste	------	no taste	Sweet
Smell/aroma	no aroma	no aroma	delicious
Weight per piece (g)			47.5±1.50
Ring diameter (cm)			10.78±0.55
Cross section diameter (cm)			1.93±0.16
Ratio of ring diameter to cross section diameter			5.42±0.66
Time taken for one complete rotation (sec)			2.66±0.22
Frying time (sec)			33.22±0.83
Temperature (initial)			210°C

Mean of triplicate analysis ± standard deviation.

value reported by Maththias (1999), Matz, 1996) and DFTQC (2011). The starch content of rice was within the range and Ash content was higher than the mean value as reported by Matz (1996).

Table No.5.30 Chemical composition and energy value of Rice and *Sel-roti*

Component	Rice	*Sel-roti*
Moisture (%)	11.98±0.11	11.41±0.30
Crude protein (%DM)	9.41±0.18	4.68±0.10
Crude fat (%DM)	1.20±0.30	26.46±1.35
Total Ash (%DM)	0.70±0.02	0.30±0.02
Crude fibre (%DM)	0.26±0.03	0.12±0.02
Carbohydrate (%DM)	88.42±0.16	68.41±1.44
Starch (%DM)	85.31±0.18	57.43±0.50
Sugar as sucrose (%DM)	ND	16.49±0.46
Reducing sugar as dextrose	0.33±0.01	0.30±0.01
True protein (%)	8.22±0.16	4.04±0.10
Water activity (a_w)	---	0.65 – 0.68
Energy (kcal)	401	532

Mean of triplicate analysis ± standard deviation of triplicate sample. DM = Dry matter and ND=not detected.

The mineral content of rice and *Sel-roti* is shown in table no 5.31. The amount of calcium, iron, sodium, and potassium was higher in rice than the values reported by Matthias (1999) for milled rice. The value for iron was found higher and potassium and phosphorous content was lower than reported by Matz (1996), DFTQC (2011). On this basis rice as well as *Sel-roti* might be the good source of iron. Rice and *Sel-roti* also contain large amount of potassium and they also contain zinc which is good for health.

Table No.5.31. Mineral content of rice and *Sel-roti*

Mineral	Rice	*Sel-roti*
Calcium (mg/100g)	11.18±0.21	6.37±0.13
Phosphorous (mg/100g)	22.19±0.11	12.65±0.13
Magnesium (mg/100g)	43.65±0.12	24.89±0.15
Iron (mg/100g)	3.35±0.03	1.47±0.01
Sodium (mg/100g)	30.60±0.28	17.44±0.20
Potassium (mg/100g)	118.36±0.06	46.71±0.03
Manganese (mg/100g)	2.20±0.04	1.42±0.02
Lead (mg/100)	0.60±0.04	0.28±0.01
Cadmium (mg/100g)	<0.02	<0.02
Nickel (mg/100g)	0.05±0.01	0.02±0.01
Zinc (mg/100)	1.34±0.04	0.86±0.06

Mean ± Standard deviation of triplicate sample.

5.13.3 Characteristics of fat and oil

The characteristics of fat/oil which are very important parameters determined are given in table no.5.32. The proportion of ghee and soybean oil was about 1:3.

The acid value, free fatty acids and iodine value of used oil (soybean oil) and ghee (dairy ghee) were found to be in the range; the saponification value of ghee was found to be high but low in soybean oil as compared to the values reported by Mayer (1978) and DFTQC (2011) and those values of extracted fat/oil from *Sel-roti* were found to be in between of the ghee and soybean oil. Because *Sel-roti* contains the mixture of both animal ghee (dairy ghee) and refined soy oil, for ghee was used as *daun* and oil was used for frying of *Sel-roti*. The peroxide value of soybean oils, ghee and extracted fat of *Sel-roti* was found to be within the safe limit as of Nepal standard (DFTQC, 2011).

Table No.5.32 Characteristics of fat and oils used in *Sel-roti* preparation

Parameter	Ghee	Soybean oil	C.fat extracted from *Sel-roti*
Moisture content	0.19	0.01	0.06
Melting point	35°C	0.0	0.0
RI at 40C	1.4539	1.4651	1.4637
BRR at 40C	-----	------	56.6
Acid value	1.57	1.65	1.26
Free Fatty Acid	0.79	0.84	0.64
Sap. Value	244	167	200
Iodine value	31	130	114
RM value	28.6	----	<25
Peroxide value	1.44	2.7	9.5

5.13.4 Sensory Characteristics of *Sel-roti*

The sensory characteristics of *Sel-roti* are very important because consumers like or dislike on the basis of these sensory attributes, in turn, they eat or buy the products. *Sel-roti* has no any fix sensory characteristics for uniformity of the product. Nobody can say *Sel-roti* should have such characteristics and there are varied opinions about the characteristics. To fix the sensory characteristics of *Sel-roti* some questionnaires were asked to consumers and their responses were collected and analyze and recommended. The responses of consumers about the sensory characteristics are given in table No.5.33 as:

Table No.5.33 Consumers' responses on the sensory attributes of *Sel-roti*.

Sensory attributes	Per cent of response of consumer (n=45)
Appearance/ color/ shape and size	
Shape and size	
Ring shape	60
Spherical	23
Circular	14
Oval	3
	100

Color	
Reddish brown	47
Light brown	21
Slightly red	14
Golden brown	9
Dark brown	9
	100
Surface	
Grainy	70
Smooth	30
	100
Taste	
Moderate sweet	60
Sweet	21
Slight sweet	19
	100
Flavor	
Sweetish and slightly burnt flavor characteristics of Sel-roti	
Texture	
Soft, and little crispy	61
Softy chewy	19
Crunchy	16
Spongy	4
	100

On the basis of the response given above the *Sel-roti* should have the following sensory characteristics:

Appearance: Ring shape, Puffed, light to reddish brown with grainy surface

Moderate sweet in taste

Sweetish and slightly burnt flavor characteristics of *Sel-roti*

Soft and little crispy in texture.

As other many foods *Sel-roti* is a food based on cereal and on top of that it is superior in that it is delicious, ethnical, cultural, and secret food item liked and consumed by almost all people of different age, sex, caste/tribes, religions and geographical locations. *Sel-roti* can be eaten with vegetable curry, meat, aludam (reported in net) or alone or in any type of curry or chutney.One foreigner also has reported in net that *Sel-roti* is eaten with Jhand and gundruk. It can also be eaten as confectionary snack.

Any consumer judges food whether he likes or not; accept or reject the food in his own way. However, there are certain set up characters of food, based upon the food is evaluated by human. Some people knows better about the particular food item based on the prior set characters for it is the expert and can evaluated better than others. Food manufacturers prepare the food products based on the standard set up quality attributes.

Sel-roti has no set up standard quality characters. There are differences or variation about these characters for *Sel-roti*; however, it is tried to set up the standard sensory quality character for *Sel-roti* with the help of the information of consumer panelists of optimization of recipe for *Sel-roti* and the respondents of survey. These sensory characters of *Sel-roti* are as follow and need to refine or confirm:

Appearance: Ring shape, puffed, light to reddish brown with grainy surface
Moderate sweet in taste
Sweetish and slightly burnt flavor characteristics of *Sel-roti*
Soft and little crispy in texture.
In appearance *Sel-roti* should be ring shaped reddish brown in color and grainy appearance on the surface. The major part of the reddish brown color is due to the non-enzymic reaction i.e., caramelization of the sugar and Maillard reaction between sugar and protein in the outer layer.

The sweet taste is mainly due to sugars. The taste is also contributed by ghee or fats and oils. The non-enzymic browning and caramelization also perhaps contribute the taste of *Sel-roti*.

Texture of *Sel-roti* should be neither so hard nor so soft but in between and, crispy/crumby. According to the response given by the most of the respondents during survey and consumer panels testing on sensory evaluation of *Sel-roti* they prefer the *Sel-roti* which is soft and tender but crispy/crumby in texture.

The flavor of *Sel-roti* should be good, slightly sweetish and fried. The flavor is mainly contributed by ghee or fats/oils and sugar and optional ingredients if added. The non-enzymic browning especially caramelization are responsible for the fried and slightly burnt smell and taste of *Sel-roti*. The happening of similar type of phenomenon in baking of bread was mentioned by Matz (1996).

Eating quality of *Sel-roti* should be oily/fatty and crumby and also influenced by other factors or other characteristics. According to the *Sel-roti* eater they prefer the *Sel-roti* which gives the sensation which is called "*Jhurum-jhurum*" on biting/chewing. *Jhurum-jhurum* is the word which is a sensation produced on biting/chewing the *Sel-roti* due to the combined effect of oiliness and crumbliness. Lawsom, (1997) reported that the eating quality of any food products is a combination of the effect of taste, odor, and physical impression, such as softness, tenderness, moistness, dryness, firmness, chewiness, toughness, coarseness, and brittleness .

Some baked products achieve their oven expansion or rise without any help from either yeast or soda. These products expand during baking because of the heat induced increase in volume of the gases (air) which have been mixed into the dough or batter and to the increase in water vapor pressure as temperature increases. It is convenient to consider the later effect as as "stream pressure" but a significant effect obtained even it if the temperature of the products'inteior never reaches the boiling point of water (Matz, 1996).Sugar contributes structure, color, bulk and texture to the most baked products (Matz, 1996).

Pathologically *Sel-roti* is safe to consume because of the restriction and inhibition of growth of foodborne pathogens due to the growth of lactic acid bacteria (Adams and Nocolaides, 1997; and Adams and Nout, 2001) and deep frying prior to consumption. There has been no report of any food poising or infectious disease infestation by consuming Sel-roti (Yonzan and Tamang, 2010).

The process flow chart of opttimized method for Sel-roti prepation is given in figure 5.36 below:

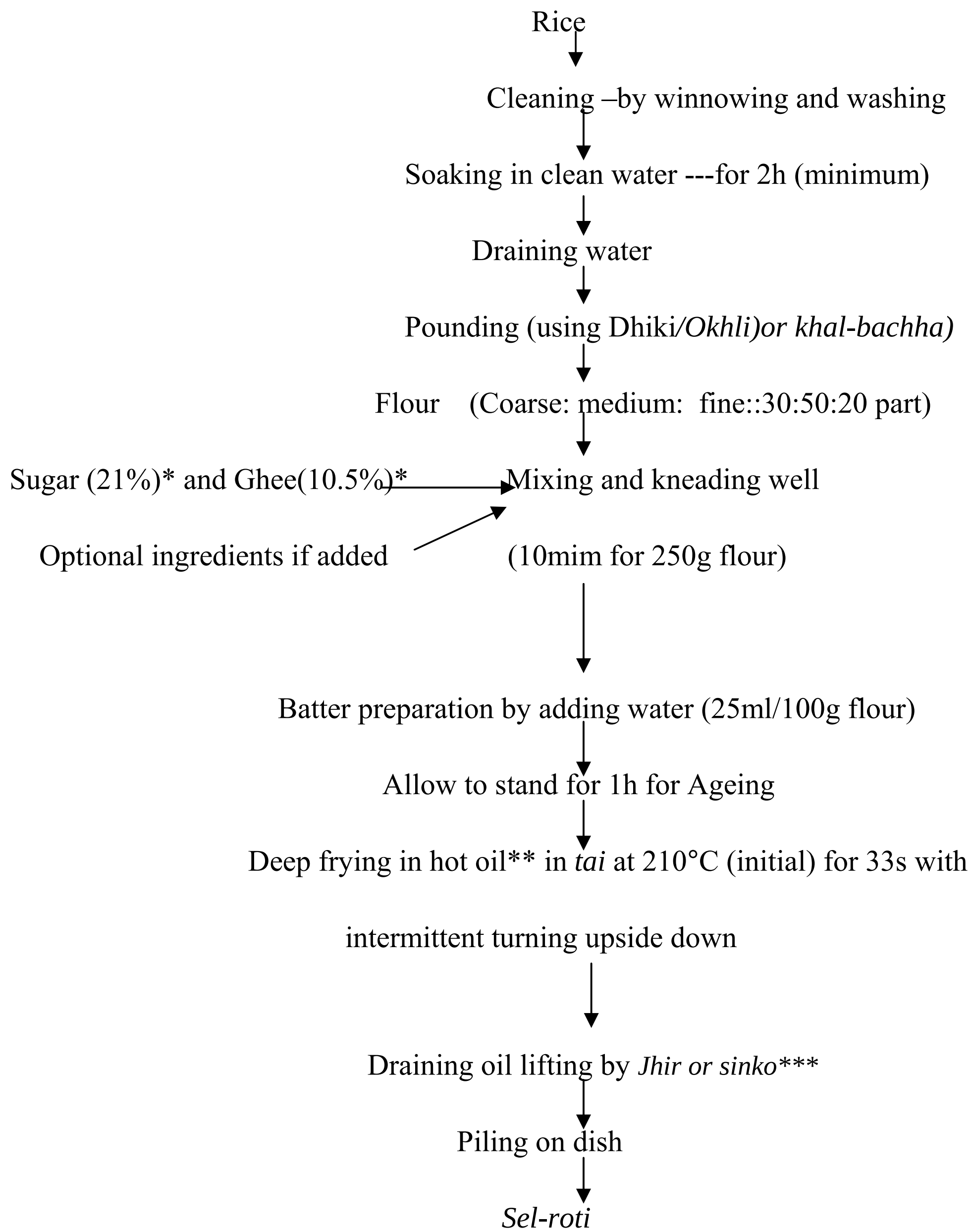


Fig.5.36 Flow-sheet for the optimized method of *Sel-roti* preparation:

***On the basis of fresh weight of flour, ** Refined soybean oil**

******Jhir* = Pointed stick of iron; and *Sinko* =Pointed stick prepared from bamboo.**

6. Conclusions

The following conclusions were drawn from the study of *Sel-roti*:

1. The meaning of *Sel-roti*, traditional method of preparation, the factors influencing the quality of *Sel-roti*, ethical and cultural/religious aspects of *Sel-roti* were collected and documented.
2. The recipe i.e., the amount of sugar and ghee on the basis of rice flour was optimized. Based on the quantity of rice flour the amount of sugar and ghee (animal) were 21% and 10.5% respectively. Likewise on the basis of rice their amounts were 25% and 12.5% respectively.
3. The effect of particle size of the rice flour was found to be significant ($p \leq 0.05$) on the bulk density and fat-uptake of *Sel-roti*. The particle size of flour was positively correlated with bulk density and negatively correlated with fat-uptake of *Sel-roti*. There was significant effect of particle size of flour on sensory quality as well as texture attributes of *Sel-roti*. From the same study of effect of particle size of flour on the quality of *Sel-roti* the optimum mean particle size of flour was found out , that was 520±6μ which was the mean particle size of flour comprising of 30, 50 and 20 parts of coarse, medium and fine flour respectively based on the particle size categories of flour.
4. The effect of different processing parameters like soaking of rice, kneading of ingredients, and consistency of batter, ageing of batter and frying temperature and time on the bulk density, fat-uptake, sensory quality and textural profile were studied and there was significant effect of each parameter. From the same studies the optimum processing parameters which are very important for good quality *Sel-roti* preparation were found out and recommended. These optimized processing parameters were 2h(minimum) soaking time of rice; 10min kneading time of ingredients for 250 g flour quantity; 1.935DS/L corresponding velocity flow rate, 2.302cm/s of 25 ml water per 100g fresh flour; minimum 1h ageing time of batter; and 210°C(initial) and 33s frying temperature and time.
5. Although among the frying medium used ghee, soy oil and sunflower oil were not significantly different ($p > 0.05$) considering cost and nutritional value refined soy oil was selected for frying *Sel-roti*.

6. The effect of *daun* was found to be significant on the quality of *Sel-roti* but the effect of age of rice was not significant. Hence *daun* i.e., ghee and sugar is indispensable for good quality of *Sel-roti*.
7. The *Sel-roti* sample prepared from optimized process was found to be superior to the *Sel-roti* samples prepared from traditional process.
8. The biochemical changes of batter during ageing were also studied. The significant changes occurred in pH, acidity, and reducing sugar during ageing of batter at different temperatures and times. The changes did not found in proximate composition of batter.
9. The physical properties, sensory characteristics and chemical composition of *Sel-roti* were determined. The physical properties of *Sel-roti* determined were 542kg/m3, 10.78±0.55cm, and 1.93±0.16cm for bulk density, ring diameter and cross section diameter of *Sel-roti* respectively. The sensory properties of *Sel-roti* were ringed shape, light to reddish brown colour and grainy surface, moderate sweet taste, soft and little crunchy texture and sweetish and burnt sugar flavor characteristics to *Sel-roti*; and the proximate composition(DM) of *Sel-roti* were found to be as 4.68±0.10, 26.46±1.35, 0.30±.01, 0.16±0.02 and 68.41±1.44 for protein, fat, ash, crude fibre and carbohydrate respectively and calorific value of *Sel-roti* was found to be 532kcal.
10. The texture attributes of *Sel-roti* were found to be 8.20±1.6, 6.01±1.4, 8.53±1.6, 7.33±1.5, 5.70±1.5, 9.47±1.6 and 15.00±3.0 for smoothness , hardness, fracturability, cohesiveness , stickiness, oily mouth feel and chewiness respectively.

7 Summary and Recommendations

7.1 Summary

Nepal is a country of different culture, religions and races.The different castes are *Brahmin, Chhetria, Newar, Limbu, Rai, Gurung, Sherpa, Damai, Kami, Sharki* etc. who are the habitat of mountain and hilly region. The different ethnic groups such as *Dhimal, Tharu , Satar, Rajbansi* etc are the Adhibasi (Tribes) of Tarai.The different races and ethnic groups have their own culture. They have their own food habits oriented from their ancestors since immemorial time. They have their own food selection and preparation. There are many traditional food products found in different parts of the country. Some of them are cultural and ethnic group specific; some are common to all.

Traditional foods with some exception are indigenous to Nepal. They are called indigenous foods of Nepal. Some of them are nutritious; some are used as appetizer; some have medicinal value. Some foods are used as snack. Some food stands for special occasion such as *Sel-roti* for Tihar and *Furoula* for *Maghe Sakranti* and is equally popular in all *Holi* and *Siruwa* among Tharu culture. Some foods are necessary to the specific ritual processes or feasts.

One of the most important indigenous products of Nepal is *sel-roti*. *Sel-roti* is a circular ring shaped product prepared from rice flour making batter of proper consistency and frying in oil/ghee at high temperature. The batter is prepared from rice flour , ghee, sugar and water .The frying medium may be different cooking oils (e.g. , mustard oil ,refined oils), ghee or may be lard or mutton tallow.

There is no proper documentation of traditional technology of *Sel-roti*. Scientific information as regards the production, nutritive value, quality etc also is lacking. Proper documentation is important and need to explore and familiarize it to authenticate its origin, preserve its culture and improve and standardize its technological parameters and eventually successfully commercialize the product. Thefore, the work, the study of *Sel-roti* was undertaken. The work was divided into three parts like 1.suevey study to collect the data or information regarding its origin, cultural and religious aspect, ingredients used, traditional method of processing, preservation and storage, consumption, socioeconomic, marketing and documentation of all the information; 2. Technological evaluation to investigate the technological parameter so that the uniform and good product could be prepared; and 3.Investigation of nutritive value and characterization of *Sel-roti*.

In survey the very important information regarding origin, culture and religious, economic and consumption, traditional processing, preservation and storage and marketing aspect of *Sel-roti* were collected from the respondents of different parts of the country with the help of questionnaires. In the survey naming of *Sel-roti*, ingredients used, factors influencing the quality of *Sel-roti* related information was also collected. On the basis of collected information there were two types of ingredients , (a) main ingredients e.g, rice flour, ghee, sugar and fat/oil, (b) optional ingredients e.g., milk and milk products; spices(fenugreek, clove,); seeds of *silam,& til*; powder from bark of plant like *kaulo, chamlayo, gogun, chiple* and latex of *udal*; egg, banana, soy flour, soda,isabgol etc,. Equipments and utensils were also identified. According to the resposes of respondents old and coarse vaietie of rice were used to prepare selroti, they are *atte*, *anadi, kanchhi musuli*, B40, *khyamti*, etc. The fat/oil used were mustard oil refine oil, animal ghee, cream, vegetable ghee (only some Sel-roti traders). Some Sel-roti traders especially in Kathmandu used about 25% of wheat flour incorporate with rice flour. If *Sel-roti* was used for religious or any ritual work, it is strictly prepared from only rice flour, sugar and animal ghee. *Sel-roti* were used to prepare from maize for general consumption purpose where rice was not available. *Sel-roti* was consumed as Prasad, confectionary bread. It can be eaten alone or with curry and chutney. It is popular for all people of different age, sex, different income groups, different ethnic, cultural or religious group and different geographical locations. It was prepared in different festival like *tihar, maghesakranti*, holly, *siruwa*; different *pooja* like *swosthani, satyanarayan, saraswoti pooja,puran*; different occasion and ceremony like naming, first food offering to child, *bratabanda*, birthday, annual, wedding, guest coming and some member going out for long period specially abroad; and some ritul process like funeral, *barakhi* and *shradhda*; and in time when family members like to eat selroti. People consumed more *Sel-roti* in winter season.

Recipe for *Sel-roti* was optimized. Frequency distribution of particle size of flour, the effect of mean particle size on physical and sensory properties like bulk density, fat uptake, sensory and textural attributes were deeply studied and the optimum mean particle size of rice flour was found out i.e., 520±6μ which was the mean particle size of flour consisting 30, 50 and 20 part proportion of coarse, medium and fine flour. The effect of processing parameters like soaking time of rice, kneading time of ingredients and ageing of batter, consistency of batter and frying temperature and time on physical and sensory characters of *Sel-roti* were investigated and the optimum processing parameters were also found out. These optimized processing parameters were 2h(minimum) soaking time of rice; 10min kneading time of ingredients for 250 g flour quantity; 1.935DS/L corresponding velocity flow rate, 2.302cm/s of 25 ml water per 100g fresh flour; minimum 1h ageing time of batter; and 210°C(initial) and 33s frying temperature and time respectively. There were significant ($p \leq 0.05$) effects of processing parameters on the physical and sensory quality of *Sel-roti*. The effect of frying medium, age of rice and addition of *daun* were also studied. Among the tested oils and fats refined soybean oil was found to be superior. The effect of *daun* was found to be pronounced and *daun* especially ghee and sugar is essential for preparation of good quality *Sel-roti*.

The biochemical changes of batter were also studied. The changes in pH, acidity, reducing sugar and total sugar except proximate components of batter were found to be significant.

The nutritive, sensory characteristics and some physical properties of *Sel-roti* as well as rice were also studied. *Sel-roti* was found to be contained low protein, high carbohydrate, and high fat, reasonable amount of mineral. The proximate composition of *Sel-roti* were found to be as 4.68±0.10, 26.46±1.35, 0.30±.01, 0.16±0.02 and 68.41±1.44for protein, fat, ash, crude fibre and carbohydrate respectively and calorific value of *Sel-roti* was found to be 532kcal. It has high calorific value because of high carbohydrate and fat content.

The texture attributes of *Sel-roti* were found to be 8.20±1.6, 6.01±1.4, 8.53±1.6, 7.33±1.5, 5.70±1.5, 9.47±1.6 and 15.00±3.0 for smoothness , hardness, fracturability, cohesiveness , stickiness, oily mouth feel and chewiness respectively.

Some of the physical and chemical characteristics of fat extracted from *Sel-roti* as well as oil and ghee used in the preparation of *Sel-roti* were analyzed.

The sensory or eating characteristics of *Sel-roti* were as follow:

Appearance: Ring shape, puffed, light to reddish brown with grainy surface
Moderate sweet in taste

Sweetish and slightly burnt flavor characteristics of *Sel-roti,*
Soft and little crispy in texture.

7.2 Recommendations

The following Optimized recipe and processing parameters are recommended for *Sel-roti* preparation:

(a). Recipe: 1kg rice, 125g Ghee, 250g sugar and 300±9.6 ml water

(b). Processing parameters:

a. Soaking time: Two hour (mim) at room temperature,
b. Particle size of flour: 520±6µ which consists 30part Coarse(>890 µ),50 part Medium(225 - 450 µ) and 20 part fine(< 120µ)
c. Kneading time: 10mim, for 250gflour,
d. Consistency of batter: 1.935DS/L(ratio of dry solid with liquid i.,e., water),
e. Ageing time of batter: 1 hour at room temperature,
f. Frying temperature and time: 210°C(initial) for 33 Second

The refined soybean oil should be used for frying of *Sel-roti* for commercial purpose and ghee for ritual or religious purposes.

The further researches need to be carried about *Sel-roti* are recommended as follows:

1. The effect of optional ingredients on the quality
2. The fortification of *Sel-roti* with proteins, minerals and vitamins.
3. Instrumental texture measurement and comparison with sensory data.
4. Amino acid and fatty acid profile
5. Shelf life study
6. Marketing aspects or commercialization
7. Automatic or semiautomatic Instruments for *Sel-roti* preparation
8. Varietal comparison of rice for *Sel-roti* preparation.

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Appendices

A Glossary:

Amilo: sour, tart or acid

Anadi: one of the types of paddy

Ari: an earthen, wooden or metal trough (used for keeping something), large steel bowl.

Aumusuli: one of the course type rice which is popular for preparing *Sel-roti*.

Bhakka: a special food prepared from steaming of soaked rice-flour

Bhakimlo: kind of tree having fine seeds with sour taste.

Bratabandha: a ceremony of wearing a sacred thread called *Janai* by Hindu for its first time inlife.

Chamlayo: kind of tree having slippery substances in its bark

Chamsur: garden cress seed.

Chhoyala: marinated and roasted meat

Chhurpi: solid food made from curd; hardened cheese.

Chimta: Pincers or tweezers.

Chiple: kind of plant, Pouzolzia viminia, having slippery substances in their stem and leaves.

Chuk: sour, tart or *amilo*; concentrated form of acidic fruit juice

Dalo: basket made of bamboo strips.

Dasain: the greatest festival of Nepalese Hindus in honour of goddess Durga, Celebrated for ten days.

Daun: ghee, sugar, etc used to make dough for preparing *Sel-roti*.

Dekchi: a kind of upright cooking pot.

Dudhiya: a kind of paddy.

Furoula: a kind of (puffed) cake made of ground pulse fried in ghee or oil.

Gogun: a kind of tree having slippery substance in its bark.

Gundruk: fermented and dried vegetable (mustard, radish etc leaves).

Jhir: a pointed iron sticks used to turn or to take out *Sel-roti*.

Kachila: a spiced flesh or meat, popular in *Newar* community (marinated and raw mincedmeat)

Karahi: a pan; a cauldron or a pan having two *kada* (ring shape) easy handling purpose.

Kaulo: kind of tree, Persea odorafissima, having slippery substances in its bark.

Khalpi: Pickle especially of cucumber (fermented).

Khyamti: kind of paddy.

Kinema: fermented soybean.

Koseli: present or gift, an offering.

Kurauni: milk boiled down till nearly solid; scum left on the saucepan after boiling milk.

Lahure: solder, Gorkha solder in Indian, and UK army.

Lohoro: ball-like stone used for grinding up something on the flat slab of stone (*silouto*).

Lohota: small metal water pot; small water vessel.

Maghe-sakranti: first day of Magh, tenth solar month (Jan-Feb).

Maghi: a popular festival of *Tharu* community.

Maseura: pellet made from colocasia and black gram.

Melko amilo: juice of mail fruit boiled down till solid.

Mohi: cultured butter milk.

*Mura*i: puffed rice.

Naibed: food consecrated to ma deity; special oblation to god.

Nanglo: winnowing tray made from bamboo strips.

Nwaran: ceremony of naming a child or name-giving rites of the infant of a Hindu performed on the 11^{th} day of its birth (Gautam C. 2059BS)

Okhal: mortar of wood in which rice –flour is made or rice is husked.

*Okhl*i: small mortar made of iron.

Okhli-musli: mortar and pestle.

Pasni: the ceremony of feeding a child its first solid food e.g, rice.

Pawa: one fourth of a kilogram.

Pokhara: a king of paddy.

Pooja: worship; adoration, respect, homage (Gautam . 2059BS)

Prasad: articles of food offered to the deity (Gautam . 2059BS)

Puran: One of the classes of Sanskrit works containing ancient lore, history, legend, mythology or theology or one of eighteen voluminous books on Hindu Mythology.

Roti: bread of cereal flour.

Roto: baked bread of soaked rice-flour pressed between two leaves. (Gautam, 2059BS)

Saraswaoti Pooja: worship of goddess of speech and learning.

Satyanarayan Pooja: worship of Vishnu Narayan

Sel-roti. Kind of circular (or ring-like) Nepalese loaf of rice-flour (fried in ghee or oil).

Shraddha: Ceremony in honor of and for the benefit of the deceased ancestors by offering water and food cooked in milk (called*Pinda*) etc in their name.

Sidra: kind of small dried fish (Gautam, 2059BS)

Sil: split and pointed bamboo.

Silam: small edible mustard -like seed.

Silauto: small stone for grinding spices with a roller stone. (Gautam,2059BS)

Simal: type of large cotton tree, Bombax malabaricum, having large thorns on its bark.

*Sink*i: fermented radishes prepared by pressing in a pit underground or in a pitcher.

Sinko: a small piece of stick; twig.

Suiro: pointed piece of iron, long needle.

*Sukuit*i: dried deat.

Swasthani Bratakatha: worship of God Shiva in Hinduism. . (Gautam, 2059BS)

Syalla: in a way of flowing sticky fluid.

Tai: a flat iron pan with a raised side.

Thunse (thunche): bamboo- band basket (without pores) used for carrying in the back.

Tihar: festival of lights observed for five days (worshiping crow, dog, cow, ox andbrother respectively.

Til: sesame

Titoura: 1. small ball (used as curry) prepared from ground pulse; 2. Dried sauce prepare from mango.

Udal: a kind of tree, Stercuria villosa. (Gautam, 2059B.S.)

(B). Questionnaires for Survey of *Sel-roti*

1. Full name of respondent: Age: Sex: Male/Female

2. Race/Tribe: 3. Religion:

4. Address:

VDC/Town: Ward No: District: Zone:

5. What do you know about *Sel-roti*? Why the name *Sel-roti* is given?

6. Which type of cereal grain you use and is best for the preparation of *Sel-roti* and why? Do you use other type of grain too, so what are they?

7. What are the main or essential ingredients used to prepare *Sel-roti*?

8. What are the optional/additional (somewhere they are called '*dawn*') ingredients used for *Sel-roti*?

9. Do you use soda or any other materials to puff the *Sel-roti*?

11. Are there any occasions when *Sel-roti* is essential?

12. How long have you been making *Sel-roti*? How often do you prepare *Sel-roti*?

13. How long *Sel-roti* can be stored?

14. What should be the desirable characteristics of *Sel-roti*?

15. Do you believe preparation of good quality *Sel-roti* is an art, too?

16. How much *Sel-roti*are produced? Yearly production ………kg.

17. Do you prepare *Sel-roti* for sale? Price: per piece of per kg.

18. Production:

a. Quantity and price of ingredients used for *Sel-roti* preparation.

Ingredient	Quantity	Price(Rs.)
Rice		
Water		
Sugar		
Oil/ ghee		
Milk & milk products		
Other if any ……….		

a. Product: …….Kg or ……No Price: per piece / per kg

(i). consumed in family

(ii). Sale: quantity……… per piece or kg per day or per week

(iii). Profit/Income:……… per day or per week or per month.

21. Who most like *Sel-roti* in your family?

(a) Children (b) adolescent (c) adult (d) old (e) very old

C. Score card for sensory evaluation

(i) Consumer testing by hedonic scale

Judge no. …… Date:…………….

The samples of Sel-roti are presented to you for quality evaluation. Eveluate the samples giving score on the basis of your judgement as of 7 point hedonic scle for each quality parameter. The scores reflect your degree of liking and disliking towards the products. Rinse your mouth between two testing with the supplied warm water. Repeated testing is allowed. The description of scale is given below:

Quality parmeter	Sample code	…..	…..	…..	…..	…..	……
1. Colour							
2. Taste							
3. Texture							
4. Flavor							
5. Overall acceptance							

Comment if any …………………………………………………..

Description of hedonic scale:

Like very much = 7Like moderately = 6

Like slightly =5Neither like nor dislike = 4

Dislike slightly = 3Dislike moderately = 2

Dislike very much = 1.

(ii) **Scoring for sensory attributes of *Sel-roti***

Panelist No.……….. Date:………………

Evaluate the provided sample of *Sel-roti* in order shown below. Score for each attribute with 1 – 15 point scale. Rinse your mouth with warm water provided to you between testing of each sample.

Quality attribute	…….	……	……	……	……	……	……
1. Appearance							
2. Taste							
3. Texture							
4. Flavor							
5. Overallaccept							

(iii). **Scoring for Textural Attributes of *Sel-roti***

Panelist No……………. Date:……………….

Evaluate the provided sample of *Sel-roti* in order shown below. Follow the procedure provided to you below. Score for each attribute with 0 – 15 point intensity scale. Rinse your mouth with warm water provided to you between testing of each sample.

Texture attribute	…...	…..	…	….	….	….	….
1. Smoothness							
2. Hardness							
3. Fracturability							
4. Cohesiveness							
5. Stickiness							
6. Oily mouth feel							
7. Chewiness							

D. Procedure for the evaluation of texture attributes of *Sel-roti*:

The texture profiles are evaluated in the following sequential order:

1. Initial (perceived on first bite): Hardness and fracturability
2. Masticatory(perceived during chewing): cohsiveness, stickiness and chewiness
3. Residues(changes made during mastication) : mouth coating

The technique for measuring individual parameter:

Smoothness: Hold the piece of Sel-roti near the mouth so that the tongue and lips cn be passed over the sample and evaluate for smoothness.

Hardness: Place the sample between the molar teeth and bite down evenly the force required to compress the sample.

Fracturability: Place sample between the molar teeth and bite down evenly until the sample crumbles, cracks, or shatters. Evaluate the degree of fracturability of a sample as the horizontal force with which a smple moves away from the point where vertical frame is applied.

Cohesiveness: Place the sample in the mouth and masticate and rotate between tongue and palate and evaluate the extent of manipulation required before the mass of food sample disintegrate.

Stickiness: Place the food sample in the mouth, press it aginst the palate and evaluate the force required to remove the it with tongue. Rinse mouth with warm waer immediately prior to each evaluation since the degree of stickiness depends upon the amount of saliva present.

Oily mouth feel: Remove he chewed material from the mouth and evaluate the oily mouth feel.

Chewiness: Place the food sample in the mouth and masticate at constn rate (1 chew/second). Count the number of chew required to make food sample swallow.

E. Meanscores of sensory evaluation.

(a) Table NoD1. Particle size distribution of market, household and lab sample of rice flour

APS(μ)	SD	GD	KD	PD	TT	BRT	EXP
1415	19.45	13.24	8.11	15.26	1.51	0.81	5.42
890	40.21	30.4	25	36.62	40.91	14.82	25.21
450	23	25.38	35.49	26.29	32.6	42.73	35.34
225	14.58	18.96	16.74	17.88	18.83	11.34	13.78
120	2.62	9.23	8.42	3.33	5.34	20.04	4.12
83	0.13	2.68	4.62	0.5	0.83	6.82	6.71
50			1.65			3.4	9.4

Where: APS = average particle size; SD= Shrestha Dharan; GD=Gurung Dharan; KD=Katawal Dharan; PD=Pandey Dharan; TT=Thapa Tarahara; BRT= Biratanagr; and EXP= Experimental /lab

Table

APS	C	M	F	CM	CF	MF	CMF
1415	46.2			24.71	22.78		10.4
890	53.8			23.86	27.82		14.26
450		70.35		36.32		30.13	37.73
225		29.65		15.06		20.11	13.2
120			29.39		10.42	11.76	3.92
83			41		17.36	15.38	8.27
<83			29.61		21.64	21.62	12.24

No. D2. Particle size distribution of rice flour (weight per cent retained) - formulation 1.

Where: C= 100:0:0; M = 0:100:0; F = 0:0:100; CM = 50:50:0; CF = 50:0:50;
MF = 0:50:50; CMF = 25:50:25. Combination of coarse, medium and fine flour.

Table No.D3. Particle size distribution of rice flour (weight per cent retained) - formulation 2.

APS(μ)	A	B	C	D	E	F	G
1415	2.84	5.67	8.51	8.37	11.34	14.18	17.01
890	7.16	14.33	21.5	21.62	28.66	35.83	42.99
450	41.01	34.18	20.51	34.24	34.18	20.51	20.51
225	18.99	15.83	9.5	15.76	15.83	9.5	9.5
120	8.62	8.62	11.48	5.45	2.88	5.74	2.88
83	12.33	12.33	16.44	7.86	4.11	8.23	4.11
50	9.06	9.06	12.08	6.7	3.02	6.04	3.02

Where: A = 10:60:30; B = 20:50:30; C = 30:30:40; D = 30:50:20; E = 40:50:10; F = 50:30:20; and G = 60:30:10. Combination of coarse, medium and fine flour.

Table No.D4 Particle size distribution of rice flour (weight percent retained) – formulation 3

APS(μ)	D	H	I
1415	8.37	9.76	9.76
890	21.62	25.24	25.24
450	34.24	34.24	30.81
225	15.76	15.76	14.19
120	5.45	4.1	5.54
83	7.86	5.89	7.06
50	6.7	5.01	7.4

Where: D = 30:50:20; H = 35:50:15; I = 35:45:20.
Combination of coarse, medium and fine rice flour.

Table No.D5 Effect of age of rice and *daun* on sensory attributes of Sel-roti

Sensory Attribute	NRWD	ORWD	NRWOD	ORWOD
Appearance	12.20(1.4)	12.67(1.6)	2.60(2.0)	2.47(1.6)
Taste	12.67(1.1)	12.47(1.2)	2.80(1.4)	3.40(1.8)
Texture	13.00(1.3)	12.47(0.7)	3.07(1.4)	2.40(1.4)
Flavor	12.67(1.1)	12.67(1.2)	4.46(2.7)	4.13(2.9)
Overall Acceptability	12.67(1.0)	12.33(1.1)	2.93(0.9)	2.67(1.1)

N=20(4x5), The values are mean score of triplicate analysis and the figures in parentheses are standard deviation. The values were recorded in 15point scale on the preference basis.
The similar alphabet in row indicate no significant different (p>0.05). NRWD= New rice with daun; ORWD= old rice with daun; NRWOD= New rice without daun; and ORWOD = Old rice without daun.

Table No. D6.Mean sensory score for *Sel-roti* as effected by kneading of flour and ageing of batter

Parameter	Appearance	Taste	Texture	Flavour	Overall accept.
A1K1	$10.94(1.7)^{a}$	$9.39(1.0)^{a}$	$9.44(1.5)^{a}$	$10.22(1.5)^{a}$	$9.61(0.8)^{a}$
A1K2	$11.56(1.2)^{a}$	$11.28(1.4)^{b}$	$10.78(1.7)^{b}$	$11.06(1.2)^{b}$	$11.11(1.3)^{b}$
A2K1	$11.44(1.2)^{a}$	$11.17(1.4)^{b}$	$10.89(1.5)^{b}$	$11.06(1.3)^{b}$	$11.22(1.3)^{b}$
A2K2	$12.61(1.2)^{b}$	$12.22(1.3)^{c}$	$12.22(1.5)^{c}$	11.78(1.4)c	$12.56(1.3)^{c}$

N=18(6x3), The values are mean score of triplicate analysis and the figures in parentheses are standard deviation. The values were recorded in 15 point scale on the preference basisThe similar alphabet in column indicates no significant different (p>0.05). A1K1=No kneeding and no ageing; A1K2= 10min kneeding and no ageing, A2K1= no kneedong and 1h ageing; and A2K2 = 10 min kneeding and 1h ageing.

E. Some Photoes

Fig.1 Paddy and rice (*Kanchhi mansuli*)

Fig. 2.*Sel-roti* of coarse and medium combination and of fine flour woth or wotuout daun.

Fig..3 *Sel-roti* with and without *daun*.

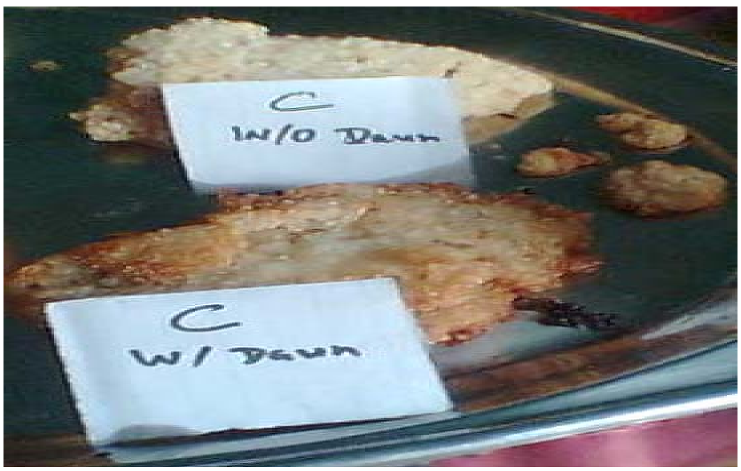

Fig.4*Sel-roti* of coarce flour particle with or without daun

Fig.5 Good Sel-roti

Fig. Pictures during training session of assessors (a) Different food items with different texture, (b) Explaining about how to test, (c) , (d), (e) & (f) Discussion and giving instruction

Fig.   (g),& (h) Performing sensoryevaluation by panelists

Fig.i.Piling of Sel-roti on the dish