PROSPECTS OF SOLAR DRYING TECHNOLOGY:

A case study of Pakhribas Municipality, Dhankuta District

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LETTER OF DECLARATION

I hereby declare that the thesis entitled **PROSPECTS OF SOLAR DRYING TECHNOLOGY: A case study of Pakhribas Municipality, Dhankuta District** submitted to the Department of Rural Development, Tribhuwan University, is entirely my original work prepared under the guidance and supervision of my supervisor. I have made due acknowledgements to all ideas and information borrowed from different sources in the course of preparing the thesis. The results of this thesis have not been presented or submitted anywhere else for the award of any degree or for any other purpose. I assure that no part of the content of this thesis has been published in any form before.

Date: …….. Kriti Ghimire

LETTER OF RECOMMENDATION

This is to certify that **Miss. Kriti Ghimire** has been completed this dissertation entitled **PROSPECTS OF SOLAR DRYING TECHNOLOGY: A case study of Pakhribas Municipality, Dhankuta District** under my supervision and guidance. Therefore, I recommend the final evaluation and approval.

Date: ……..

…….

Prem Sharma, PhD

Supervisor

APPROVAL LETTER

This is to certify that the thesis submitted by Miss. Kriti Ghimire entitled **PROSPECTS OF SOLAR DRYING TECHNOLOGY: A case study of Pakhribas Municipality, Dhankuta District** has been approved by the department in the prescribed format of the faculty of Humanities and Social Sciences.

Executive Committee

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ABSTRACT

Open sun drying of various crops is the most widespread conventional method for food preservation practiced in many urban and rural areas of developing countries. The traditional open sun-drying widely practiced by rural farmers has some sort of difficulties such as; high crop losses due to inadequate drying, fungi attacks, insects, birds, rodent encroachment and unpredictable weather effects Labor requirement, long drying time, and direct exposure of the produce to sun and wind are the further difficulties with this method. However, taking into account the low income of the rural population, the relatively high investment for energy based dryers still remains a barrier to wide application. In view of this, solar dryers can be a good alternative over conventional dryers and open sun drying technique. General objective of the study is to identify the prospects of solar drying technology with the case study of Pakhribas Municipality of Dhankuta district. The study explored the prospects of solar drying, using descriptive research strategy because it aims to study the prospects of soar dryer in underscoring rural enterprises. It looked into the problem by exploring the views of different set of respondents, as well as by exploring different literatures related with the study.

Vegetables especially off season, tea, large cardamom and ginger are major source of income for the eastern hill people. Farmers try to sell all the produces at once as they may go rotten, being perishable produces. In this effort they sell them even in lesser prices. This down price occurs when the overall production is high. They do not know about the drying technologies like solar drying. And even do not know about the subsidy they can receive. Most of the agricultural products are exported to the neighboring countries. Some agricultural products like Tea, coffee, spices are also exported to the countries of Europe. Because of the small size of export, the bargaining power of Nepali exporters is limited and weak.

One of the benefits of Solar Dryer system compare to the sun drying is quick dehydration. It is estimated about 50 to 60 percent of the time is saved in solar dehydration compared to direct sun drying. Besides this, with the installation of Solar Dryer, women got some relief. They can dry the products easily. Several sun dried products eg., dried herbs, dried ginger, dried turmeric, dried cinnamon, dried vegetable seeds and tea are exported to India. Some vegetable seeds are also exported to Bangladesh and Pakistan. Therefore the dried products have huge possibility of receiving internal and external market.

The temperatures in a solar dryer are higher than in sun drying and this reduces the drying time and usually improves the final product quality. Crop losses and spoilage from rain and animals are prevented because the crop is protected within the solar dryer. Solar dryer comprises three parts; in some types of drier these parts are distinct whereas in other these parts are in combined form. The introduction of low cost and locally manufactured solar dryers can offer a promising alternative to reduce the tremendous postharvest losses as small farmers mostly use open sun drying methods for drying of certain produces. Thus along with promotional activities of Solar dryer through subsidy, technical backstopping and massive consumer awareness raising program is necessary to create market for the dried products. The technical improvement is also necessary; the Capacity of the drier needs to be increased and should be affordable to the farmers.

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Date: …….. Kriti Ghimire

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ACRONYMS / ABBREVIATIONS

AEPC	Alternative Energy Promotion Centre
CRTN	Central Rural Technology Nepal
FNCCI	Federation of Nepalese Chambers of Commerce and Industry
GDP	Gross Domestic Product
Gm	Gram
GTZ	Technische Zusammenarbeit GmbH (German Agency for Technical Cooperation)
Kg	Kilogram
MT	Metric Tonne
NPPR	Nepal portfolio performance Review
RECAST	Research Centre for Applied Science and Technology
NARC/AED	Nepal Agricultural Research Council/ Agricultural Engineering Division
NGO	Non Government Organization

CHAPTER-1. INTRODUCTION

1.1. Background

Nepal is predominantly an agricultural country, with the majority of the population living in the rural areas and depending mostly on agriculture for their livelihood. Gross Domestic Product (GDP) shares 33.9 percent on agriculture. Agricultural system is subsistence and mixed farming system with domination of small holder farmers. Agriculture employs about 80% of the population, (NPPR, 2015).

Since the majority of the population depends on agriculture characterized by low productivity and small landholdings, it is not surprising that poverty is widespread in the country covering 38 percent of the population and concentrated mainly in rural areas. Considering its physiographic structure, Nepal is bound to remain an essentially a rural country with predominantly agricultural population. Therefore, for the foreseeable future, the one and only way for ensuring possible well-being of the vast majority of the Nepali populace is to achieve effective rural development through improving technologies in agriculture.

A considerable proportion of post-harvest loss of fruit and vegetable is a matter of great economic concern in Nepalese agriculture. Post-harvest loss could be rightly stated as the qualitative and quantitative loss of horticultural produce at any moment along the post harvest chain which includes the change in the edibility and wholesomeness i.e. quality of the produce finally preventing its consumption (Adeoye, 2009; Buyukbay, Uzunoz & Sibel, 2010). The estimated post harvest loss of fruit and vegetable in Nepal lies in the range of 20-50 percent (Gautam and Bhattarai, 2006). Between the harvest location and the retail market, produce undergoes a number of processes including transportation and storage under various environmental conditions. For perishable fruit and vegetable marketing, post harvest loss during handling, transportation, storage and distribution are the major problems. Such loss resulting in low per capita availability represents not only the loss of much money but also increases the costs of transportation and marketing (Subrahmanyam, 1986) which is a double loss for farmers and traders. Turan (2008) reported that improper post-harvest practices result in loss due to the

spoilage of produce before reaching the market along with the loss in quality of the produce such as deterioration in appearance, taste and nutritional value. The high perishable nature of fruit and vegetable, lack of storage facilities, mechanical injuries due to improper handling, packaging, transportation and microbial infection are the major reasons for post harvest loss in vegetables and fruits.

Drying has a vital role in postharvest processing. It has always been of great importance for conserving agricultural products and for extending the food shelf life. Many of the moisture-mediated deterioration reactions and reproduction of micro-organisms causing decay can be prevented by removal of moisture by appropriate drying method. Drying preserves crops by removing enough moisture from it to avoid decay and spoilage. While water content of most agricultural produce is greater than 50%, that of properly dried food varies from 5-25%, depending on the food (Bhandary, Sharma and Zafar, 1997).

Varieties of mechanical energy driven dryers are available for preventing the deterioration of products and to reduce the drying time. Commercially various energy based drying techniques such as forced convective drying, fluidized bed drying, heat pump drying, microwave drying, freeze drying, and many more are available and widely practiced These conventional dryers and drying techniques are not economical due to high energy cost.

Open sun drying of various crops is the most widespread conventional method for food preservation practiced in many urban and rural areas of developing countries. The traditional open sun-drying widely practiced by rural farmers has inherent limitations; of high crop losses due to inadequate drying, fungi attacks, insects, birds, rodent encroachment and unpredictable weather effects (Ekechukwu, 2010) such as dust, rain and wind; against which they are not protected (Ebewele and Jimoh, 1981). The implication of this improper handling and drying is far reaching.

However, taking into account the low income of the rural population, the relatively high investment for energy based dryers still remains a barrier to wide application. In view of this, solar dryers can be a good alternative over conventional dryers and open sun drying technique.

Solar energy is free, abundant, environmentally clean, and therefore is recognized as one of the most promising alternative energy. In near future, the large-scale introduction of solar energy systems, directly converting solar radiation into heat, can be looked forward. Moderate amounts of fuel wood or fossil fuels currently used in developing countries for the process of food and crop can be replaced by proper use of solar drying technologies.

Also most of the Nepalese rural small and medium enterprises are involved in processing and manufacturing of food items, consumer and household goods, and textiles and related products, both for exports as well as the domestic market. Among them, dried vegetables have also dominated SMEs activities in Nepal. In this context the use of solar dryer seems to have prospective in the rural enterprises for processing (drying).

1.2. Statement of the Problem

Open sun drying of various crops is the most widespread conventional method for food preservation practiced in many urban and rural areas of developing countries. The major disadvantage of this technique is low quality and hygienic problems of the product. The product gets contaminated from dust, insects, rodents, and other animals which seriously degrade the food quality and ultimately results in a negative trade potential and economical worth. Labor requirement, long drying time, and direct exposure of the produce to sun and wind are the further difficulties with this method. In order to ensure continuous food supply to growing population and to enable the farmers to produce high quality marketable products, efficient and at the same time affordable drying methods are necessary.

Due to poor post harvest management of agricultural produces some of the Nepalese commodities are unable to reach the markets with quality standard and with prospects of competitiveness. Majorities of the farmers sell their agriculture products immediately after harvest at low price with few value additions. So the farmers who are involved in producing perishable commodities are compelled to sell their produce immediately after the harvest. In such process sometime they even have to sell in low price whenever production exceeds the demand. Vegetables especially off season, tea, large cardamom and ginger are major source of income for the eastern hill people In Nepal. Solar drying seems suitable for ginger and vegetables.

As drying is one of the important post harvest method, the study on this proposal is more focused on the solar drying of perishable agricultural produces and the rural enterprises it can drift. Solar technology has found applications in almost all areas of agriculture, namely: drying of agricultural produce, irrigation and powering agricultural equipment for agro processing industries. The dried agri produces now are on scaling demand in the local market and also has high prospect in the international market if quality aspects are cared of. These drying technologies would help in flourishing rural enterprises and can contribute to income, jobs, innovation, capacity, technology transfer, economic sustainability and equity.

Varieties of mechanical energy driven dryers are available for preventing the deterioration of products and to reduce the drying time. These conventional dryers and drying techniques are not economical due to high energy cost. Commercially various energy based drying techniques such as forced convective drying, fluidized bed drying, heat pump drying, microwave drying, freeze drying, and many more are available and widely practiced. Diminishing reserves of fossil fuels and increased cost have made drying as an energetically expensive and unaffordable technique for farmers. Studies have shown that even small and most simple oil-fired batch dryers are not applicable for most farmers, due to lack of capital investment and insufficient supply of energy for the operation of dryers. Therefore the introduction of low cost and locally manufactured solar dryers can offer a promising alternative to reduce the tremendous postharvest losses. The opportunity to produce high quality marketable products seems to be a chance to improve the economic situation of the farmers.

In this context following research questions could be generated

1) What are the prospects of solar dryer in value addition of agricultural production?
2) What is the market situation of dried products?

1.3. Research Objectives

General objective of the study is to identify the prospects of solar drying technology with the case study of Pakhribas Municipality.

Specific objectives of this study are:

I. To identify the prospects of different solar drying technologies in value addition of the agricultural products of the study area.
II. To analyze the market situation of the dried products.

1.4. Significance of the Study

The farmers grow fruit and vegetables, which have to be sold in the market immediately after harvesting. When the production is high the farmers have to sell the material at very low price, there by incurring great loss. This loss can be minimized by dehydrating fruits and vegetables. The dried product can be stored for longer time in less volume. A successful enterprise can be run based on this principle which can easily utilize the surplus produce facing the seasonal glut. In off seasons the farmer can sell the dried product at higher. The traditional methods for drying the agricultural produce are to dehydrate the material under direct sunshine. This method of drying is slow process and usual problems like dust contamination, insect infestation and spoilage due to unexpected rain. These problems can be solved by using either oil-fired or gas fired or electrically driers. However, in many rural locations, the electricity is either not available or too expensive for drying purpose. Thus in such areas the drying systems based on the electrical heating are inappropriate. Alternatively, the fossil power dryer can be used but it poses such financial barriers due to large initial cost that these are beyond the reach of small and marginal farmers. In the present energy crisis, it is desirable to apply a little solar technology for dehydration of fruits and vegetable, so that gas, oil and electricity can be saved. Keeping the above facts in mind this innovation of local drier can prove to be of much help to farmer of most developing nations where sunshine is abundant. Moreover, the products are easy to sell as the products are having high demand in local market also.

The food production especially fruits and vegetables are surplus during the harvesting season, resulting in low selling price. Towards the end of the season the produce which was not sold goes uneaten or rots. Similarly, in alpine climate the food production is limited to few months in a year. Hence food preservation is important, among the various techniques available sun drying is one of common.

However, taking into account the low income of the rural population, the relatively high investment for energy based dryers still remains a barrier to wide application. In view of this, solar dryers can be a good alternative over conventional dryers and open sun drying technique. Solar energy is free, abundant, environmentally clean, and therefore is recognized as one of the most promising alternative energy. In near future, the large-scale introduction of solar energy systems, directly converting solar radiation into heat, can be looked forward. Moderate amounts

of fuel wood or fossil fuels currently used in developing countries for the process of food and crop can be replaced by proper use of solar drying technologies. Such technologies would provide the gateway for the enhancing of the rural enterprises. Small and medium rural enterprises play an important role in creating self-employment opportunities, mobilizing and using local resources, and raising the income of the rural populace. Such rural enterprises (Small and Medium Enterprises) comprise a substantial part of the economic activity of developing countries. The dried produces are now getting market which indicates the prospects of enterprises based on solar drying technologies.

1.5. Scope and Limitations

The study is limited to the Pakhribas Municipality of Dhankuta district. The subsidy on solar is distributed through some pre qualified companies. According to the company this distribution is on demand basis. Solar dryer operate effectively on good weather and sunny days. There are no small scale processing industries according to gharelu tatha sano udhyog bikash of Dhankuta. So the primary information was gathered from commercial farmers.

CHAPTER-2. REVIEW OF LITERATURE

1.5. Traditional Food Conservation Methods and Technologies

The most widely practiced traditional food conservation technology in Nepal is drying, this is this is accomplished in various, among them solar drying is most popular, in this method crops are spread in open field, courtyard, balconies, and streets to expose them to sun and wind, in this way moisture content of the cereal grains are usually at 20 to 40 percent are brought down to a safe limit of storage (12 to 14 percent). Even the surplus vegetables and fruits are sundried as no other alternatives are available. Other commercially sun dried products include cauliflower, radish slices, potato chip, onion, mushroom and vegetables seeds.

Fire and smoke drying and shade drying are other traditional conservatio0n methods which are also widely practiced in Nepal.

Fire and smoke drying is used for few agricultural products like ginger and cardamom. In this method the produce to be dried are place over the traditional kiln.

Shade drying is used for the preservation of apples in mid-western region of Nepal. In this method sliced apples are hanged on the ceiling on cross ventilated and air at room temperature is passed through them.

1.6. Modern Food Conservation Methods and Technologies

Freezing and drying are two major are two major conservation techniques frequently used in Nepal. Freezing techniques are applied to fresh products for future consumption. Their application are however limited only to urban cities for conserving potatoes, tomatoes and few types of fruits like apple and oranges. Electric drying techniques are used mainly by commercial enterprises to produce baked and other valuable products. Both of these techniques require substantial amount of electrical energy, which in case is not available in largest part of the country. Thus solar drying has emerged as one of the bright options among known modern conservation technologies, because it uses natural resources (which is abundantly available

across the country, is simple, environmental friendly and low in initial cost as well as in operation, maintenance and repair costs.

1.7. Solar Dryer in Food conservation

1.7.1. Historical Background in Nepal

Planned development of solar dryers has been introduced in Nepal since the eighth five year plan (1980-1985). Emphasis upon its development has however been given only during the ninth five year plan (1997-2002).Since then the policy for subsidizing solar dryer through the Alternative Energy Promotion Centre (AEPC) was implemented, dissemination work and studies on different aspects of solar dryers were carried out, soft loans were provided, and various organizations had started to be involved in this sector.

RECAST (1998) undertook a sample survey of soar dryers used in different regions of Nepal encompassing the mountain, hill and Terai. The study revealed that some fifteen types of solar dryers have been used in different parts of the country drying a variety of products and there were commonly used viz. cabinet dryer, rack dryer and tunnel dryer. Most of the solar dryer were based on natural air convection while tunnel dryer and some of the rack dryer were based on forced convection. The rack dryer is somewhat sophisticated in design and more expensive compared to the cabinet dryer. The cabinet dryer is a wooden box with its upper part consisting of an inclined glass sheet. Inside it, the walls are blackened to absorb the incoming solar radiation entering through the transparent cover. For ventilation, holes are made at bottom and on the upper part of the backside wall.

These solar dryers can be classified as cabinet type (box type), rack type and tunnel type

Solar cabinet dryer consisting of rectangular container. It is insulated as its base and covered with a transplanted glass sheet. Holes are drilled through the base to permit entry of fresh ventilated air into the cabinet. Outlet posts are located on upper parts of the cabinet side and rear panels. The design of this type has been adopted from the one developed at Brace research institute, Canada.

Solar rack dryer consists of two separate parts: a collector to heat air from ambient temperature to a desired temperature with the help of solar radiation, and drying chamber. The commodities to be dried are spread on number of trays at different layers.

In **Solar tunnel dryer** air is heated in the collector, flows over products placed in thin layers. The collector panel has two layer of glazing made of UV resistant polyethylene sheets and blackened aluminum plates as absorbers, Air is pumped into the system by using an electrical blower or a venture unit attached to the air exit of the dryer

RECAST (2001), developed indirect type cabinet dryer of steel body having collector area of 0.85 m^2, the slope having 30^o, the experiment was conducted to dry radish and mushroom in the month of MAY. It took 4 to 8 hours and 6 to 8 hours respectively. Because of inability of the farmers to afford expensive solar crop to dry their produce, attention was made towards development of low cost solar crop dryer made of locally available materials. In the course, ITDG () designed sasto solar drier of dimension 4 ft*6 ft brick body with transparent polyethylene collector cover, finely chopped hay or rice husk in clay as insulating material and drying surface was inclined. It reduced the drying time by 41 percent.

Similarly, a comparative study for mushroom drying in wooden and metallic (galvanized sheet fabricated) solar dryer was done by Nepal Agricultural Research Council/Agricultural Engineering Division (NARC/AED). Result showed that the duration of drying mushroom to the moisture content level below 10 % attained within 2 days of drying.

In order to help agro-entrepreneurs in drying coffee, turmeric and mushroom in large scale Agricultural Engineering Division, NARC developed solar tunnel drier. 150 to 200 kg agricultural products can be dried and according to the nature of product and sunshine hour it takes 2 to 4 days for drying. (Semi- annual bulletin 2070, Agricultural Energy technology)

Alternative Energy Promotion Centre (AEPC) is a Government institution established on November 3, 1996 it is under Ministry of Population and Environment, having objective of developing and promoting renewable/alternative energy technologies in Nepal. AEPC is responsible for promotion, dissemination and market regulation and also for providing technical backstopping to manufacturers. For the quality assurance and effective implementation of the subsidy program AEPC has set quality standard and subsidy delivery mechanism. From 1963/64 to 2067/68 AEPC has supported installation of about 684 Solar Dryers and 488 Solar Cookers (AEPC, Official Reports).

With the intention to promote the utilization of solar thermal energy for cooking and drying of agricultural products, Government of Nepal through its authority Alternative Energy Promotion Center (AEPC) under Ministry of Environment has been providing subsidy for SD/SC through prequalified manufacturers. Since FY 2063/64,

Government subsidy on solar dryer

Subsidy for solar thermal technologies will be provided in the rural areas only. The following will be the subsidy for the various types of solar thermal technologies:

1. The maximum subsidy amount of 50% of the total cost but not exceeding Rs. 10,000 will be provided for the specified solar cooker per household.
2. The maximum subsidy amount of 50% of the total cost but not exceeding Rs. 15,000 will be provided per household for specified domestic scale dryer with drying area of 3-20 sq ft.
3. The maximum subsidy amount of 50% of the total cost but not exceeding Rs. 100,000 will be provided for specified medium scale commercial dryer with drying area of 20-85 sq ft.
4. The maximum subsidy amount of 50% of the total cost but not exceeding Rs. 150,000 will be provided for specified large scale institutional or commercial dryer with drying area of more than 85 sq ft. Additional Rs. 20,000 will be provided if the at least 50% of the target groups are single women, backward, disaster victim, conflict victim, endangered ethnic group identified by the Government of Nepal.

(Subsidy policy, 2016)

1.7.2. History of Solar Dryer in the World

GTZ (undated) built solar dryer in Morocco to dry apricots. The fruits were spread in a single layer on the grating of the dryer, in a shingled pattern with the cut surface facing up (application density = 15 kg/m^2) and in case of grapes (application density= 20 kg/ m^2). The dryer was then closed and placed in operation. In order to prevent damage to the fruits, temperature of the

drying air was not exceeding 65^{o}C. The final moisture content of 25 % was reached under cloudless weather condition in about two days for approximately 120 kg for the product.

Patil (1984) designed and developed a solar crop dryer 9 poly dryer and cabinet dryer which reduce drying time to 5.5 to 6 days at an average air velocity of 5m/min using black painted Palmyra mat as drying floor and double layered polyethylene sheet as transparent tested on which was tested on copra. The solar cabinet dryer had drying surface inclined at an angle equal to latitude provided with reflectors from three sides of the dryer and also a provision for manual sun tracking was developed. The drying time required was 3.5 to 4 days at double the spreading density compared to open sun drying. The initial moisture content of the copra was 46% wb) and under average drying condition outside the cabinet RH 60 % and temperature 30.4^{o}C, relative humidity decreased to 49 % with a rise in temperature of 46.1^{o}C. the difference in air temperature in the drying and outside was minimum at 7^{o}C and maximum at 20^{o}C. Result showed that the drying capacities were 0.91 g/m^{2}/day and 3.6 g/m^{2}/day for open, poly dryer and cabinet dryer. The saving of time was found to be 21.4 % and 42.8% in poly dryer and cabinet dryer respectively as compared to open drying whereas per day capacity of drying per m^{2} could be increased by 91% to 96% by the use of poly dryer and cabinet dryer respectively.

David B. Ampratwum (1988) developed a solar dryer to dry dates under controlled and protected conditions. A prototype of the dryer with 1.6 m^{2} solar collector area was built for experimental drying tests that dried batch of 100-200 kg in 14 to 21 days. The controlled drying with solar dryers in 10 hours reduced the drying time to 2 to 3 % of the open sun drying time and resulted in improvement in the quality of the dried material. (Sultan Qaboos University).

India performed the solar drying in tea leaves, species, fish drying and fruits and vegetable dehydration which showed good result. The technology developed by Planters Energy Network (PEN) is able to provide a low cost non-fossil fuel operated methodology for processing large quantity of fruits, vegetables, spices, grains, other cash crops and other industrial and chemical products.(PEN 2009)

CHAPTER-3. RESEARCH METHODOLOGY

The study explored the prospects of solar drying, using descriptive research strategy because it aims to study the prospects of soar dryer in perspective of value addition of the agricultural and the market situation of the dried products in the country. The study looked into the prospects by exploring the views of different set of respondents, as well as by exploring different literatures related with the study.

3.1. Research Design and Methodology

3.1.1 Research Design

It is the blueprint for the collection of data, its measurement and analysis. The explorative research design was used; it is because the characteristics tend to study quires how and in what respect the solar drying technology could help for rural enterprise.

3.1.2. Nature and Types of Data

Data is a piece of fact, the wholesome aggregate of which gives the information. This information in fact contributes to the inquiry of truth and approaches towards the reality. The natures of data that will be used as per research question are:-

3.1.2.1. Primary Data

Primary data are the first hand data collected for the first time for a particular purpose of investigation. In the due course of investigation/research, primary data were collected viz. observation, focus group discussion, interview, and questionnaire as per the convenience to aid to the study. Since, the study was more about descriptive baked by casual relationship; the primary data were helpful for generalization.

3.1.2.2. Secondary Data

Those data which are already been collected for any other purpose or investigation are the secondary data. Since, this research is mounted on the base of description and analysis, secondary data was must. Therefore, secondary data plays the role of corner stone for this research. The various internal and external sources were used for acquiring the secondary data. The various sources consist of:-

- Central bureau of statistics

- Ministry of energy
- Alternative energy promotion centre
- Google
- Bulletins/reports, etc.
- Library

3.2. Data Analysis

Since, this thesis is more concentrated towards the prospects of solar drying technology in rural area of Nepal i.e. Pakhrribas VDC, Dhankuta district. On this regard both quantitative and qualitative methods were carried out.

Since, the objective of the thesis is to study the technical aspects of the solar drying technology and its prospects on rural enterprise support in long run. The attitude, awareness and perception of various stakeholders- were studied through qualitative research method.

3.4. Data Collection Process and Procedures

This dissertation is more descriptive in nature so the primary data was collected via observation, questionnaire, and interview. This data are more authentic and bias less. The various secondary data were collected from different internal and external sources.

3.6. Sampling Plan

The interview was done with 10 farmers to know their indigenous practices in drying the agricultural produces mainly horticultural produces. Their knowledge about the drying technologies and subsidy related were inquired (For the questionnaire see Annex B).An unstructured interview and focus group discussion were conducted to obtain more information.

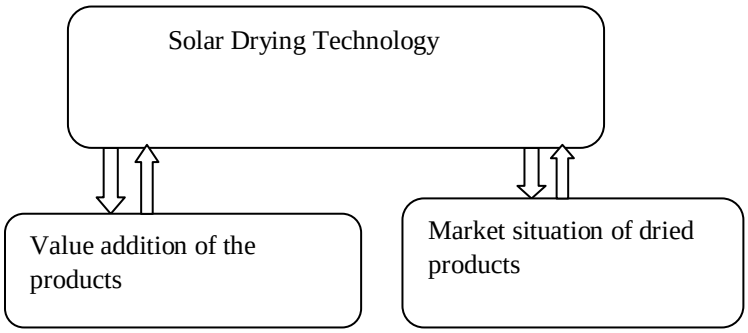
3.7. Study Area Selection

Eastern Hilly region was selected for the case study. The site was pakhribas VDC of Dhankuta district. The district is famous for producing cash crops like Akabare, ginger, cardamom and tea.

3.9. Theoritical Framework

The aim of this study is to identify the prospects of solar drying technology. The time for drying and the quality of the dried product ensures the value addition of the products. And the market situation of the dried products also signifies the prospects of the solar drying technology.

Therefore, value addition of the products and the market situation of the dried products are considered as factors which determine the prospects of the solar dryer.



CHAPTER-4. RESULT DISCUSSION

4.1. Study Area

Pakhribas is situated in Dhankuta district at ward number 7 of Pakhribas village development committee. Pakhribas lies in Koshi zone of eastern development region. Pakhribas is 17 kilometers north west of district headquarter Dhankuta. The VDC is connected through Hile-Bhojpur road and is located four kilometer west of Hile Bazar. The nearest airport Biratnagar is 110 kilometer, elevation ranges from 1,315 meter to 2,025 meter above mean sea level. Pakhribas lies 270 02.98' north latitude and 870 17.61' east longitudes. The average minimum temperature ranges between 5.6^0 C (January) to 17.4^0 C (July) with lowest 2.4^0 C in January and average maximum temperature ranged between 15.5^0 C (January) to 26^0 C (April) with maximum of 29^0 C in May. Average annual rainfall at the station occurred 1492.3 mm with 126 rainy days and highest 440.7 mm rainfall occurred in July with 29 rainy days. Maximum 9 hours/day sunshine recorded in April and November and lowest 3.31-2.64 hours/day recorded in June to August. Relative humidity at the station was recorded between 50.3% (April)-92.68% (July). The climate of Pakhribas is sub-tropical to temperate. There are 358801 households in the eastern hills with 1623358 populations.

Maize is the major food crops followed by rice, millet and wheat of the eastern hill people. Vegetables especially off season, tea, large cardamom and ginger are major source of income for the eastern hill people. Among the livestock commodities cattle, pig, poultry and goat are integrated with crop and horticulture farming systems. Cropping intensities under irrigated domain is 246% and under rainfed domain is 165 percent. In the eastern hills total food production is 463039 metric ton whereas the food requirement is 326296 metric ton with food balance of 136743 metric ton. There are sufficient production of milk (170506 mt), meat (22693 mt), egg (92634000 numbers), fruits (137285 mt) and vegetables (379556 mt) in the eastern hills.

4.2. Primary Information

Vegetables like cabbage, tomato, cauliflower, akabare chilli were mainly cultivated in the Pakhribas Municipality. Ginger was also produced substantially. The place is famous for akabare, ginger and cardamom. Since cardamom is not able to be dried in the solar drier, the farmers were inquired about the other possible produces which can be dried through solar dryers.

Table 6: Primary Data from farmers group

Items	Max selling price per Kg	Min selling price per kg
Ginger	65	40
Akabar	400	250
Cauliflower	60	25
Cabbage	16	8
Tomato	80	30

Source: Field survey, 2016

Farmers try to sell all the produces at once as they may go rotten, being perishable produces. In this effort they sold them even in lesser prices. The down price occurred when the overall production was high. They did not know about the drying technologies like solar drying. And even did not know about the subsidy they can receive. They opined that such knowledge about the drying is necessary for the farmers and could be very helpful in enhancing the product quality after being processed and enable for longer storage. Such get good market value. Subsidy from government is very necessary.

Apart from this the farmer made gundruk, sinki for the household use. The drying was in open sun drying and mostly, women perform these drying activities. The data of solar dryer showed that the district do not have solar dryer. There is a solar tunnel dryer on the research station of Pakhribas. Government institution provides subsidy on solar dryer through some pre qualified companies. This work is done according to the demand driven basis.

4.3. Prospects of Solar Dryer

- **Impact of Solar Dryers on saving of time required for dehydration:**

One of the benefits of Solar Dryer system compare to the sun drying is quick dehydration. It is estimated about 50 to 60 percent of the time is saved in solar dehydration compared to direct sun drying. But it cannot be generalized as exact time requirement for drying the products because it all depends on several factors like duration of sunny days (solar radiation), wind, humidity, types of solar dryers, moisture content of the products, sizes and thickness of the products sliced for drying purpose. Also it depends upon how it is spread in the tray for drying purpose. The same factors determined the timing of drying in case of direct sun drying.

Table 2: Time duration for the direct sun drying

S.N.	Items	Weight before	Weight after	Time for drying
1	Potato	1000 gm	140 gm	7-8 hour
2	Raddish	1000 gm	100 gm	9-10 hour
3	Tomato	1000 gm	100 gm	7-8 hour
4	Brinjal	1000 gm	170 gm	6-8 hour
5	Cauliflower	1000 gm	170 gm	8-10 hour
6	Cabbage	1000 gm	70 gm	7-8 hour
7	Carrot	1000 gm	120 gm	7-8 hour
8	Garlic	1000 gm	180 gm	6-7 hour
9	Ginger	1000 gm	130 gm	7-8 hour
10	Mustard green leaves	1000 gm	50 gm	4-6 hour
11	Bittergourd	1000 gm	120 gm	6-7 hour
12	Onion	1000 gm	120 gm	6-7 hour
13	Masyoura	1000 gm	420 gm	9-10 hour
14	Apple	1000 gm	130 gm	9-10 hour
15	Banana	1000 gm	140 gm	7-8 hour

Source: Centre of Rural Technology Nepal CRTN

Another thing to be noted is that there is possibility of products to be contaminated when the products are dried in open space. It would be difficult to protect the products from dirt and dust. Similarly the probability of products being spoilt is higher when the solar radiation is weak like during the cloudy day. The products are to be dehydrated within 6 to 7 hours otherwise it will rot. So when the products are contaminated or rot the nutrient content of the dehydrated products will be decayed. But in case of dehydrated products using Solar Dryer technology, it has been confirmed by many studies that the nutrient content of the products remain same as that of fresh products and probability of products being spoilt or contaminated is relatively smaller than in case of direct sun drying.

- **Impact of Solar Dryers on women's work load:**

All the activities relating to drying process are carried out by women. It takes many days to dry the products. Since the drying is done in the open space, it should be brought inside and kept in the airy place during the night, and also when there is no sun light, or when it rains. With the installation of Solar Dryer, women get some relief. They can dry the products easily. The dehydration is quick and takes 1 to 2 days in most cases. Moreover, it is not necessary to keep

the products indoor during the night or when there is no sunlight or when it rains (CRE field survey, 2012).

- **Internal market**

Dried produces, either in ordinary or mixed with some ingredients are highly popular in Nepal. Similarly some fermented dried vegetables (Gundruk, sinki, tama) are widely used all over the country in form of cooked vegetables, soups and chutneys. Likewise, dried spices and medicinal herbs are also extensively used in Nepal for preparing routine meals and medicines, respectively. Due to recent changes in lifestyle and work pattern, women now find difficulty in producing traditionally sun dried products in urban area. This situation allows for marketing of traditional food products from rural to urban and semi-urban areas. The growing number of dried food shops in almost every corner of market areas is an indication of their popularity among the native consumers. Lately trekkers and tourists have become the main consumer in dried fruits, which are processed in solar dryer. Solar dried products, eg. Apple slice, apricots and mangoes are heavily sold in department stores of Kathmandu and other big cities, which caters to the needs of foreigner and wealthy people. Besides fruits, some entrepreneurs have also started promoting sales of dried tomatoes, ginger powder, garlic powder and turmeric powder.

- **External market**

Several sun dried products eg., dried herbs, dried ginger, dried turmeric, dried cinnamon, dried vegetable seeds and tea are exported to India. Some vegetable seeds are also exported to Bangladesh and Pakistan. Dried mushrooms, the wild extic varieties from remote mountains, have also found market in India and England. At present, the marketing channels for the dried products are farmers, small traders and retailers. If solar dried products could be produced in larger quantity and marketing channels enlarged, they would easily find their way to international market.

Table 3: Sun dried products exported to India

Dried product/yr (MT)	1993-94	1994-95	1995-96	1996-97	1997-98
Dried herbs	28100	41700	40500	52600	43700
Dried ginger	23100	76900	47200	46500	36100
Dried turmeric	-	200	1100	2300	4000
Dried cinnamon	8900	3700	5800	10100	2500
Dried vegetable seed	-	700	2300	2300	400
Total	50100	123200	96900	113800	96900

Source: FNCCI,1999.Nepal and the world-A statistical profile. Kathmandu-FNCCI

4.4. Market Scenario of Drying Products

Most of the agricultural products are exported to the neighboring countries. Some agricultural products like Tea, coffee, spices are also exported to the countries of Europe. Because of the small size of export, the bargaining power of Nepali exporters is limited and weak.

Most part of the ginger is exported to India in the form of fresh ginger and processing is uncommon except poor quality dry (sun and smoke dried) ginger (Some major agricultural products exported to India are presented in Annex A).The quality of Nepalese ginger is rated quite good but due to poor post-harvest handling it fetches lower price in India. In the FY 2002/03 ginger was grown in 11480 ha and 140056 metric tons was produced.

Table 4:Export of Agricultural Commodities(NRs. In million) in year 2002/03

SN	Commodity	Export to India	Export to overseas
1	Dried Ginger	96.60	-
2	Dried Mushroom	-	3.68
3	Dried Vegetables	-	0.26

Source: HMG, 2004. Statistical information on Nepalese agriculture 2002104, His Majesty's Government of Nepal, Ministry of Agriculture and Cooperatives, Agribusiness Promotion and Statistics Division, Kathmandu.

The following table shows the internal market value of the dried product in urban place:

Table 5: Internal Market Price of Dried product

S.N	Product	Price per Kg (NRs)
1	Gundruk (Mustard)	675
2	Gundruk (Rayo)	509
3	Chilly	350
4	Akabare	1125
5	Masyoura(maas, Karkalo)	600
6	Masyoura (mung)	600
7	Mushroom	1540
8	Fish	1700
9	Kiwi	1250
10	Peach	870
11	Orange	880
12	Coconut	1190
13	Pineapple	900
14	Mango	880

Source: Field survey. 2015

- **Government subsidy on Solar Dryer**

Government provides subsidy through the pre qualified solar companies. 50 percent subsidy is being given for family size or small dryer of varied models whereas 70 percent subsidy goes with bigger size dryer bought for commercial purpose. The later is limited only for the rural areas and also for the community use only. Following are some solar dryers with their respective capacity, cost and granted subsidy:

Table 6: Solar Dryers with the respective capacity, cost and granted GON subsidy

Size	Capacity	Costs (Rs.)	Subsidy (Rs.)	Life Time (year)
Box type (Direct Type)	3 Kg	5000-6000	2500-3000	10 yrs
Flat plate type (Direct Type)	10 kg	14400 - 20000	7200-10000	
Mini Tunnel Dryer (Direct Type)	15 kg	26000-27500	10000	
Solar Tunnel Drier (Direct Type)	50 kg	155000	108500	

Source: Different capacity of Solar dryer distributed along with subsidy from 2061to2069 B.S. Solar Energy Component, AEPC.

4.5. Working Principle of Solar Dryer

Drying involves the removal of the internal moisture to the surface and then to remove this moisture from the surface of the drying material. The sun has been used for drying as long as humans have inhabited the planet and laying a product out in the sun to remove its moisture is known sun drying. When sun drying, the temperature of the surrounding air remains at ambient temperature, while the temperature of the product is raised by the direct absorption of solar radiation. Although sun drying is still by far the most common method of drying it does have several inherent disadvantages. The unprotected crop can be damaged by rain, contaminated by dirt and animals and/or eaten by birds and insects. Since the temperatures attained during sun drying are usually lower than in a solar dryer, drying times are longer. This usually results in poorer final quality because of color discoloration caused by enzymic and non-enzymic browning, and often because of the formation of moulds. In a solar dryer however the temperature of the air surrounding the product is raised above the ambient air temperature. Depending on the type of solar dryer, the temperature of the product may also be raised by direct absorption of solar radiation. The temperatures in a solar dryer are higher than in sun drying and this reduces the drying time and usually improves the final product quality. Crop losses and spoilage from rain and animals are prevented because the crop is protected within the solar dryer.

Solar dryer comprises three parts; in some types of drier these parts are distinct whereas in other these parts are in combined form. These three major parts of dryer are as follows:

i. Solar collector: converts the light to heat energy. Drying air upto 50 to 75 ^{o}C is sufficient for drying agricultural produces, so the solar collector heats the air. The solar collector further consists following parts:

   a. Black pata for absorbing the heat
   b. Outlet for easy exit of air
   c. Glass above the absorber

   The solar collector functions in two stages: firstly, converts the light to heat enrgy and thus raises the inside temperature and secondly reduces the moisture of the drying produces enabling for the safe storage.

ii. Drying chamber

   Here the produces are placed after processing (slicing etc.) on layers.The hot air flow from the collector to this drying chamber. The hot air heats the produces and takes up the moisture. In indirect type of dryer the air needs to be rise upto 50^{o} C to 75^{o} C. After 2 to 3 hour the trays need to be shuffled.

iii. Chimney: On the topmost pace is chimney, its main purpose is to alow the inflow of air into the chamber. The vapor released from the produces on the drying chamber exit from the chimney. In the case if the vapor is not able to release from the chimney the drying process gets halt the produces remains in the moistuned form and get rotten.

4.6. Construction Precaution

Following things should be considered while installing solar dryer:

- The area should not have tree, house and shade.
- The place must allow sufficient sunlight
- The dryer shiold be placed in north south orientation
- The ground should be same level, and ensure good drainage

4.7. Different Solar Dryers

Agricultural Engineering Division of Nepal Agricultural Research Council has done research work on solar dryer. So, following are the different solar dryers according to "Agricultural Engineering Technologies, 2015" booklet published from the engineering division:

- **Solar Tunnel Dryer**

This dryer is similar like green house. It accumulates the short wavelength of sunlight and converts to long wavelength due to this the heat can be retained for longer period inside of the dryer. The inside area of the dryer is black painted in order to absorb the heat and help to increase the inner temperature. The higher the inside temperature rises the moisture of the dried produces comes out as vapour. On the other side in the case of higher vaporization the exhaust fan helps in drawing out the vapor present in inside air. There is an inlet on the lower surface where the dry air comes in whereas for the vapor exit there is chimney on the upper surface of the dryer. This process continues till the days are sunny. Normally 50^{o}c to 60^{o}c is appropriate for drying the agricultural produces. If the temperature is higher than the quality of the produces deteriorates.

In Nepal the high capacity driers are not available. Nepal agricultural research council have built high capacity solar dryer with low cost materials. The temperature reaches to 55^{o}c and 120 to 150 kg produces can be dried at once.

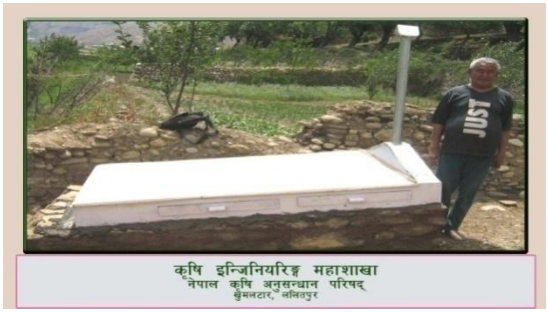
Benifits: The produces are dried using solar energy in large capacity. Capacity 150 to 200 kg protects the produces from dust dirt and insects. SilpolineUV stabilized plastic is used which is durable and thus it can be installed in fewer prices compared to other dryers. Built with the local bamboo. The chimney and the fan driven by solar helps to drive out the inside vapour. In large amount apple , mushroom , spices coffee, sisnoo, ginger and turmeric can be dried.

Other Dryers

- **Multi Rack Solar Dryer**

Solar ray passes through the iron mesh due to which the green vegetable can also be dried. No need to turn over the dried produces. There is no heat loss. Perishable produces like apple, vegetable, fish, mushroom can be dried Capacity of 25 kg can be dried within 1 to 1.5 days. This type of dryer is applicable for small farmer and in remote places.

- **Flat Type Solar Dryer**



This type of dryer can be built in low cost using local materials. Maximum inside temperature is 50^0C therefore quality of the dried produces is retained. It is of 10 kg capacity and the produces are dried within 2 days. Perishable produces like apple, vegetable, fish, and mushroom can be dried. It is applicable for small farmer and remote area.

- **Mix Mode Solar Dryer**:

This dryer uses solar and biomass for drying the fish, meat and other agri produce in one day. Its capacity is 20 to 25 kg capacity. Generally, for drying 1 kg fish consumes 1 kg fuel wood. It is useful for commercial purpose in drying fish, meat and agricultural produces.

CHAPTER-5. CONCLUSION AND RECOMMENDATIONS

4.1. Conclusion

Majorities of the farmers sell their agriculture products immediately after harvest at low price with few value additions. So the farmers who are involved in producing perishable commodities are compelled to sell their produce immediately after the harvest. In such process sometime they even have to sell in low price whenever production exceeds the demand. They do not get proper price because of high overall production. Drying is one of the important post harvest method. The introduction of effective, efficient and affordable solar dryers can offer a promising alternative to reduce the tremendous postharvest losses with value addition of the products. The present market situation also signifies the prospect of solar drying technology. This indeed would pave the way of rural enterprise development through small scale processing industries based on solar drying technology.

4.2. Recommendations

- The farming population has very limited access to the technologies particularly in case of driers. Thus there has been limited use of driers for agro processing business despite its high potentialities Also; it is yet to develop the habit of consuming the dried agro-products. Thus along with promotional activities of Solar dryer through subsidy, technical backstopping and massive consumer awareness raising program is necessary to create market for the dried products.
- Proper dissemination is necessary where cash crops are grown in substantive amount. Therefore, it is necessary to aware them about it advantages and proper use of these devices. Farmers should be made aware about the appropriate post harvesting method and technologies.
- The technical improvement is necessary; the Capacity of the drier needs to be increased and should be affordable to the farmers. Researches should be done for the betterment. Therefore coordination between different stakeholders is necessary, as in this alliance the appropriate technology can reach in the demand area. Research Academic and Government, NGO and Private sector coordination is important.

- Government provides subsidy on solar dryer, but the process is tedious and still the farmers cannot afford it. Blanket approach to subsidy rate (same rate to all), irrespective of his or her residence and economic status, is not appropriate. Priority should be given to the people from the remote region and for those belonging to lower economic group. The technological backstopping and monitoring need to be carried out regularly, AEPC should provide fund for technical backstopping and monitoring works.
- As standalone subsidy program is not adequate for the promotion of the technologies with higher performance. Integrated approach is recommended. The program should be integrated with training on food processing; microfinance facilities and other technical backstopping. The promotional program should be integrated with agricultural development of the government, with particular focus on agro processing business.
- Similarly, it is recommended to provide subsidy for commercial models of dryers not only for the community use but also for the individual ownership in both rural and urban Which will help in Promotion of agro processing business based on solar dryers will definitely help to generate income and employment opportunities in both rural and urban areas thereby helps to alleviate poverty indirectly.
- Labeling and packing of the products should be maintained according to the national or international standard.

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ANNEXES

ANNEX-A Export of Major Agricultural Commodities

(NRs in million)

Year	Cardamom	Ginger	Dried Ginger	Vegetables
1992	113.70	84.60	21.90	0.0
1993	90.74	53.90	22.39	2.33
1994	81.33	40.77	12.76	0.0
1995	64.44	42.54	35.99	10.58
1996	86.81	61.00	20.97	1.20
1997	76.10	51.33	16.96	2.33
1998	80.95	59.44	14.75	3.38
1999	82.59	53.68	14.54	3.86
2000	70.77	51.25	18.88	2.67

Source: Ministry of finance (MOF) Economic Surveys of different years

ANNEX-B Questionnaire

प्रश्नावली

नाम	जिल्ला	ठेगाना

कुन बाली लगाउनु भएको छ

नगदे बाली : कफि, च्याउ, अन्य :

तरकारी खेती :

फलफुल :

कति क्षेत्रमा : .....

कति उत्पादन हुन्छ ? .....

बजार भाउ सम्बन्धमा

क्र.स.	तरकारी र फलफुल	बजार भाउ	बजार लैजाने साधन र खर्च	उच्च बिक्रि मुल्य (रु प्रति केजी)	कम बिक्रि मुल्य (रु प्रति केजी)

बजारमा लैजान ढिला हुदा के कति नोक्सानी बेहोर्न पर्ने हुन्छ(आर्थिक)

-

अन्य केही उपाय लगाउनुहुन्छ नोक्सानी जोगाउन

-

उत्पादित कृषि सामग्री सुकाउन के प्रविधि प्रयोग गर्नु हुन्छ

-

कति समय लाग्छ सुकाउन ?.....

के के समस्या आइपरेका छन यसरी सुकाउदा ?

-

सोलार ड्रायर बारे जानकारी छ ?.....

यस सम्बन्धि सरकार द्वारा अनुदान सहयोग बारे थाहा छ, छ भने कसरी थाहा पाउनु भयो, छैन भने कसरी प्रभाव कारी बनाउन सकिन्छ ?

सरकारी अनुदान प्राप्त गर्नु भएको छ केही सम्बन्धि र अरु कसैले प्राप्त गरेको जानकारी ?

-

अनुदान प्रकृया कति सहज छ ?

-

समयमै प्राप्त हुन्छ अनुदान ? ……..

के सुधार गर्न उचित देखिन्छ ?

-

सोलार ड्रायर मा दिइने अनुदान पर्याप्त छ ?.....

अनुदान सहयोग वृद्धि या कम गर्दा सहज होला ? …….

ANNEX –C Photographs

Interaction with Farmers

Solar Dryer in Agricultural research Station pakhribas

Some of the dried Products available in Department Store

Dried Akabare chilly

Dried Chilly

Dried Nuggets

Dried Papaya

Dried Kiwi

Dried Mango

Dried Coconut

Dried Peach