A need assessment for designing sustainable solar drying technology in Nepal and Bhutan

Pia Otte
Bivek Baral
Ananta Aacharya
Karma Yangdon
Tshewang Lhendup
Martin Andersson
Elina Andersson
Henrik Davidsson

RURALIS – Institutt for rural- og regionalforskning

Rapport nr 8/2022
ISSN 1503-2035

RURALIS – Institutt for rural- og regionalforskning
Universitetssenteret Dragvoll
N-7491 Trondheim
Telefon: +47 73 82 01 60
Epost: post@ruralis.no

Rapport 8/2022

Utgivelsesår: 2022 Antall sider: 44 ISSN 1503-2035

Tittel: A need assessment for designing sustainable solar drying technology in Nepal and Bhutan
Forfatter: Pia Otte, Bivek Baral, Ananta Aacharya, Karma Yangdon, Tshewang Lhendup, Martin Andersson, Elina Andersson, Henrik Davidsson
Utgiver: Ruralis
Utgiversted: Trondheim
Prosjekt: SolarFood: Reducing post-harvest losses through improved solar drying
Prosjektnummer: 6614.00
Oppdragsgiver: Vetenskapsrådet Sverige
Oppdragsgivers ref.: VR2020-04071

Kort sammendrag

Nepal og Bhutan er to land som er preget av høye tap på avlinger etter innhøsting på grunn av mangel på lagringsfasiliteter og konserveringsteknologi tilpasset lokale forhold. Det internasjonale forskningsprosjektet *SolarFood* har som mål å utvikle en teknologi som muliggjør soltørking med kort tørketid, som produseres lokalt og som er sosialt akseptert av småbønder i disse landene. Denne rapporten presenterer en behovsvurdering for soltørking i Bhutan og Nepal. Vi gjennomførte totalt 80 strukturerte intervjuer med bønder i de to landene for å identifisere (1) relevante avlinger for soltørking, (2) eksisterende tørkepraksis og (3) for å gi anbefalinger for videreutvikling og implementering av soltørkere gjennom prosjektet *SolarFood*.

Stikkord
Solar drying, agriculture, technology adoption, farmers, Bhutan, Nepal

Preface

This report was written as part of the *SolarFood: Reducing post-harvest losses through improved solar drying* project. *SolarFood* is an international research project led by Lund University in partnership with Ruralis - Institute for Rural and Regional Research, Royal University of Bhutan, and Kathmandu University. It is financed by the Swedish Research Council (Vetenskapsrådet) (project number VR2020-04071).

The overall aim of the *SolarFood* project is to develop solar dryers with short drying time, that are produced locally and are socially accepted by smallholder farmers in Bhutan and Nepal.

This report represents a major deliverable of work package (WP) 1 entailing a study of the socio-economic and cultural constraints and possibilities as well as the scope of entrepreneurship in solar drying. The report presents a descriptive overview and analysis of work carried out within WP1 to address the two main objectives; 1.) Mapping of existing (indigenous) crop drying practices; 2.) Identification of drying needs and end-users' preferences for dried products.

This document serves as a public report for relevant stakeholders nationally and internationally and is therefore written in English. In addition, the report provides an overview of relevant societal information to inform the technical development of improved solar dryers in the project, and guidelines for further social science data collection in the project.

We would like to thank all farmers and local assistants who participated in the interviews and Dr. Gunn Turid Kvam for conducting a quality check of this report. We would also like to thank Dr. Richard Helliwell for language proofreading of an earlier version of this report.

Pia Piroschka Otte (editor)

Trondheim 16.09.2022

Cover photo: Sonam Dorji, JNEC-RUB, Bhutan

Table of contents

List of figures

List of tables

Sammendrag

Nepal og Bhutan er to land med en stor rural befolkning og hvor landbruk er den viktigste sysselsettingen og inntektskilden for flertallet av befolkningen. Imidlertid er begge land preget av høye avlingstap etter innhøsting på grunn av mangel på lagringsfasiliteter og konserveringsteknologi tilpasset lokale forhold. Dermed er tap av en stor andel av produksjonen en viktig barriere for å oppnå matsikkerhet og bygdeutvikling i Bhutan og Nepal.

Det internasjonale forskningsprosjektet *SolarFood* har som mål å utvikle soltørkere med kort tørketid, som produseres lokalt og som er sosialt akseptert av småbønder i Bhutan og Nepal. Denne rapporten presenterer en behovsvurdering for soltørking i Bhutan og Nepal som én hovedleveranse av *SolarFood*-prosjektet.

Vi gjennomførte totalt 80 strukturerte intervjuer med bønder i Bhutan og Nepal for å identifisere (1) relevante avlinger for soltørking, (2) eksisterende tørkepraksis og (3) gi anbefalinger for videre utvikling og implementering av soltørkere gjennom prosjektet *SolarFood*.

Resultatene viser at kardemomme i Bhutan og eple i Nepal er relevante vekster for kommersialisering etter soltørking. Intervjuene viser også at dagens tørkepraksis i begge land er lite effektive, kostbare og kan være helseskadelige.

Rapporten konkluderer med 6 anbefalinger for videre utvikling av soltørke-teknologi. Disse inkluderer (1) nødvendigheten av optimalisering av soltørkere når det gjelder tørketid og produksjon av soltørkere, (2) teknologivurderingsstudie i begge land for å identifisere eksisterende soltørketeknologier og design, (3) dybdestudie av faktorer som hindrer bruk av eksisterende soltørketeknologi, (4) implementering av soltørkere via bønders organisasjoner eller gjennom direkte samarbeid mellom bønder. (5) Behovsvurdering innenfor husholdninger for å adressere kjønnsdynamikk som er relevant for teknologiimplementering. (6) Opplæring i design og bruk av soltørkere via lokale samarbeidspartnere.

Summary

Nepal and Bhutan are two countries with largely rural societies where agriculture is the main source of income and employment for the majority of the population. However, both countries are characterized by high levels of post-harvest losses due to the lack of storage facilities and preservation technologies adapted to prevailing conditions. Thus, loss of agricultural produce is a key barrier for achieving food security and rural development goals in Bhutan and Nepal.

The international research project *SolarFood* aims to develop solar dryers with short drying time, that are produced locally and are socially accepted by smallholder farmers in Bhutan and Nepal. This report presents the first part of a needs assessment for solar drying in Bhutan and Nepal as a deliverable of WP1 of the *SolarFood* project.

We carried out 80 structured interviews with farmers in Bhutan (65) and Nepal (15) to identify (1) relevant crops for solar drying, (2) existing drying practices and (3) provide recommendations for further development and implementation of solar dryers through the *SolarFood* project.

The results show that cardamon in Bhutan and apple in Nepal are relevant cash crops for solar drying. The interviews also show that current drying practices in both countries are ineffective, costly and can be damaging to health.

The report concludes with 6 key recommendations for further solar drying technology development. These include; (1) necessity for optimization of solar dryers in terms of drying time and production; (2) technology assessment study in both countries to identify previous solar drying types and designs; (3) in depth study of existing adoption barriers of previous solar dryers; (4) implementation of solar dryers via farmers' cooperations and associations, (5) intra-household needs assessment to address gender dynamics relevant for technology implementation; (6) training on the design, and use of solar dryers via local partners.

1. Introduction

1.1 Aim of the study

Nepal and Bhutan are two countries with largely rural societies where agriculture is the main source of income and employment for the majority of the population. Both countries are characterized by high levels of post-harvest losses due to the lack of storage facilities and preservation technologies adapted to prevailing conditions (Wangmo and Dendrup, 2021; Bhattarai et al. 2013; Tiwari et al. 2020). These post-harvest challenges are a key barrier for achieving food security and rural development goals in Bhutan and Nepal (GC and Ghimire, 2019).

In both countries smallholder farmers[1] carry out traditional food drying practices that can reduce post-harvest losses significantly. However, these practices are inefficient and have negative health and environmental consequences. Fire, smoke, and shade drying is practiced in Nepal. The limited efficacy of open drying techniques leads to mold and fungi attacks on a large fraction of the harvest. Furthermore, drying practices that make use of biomass such as firewood lead to increased deforestation and smoke production. Hence, an improved drying system based on solar energy that can dry crops safely, affordably, and quickly could provide a solution to these problems.

The international research project *SolarFood* aims to develop locally adapted solar dryers for crop drying with short drying times with smallholder farmers in Bhutan and Nepal. The aim is to develop solar dryers that will provide a low-cost, energy-efficient and hygienic method for turning agricultural produce into stable, storable, nutritious and more profitable food products. The project combines knowledge from the fields of heat and mass transfer, solar energy engineering, social sciences, rural development and sustainability science as well as entrepreneurship to develop solar dryers that are contextually sound. The research methodology follows an iterative process actively involving smallholder farmers in the technology design process. Through this interactive engagement process we aim to develop improved solar drying methods for effective processing and preservation of crops thus contributing to improving farmers' livelihoods, rural development and local food security and nutrition. The report analyzes the local agricultural context in both countries by, (1) identifying relevant

[1] In general, households with small farmland and insufficient land to grow food at a large scale commercially are categorized as smallholder farmers in this report.

crops for solar drying, (2) identifying existing drying practices and (3) providing recommendations for further technology development and implementation.

The report is structured as follows: Chapter 1 provides an introduction to the study and describes the agricultural context in the case countries. Chapter 2 provides an overview of the technical and socio-cultural aspects for solar drying development and adoption. Chapter 3 presents the methodological approach of the study followed by the results in Chapter 4. Chapter 5 concludes with recommendations for further development of solar dryers in both countries.

1.2 The agricultural context in Bhutan

Bhutan is located on the southern slopes of the Eastern Himalayas with a geographical area of 38,394 km2 and a population of 779,900 people (Worlddata, 2022a). Bhutan is a largely rural society with minimal use of advanced (mechanized) technologies in agriculture and a lack of storage facilities and preservation technologies for post-harvest processing and storage. Hence, most farmers experience heavy losses during the post-harvest season. One of the main objectives of Bhutan's agricultural sector is to boost agriculture production for self-sufficiency, nutritional security, and income generation. Bhutan currently depends on food imports from India and other countries to meet its populations food needs, and the level of imports is expected to increase in the future. The agricultural sector employs 49.7% of the population but contributes a disproportionately low 15.8% to the country's GDP (MoAF, 2021). This indicates that the country's domestic food production is relatively low and unable to meet current demand. However, according to the statistical yearbook, (NSB, 2021:93), "Agriculture practices have changed tremendously over years from subsistence basis to commercial agriculture. Until decades ago, farmers produced for consumption with little or no marketable surplus". Due to favorable climatic zones, a large variety of vegetables and crops are cultivated in various land types present in Bhutan which includes both wetlands and drylands, and in kitchen gardens, and orchards. The most common seven commodities grown in Bhutan are; 1) cereals, 2) oilseed, 3) pulses, 4) vegetables, 5) fruits and nuts, 6) roots and tubers, 7) and spices. Nonetheless, fruits like banana, pineapple, papaya, mango, guava, and cucumber are on the deficit side.

Today, most villages, despite being located in rugged mountainous terrain; have gradually incorporated modern agricultural technologies to escalate their production with better access to the market. In the past, the majority of farmers used integrated subsistence farming and low-yielding crops; to only feed their families with minimal products for sale. They were exclusively dependent on indigenous knowledge and traditional agricultural practices. Similarly, they did not have access to adequate market opportunities leading to limited investment in developing value-added products. Now the farmers have gradually begun to orient to more commercially driven activities including producing high-value cash crops. This enables them to produce agricultural/dairy products to meet the demand from the cities and develop export markets for producing including apples, oranges, areca nuts, hazelnuts, and cardamom. For commercial purposes, some parts of Bhutan do grow ginger, chillies, red rice, and vegetables. However, it is evident that Bhutanese farmers find it very challenging to compete globally due to the small scale of Bhutanese farming, and the broader agricultural and socio-economic conditions experienced in Bhutan.

1.3 The agricultural context in Nepal

Nepal is located mainly in the Himalayas with parts of the South located in the Indo-Gangetic Plain. It has a geographical area of 147,180 km2 and a population of 29,675 million people (Worlddata, 2022b). Food security has become a central topic of the national agenda in Nepal (USAID, 2021). According to the 2016 Nepal Demographic and Health Survey (DHS), 20% of households are mildly food insecure, 22% moderately food insecure, and 10% severely food insecure, resulting in a total of 4.6million people suffering from food scarcity and malnutrition (IPUMS, 2016). The Government of Nepal has focused on increasing agricultural production by encouraging youth participation in farming (Khanal et al. 2021). The seasonal production of agricultural commodities has created a supply-driven market structure with excessive production during the season and almost zero production during the off-season (Dhital, 2017). As a result, farmers are compelled to sell their products at low selling price due to lack of food preservation and storage facilities. Post-harvesting losses of highly perishable agricultural products are central problems especially in rural areas of Nepal. Fruits and vegetables are easily contaminated because of their high moisture content (more than 80%). The postharvest loss is around 20-44% for fruit and vegetables and can reach up to 50% in extreme cases (Faqeerzada et al. 2018). Moreover, the transportation from the farmyard to the collection center, onto wholesalers and the retailer market causes significant losses. For instance, while exporting to the Indian market; improper handling and transportation share about 15-36 % losses (Bhattarai, 2018). As a result, farmers are compelled to sell their produce in the local market or to middlemen at a low price. Many agricultural products are being wasted due to a lack of knowledge of appropriate food preservation techniques and transportation difficulties. There is an urgent need for simple, inexpensive, and environment-friendly food preservation techniques (Poverty Alleviation Fund, 2009).

2. Socio-technical context for solar drying

2.1 Solar drying technical developments

Drying food to increase its shelf time is an ancient practice. The main purpose of drying is to reduce the water activity in the food stuff. The water activity of a food is defined as the ratio of the partial water pressure for the food stuff compared to the partial pressure for free water (Scott, 1957). Reducing the water activity in the food means that less water is available to be used in chemical processes (Rahman 2007) reducing the ability of bacteria, yeast, and mold to proliferate. Water activity is measured as a unitless number between 0 and 1. It is often considered that a water activity level below 0.7 is safe for long term storage of the food (Phinney et. al. 2015, Phinney 2019).

There are many factors affecting the drying rate of food. We can identify 4 main factors that are crucial to address for technology development. These include (1) geometry/size, (2) temperature, (3) humidity and (4) air velocity. Table 1 describes the relation of these factors on the drying rate.

Table 1: Factors affecting drying rate of food

Geometry / size	A large surface area on the food gives a large area from which the water can evaporate from. A thin layer of food also has a shorter distance from the centre to the surface where the drying takes place, (Enachescu 1995).
High temperature	A high air temperature gives more energy to the fruit. This will increase the drying rate for the food as there is more energy available to drive the evaporation (Enachescu 1995).
Relative humidity	A low relative humidity in the air surrounding the food means that the air has higher capacity to receive moisture from the food (Enachescu 1995).
Air velocity	A higher air velocity means higher heat transfer rates and a higher potential to remove moist air from air surrounding the food (Phinney 2019).

One of the more common ways to increase temperature and at the same time reducing the relative humidity for the air surrounding the food is to place the food in a dryer. This dryer can be powered by a vast number of energy sources. However, one source that has caught a lot of attention is the sun. Solar drying has been around for a long time. Many different types have been tested and evaluated. The dryers can be divided into direct or indirect dryers and passive and active dryers. Mixed mode dryers are also possible to construct (Leon et. al 2002). The direct solar dryers have a transparent cover that allows the solar radiation to shine directly on the food while the indirect dryers heat air in a solar collector part and before transferring this heated air to a drying chamber where the food is placed (see Figure 1). The active dryers are equipped with a fan for moving the air while the passive driers rely on natural forces such as wind and/or air buoyancy to drive air movement, (Hii et al 2012).

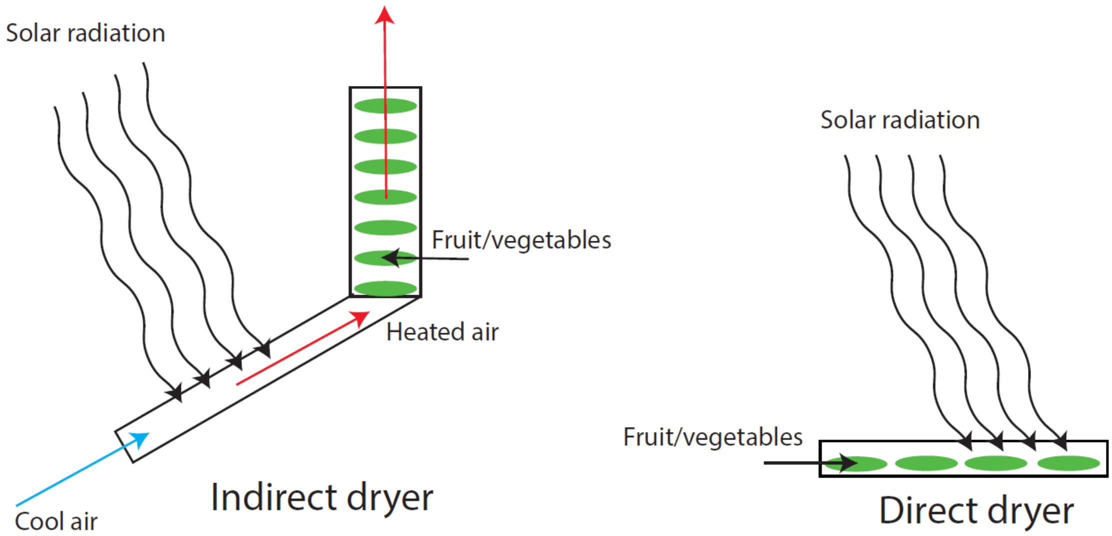


Figure 1: Indirect and direct solar dryer

Direct solar dryers are reported to give a lower quality dried food product in comparison to indirect and mixed mode dryers. Indirect solar dryers have also been found to produce a higher quality food product when compared to mixed mode dryers (Kumar et. al 2016). The indirect solar dryers are also known to preserve vitamins better compared to direct solar dryers (Udomkun, 2020). The active solar dryers using a fan offers a more controllable system than the passive dryers. However, the need for fans and electrical consumption can lead to a more costly product.

Heat exchangers are equipment that is used for the transfer of heat between two or more fluids at different temperatures. Various types of heat exchangers have been developed such as shell-and-tube, plate and double pipe heat exchangers (Sundén, 2012). They have a broad utility and use cases, for example being used in power plants, chemical industries, cars, air-conditioning, and in heat pumps. In plate heat exchangers, heat is primarily transferred by convection and conduction from a hot fluid to a cold, separated by a metallic wall. In the context of solar drying, heat exchangers can be used to pre-heat the incoming air with the outgoing air (e.g, the warm humidified air leaving the solar dryer). The sizing and design of heat exchangers is complicated and must account for pressure drop, convective heat transfer, estimation of the thermal performance and economical issues. Heat exchangers may be classified by 1) how the transfer process occurs, 2) compactness (area-to-volume ratio), 3) design principle, 4) flow process and 5) mechanism for the heat exchange (Sundén 2012).

2.2 Socio-cultural factors for solar dryer development and adoption

Agricultural technology and innovation are not socially neutral. Yet, efforts to development and disseminate such technologies have historically tended to overemphasize issues around technical efficiency and performance, without properly understanding the socio-economic and cultural context in which technology use is embedded. Multiple and intersecting social categories such as gender, age, class and race/ethnicity typically shape resource access, rights and responsibilities, priorities, needs and challenges among individuals and groups in rural societies (Quisumbing et al et al. 2014). As such, social norms and structures of power strongly influence "who does what, under what conditions, using what means, and to what ends" (Tarjem et al. 2021:1). Nevertheless, there has for long been a tendency to pay inadequate attention to such structures in the design, implementation and evaluation of agricultural technologies.

Failing to address intersecting social factors in technology design and development may not only contribute to low levels of technological adoption, but may also inhibit the intended outcomes. At worst, it may even bring negative impacts to particular groups, such as by increasing labour burdens, displacing important resources and opportunities and/or reinforcing unequal control and ownership of resources (Tarjem et al. 2021, Otte et al., 2018). Conversely, if new technologies are developed to target the strategic needs of disadvantaged groups and disseminated alongside complementary interventions, such technologies may contribute to transforming unequal power structures (Tarjem et al. 2021).

Examination of relevant socio-economic and cultural aspects forms the backbone of the project and is expected to provide crucial contextual inputs for developing locally adapted and contextually appropriate solutions for food preservation.

3. Methodology

3.1 Research design Bhutan

A convenience sampling method was used to investigate how Bhutanese rural smallholder farmers typically carry out their daily farming activities to produce and/or dry fruits and vegetables for a personal usage or market sale. The interviews were conducted between July and October 2021. The questionnaire can be found in Appendix 1.

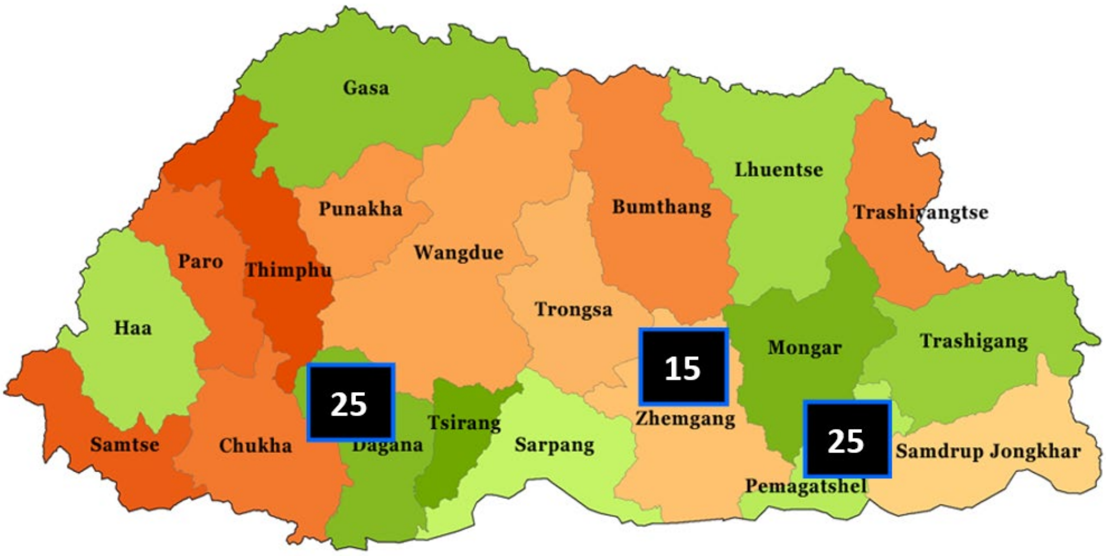


Figure 2: Administrative map of Bhutan with number of respondents across the three selected regions.

The information was collected in person by visiting households in three selected regions, Dagana, Pema Gatshel and Zhemgang. The selection of each region is justified as follows. Dagana was chosen because it produces the most cardamom of any region in Bhutan and cardamom was identified as a potential target crop for solar drying by the Bhutanese research team. Pema Gatshel was chosen because it is the area where the Bhutanese research team is based. It is an agricultural area, and it is planned that a solar dryer prototype will be tested in this region. Zhemgang was chosen because it has a strong presence of farmer cooperatives, one hypothesis is that these cooperatives could assist in supporting the adoption and implementation of new solar dryer technologies. A total of 65 farmers were interviewed across all three regions (see

Figure 2). Due to COVID protocols and restrictions, instead of research assistants, locals were hired to collect data in the identified villages in Bhutan.

3.2 Research design Nepal

In Nepal we carried out structured interviews with 15 farmers in the Mustang region. The region is known for apple cultivation, and apples have been identified by the Nepalese project team as a potential crop for solar drying. Apples have high nutritional and commercial values among farmers in the high mountain regions of Western Nepal. Out of more than 50 districts growing apples, 12 districts cultivate apples at a commercial scale. Globally, more than 7500 varieties of apples are commercially grown, processed, and consumed on a large scale (Simmonds and Howes, 2015). Red delicious, Royal delicious and Golden delicious are the most popular among Nepalese farmers. The majority of apples are consumed fresh, although some are processed into juice, dried apple slices, and brandy products.

Mustang is located in the Trans Himalayan region in the Northern part of Gandaki province and is famous for apple cultivation (Figure 3). The climatic conditions in Mustang are cool and semi-arid and well suited for apple farming. For decades, apple production in Mustang has been hindered by low productivity and lack of marketing networks to sell the product in nearby cities. However, the situation has changed due to the construction of a road linkage that connects Jomsom to Beni and then to Pokhara, a main tourist destination (Nepali Headlines, 2019).

Figure 3: Map of Nepal pointing Mustang District (Rijal, 2021)

Mustang has a total active apple productive area of 415ha with production volumes of 5188Mt[2] (MoALD, 2019). Historically apple farming first began in Kaligandaki river basin, however, the adoption of commercial scale production methods and apple varieties started in Marpha (popularly known as the apple capital) after 1960s (Organic Farm Nepal, 2022). Besides apples, Mustang is a famous tourist destination, which adds value to apple cultivators because of the booming domestic market for fresh as well as dried apple products. The regional context, including its socio-economic status, commercial apple farming sector, access to different marketing channels, drying applications, and possibilities of drying businesses has not been studied following the establishment of the road linkage from Jomsom to Beni and then the famous tourist destination Pokhara. Thus, the study was carried out in Jomsom and the surrounding area rather than other apple-growing districts.

The rough terrain of the high mountain regions isolates these regions from infrastructure such as transportation links to major cities, storage, and irrigation facilities (MoAC, 2011). The seasonal production has resulted in peak supply at low prices and minimum supply during the lean season. Apart from these issues, improper post-harvest management practices while grading, scaling, and transporting causes a significant amount of post-harvest loss. The total post-harvest loss for apples was estimated to vary between 40% and 44% (NARC, 2019). Most losses occur during transportation, especially from the farmyard to the collection center and then to retailers. The transportation losses vary crop-wise but account to 35% of total postharvest loss for apples (Dhital, 2017). The primary reasons for these losses are road conditions, mode of transportation, cold storage deficiency, and improper handling. Dried apples are more resistant to damage and could overcome these problems.

Interviews with farmers were conducted in December 2021. The questionnaire included information on socio-economic background, the scale of farming, drying application, and marketing channel for cash crops, especially for apples (see appendix 2). In total, 15 households were interviewed with informants from multiple ethnic groups, religions, and cultures to obtain a more representative sample. Since the respondents were illiterate, the questionnaire was conducted as a structured in-person interview in Nepali. An original report based on the interview data was published by

[2] Metric ton.

Kathmandu University and the result and discussion part in this report is based on this (see Baral and Aacharya, n.d).

3.3 Methodological limitations

Due to the long lasting Covid 19 pandemic it was difficult to collect a larger amount of data. International travel was not possible and in addition there were several national restrictions for citizens in both countries. Hence, some of the interviews were carried out by locals living in the regions coordinated by the researchers in Bhutan and Nepal electronically. This limited the amount and quality of empirical data collected. However, the data provides first insights, which will be built upon in the next data collection phase planned to take place between September and October 2022.

4. Results

The following sections provide a description and analysis of the results from the interviews conducted in Bhutan and Nepal. The results are structured for each country into 1) socio-economic background information of the farmers, 2) major identified crops grown for commercial use and own consumption, 3) identification of existing traditional drying practices.

4.1 Results Bhutan

Socio-economic background of farmers

A total of 65 farmers were interviewed in Bhutan, including 15 farmers from Dagana, 25 from Pemagatshel and 25 from Zhemgang. One of the common challenges that rural populations face today in Bhutan is a high rate of rural-urban migration like in many other low-income countries. Hence, the majority of farmers in the villages are older than 40 years, because the young have largely left for towns/cities to work or study. The average age of respondents is 40. Most of them have been in farming for the past 20 years. All interviewed farmers were primarily subsistence farmers, who sell surplus production. On average, each farmer holds 5 acres of wet and dry land, with the average household size being 5 members. The husband is usually the principle household decision-maker regarding the decision to purchase and sell goods and commodities. About 64% of the interviewed farmers are members of agriculture cooperations mainly in the Zhemgang region.

Major relevant crops

Figure 4 shows cash crops grown by the farmers interviewed. The main cash crops are cardamom, ginger, orange, chilli, cucumber, onion, garlic, tomato, potato, pineapple, mango, groundnut, and hazelnut. The majority (92%) of the farmers grow cardamom as a cash crop. Figure 5 shows the variety of food crops grown by the farmers for own consumption. These include maize, paddy, potato, vegetables, ground apple, beans, cassava, and buckwheat.

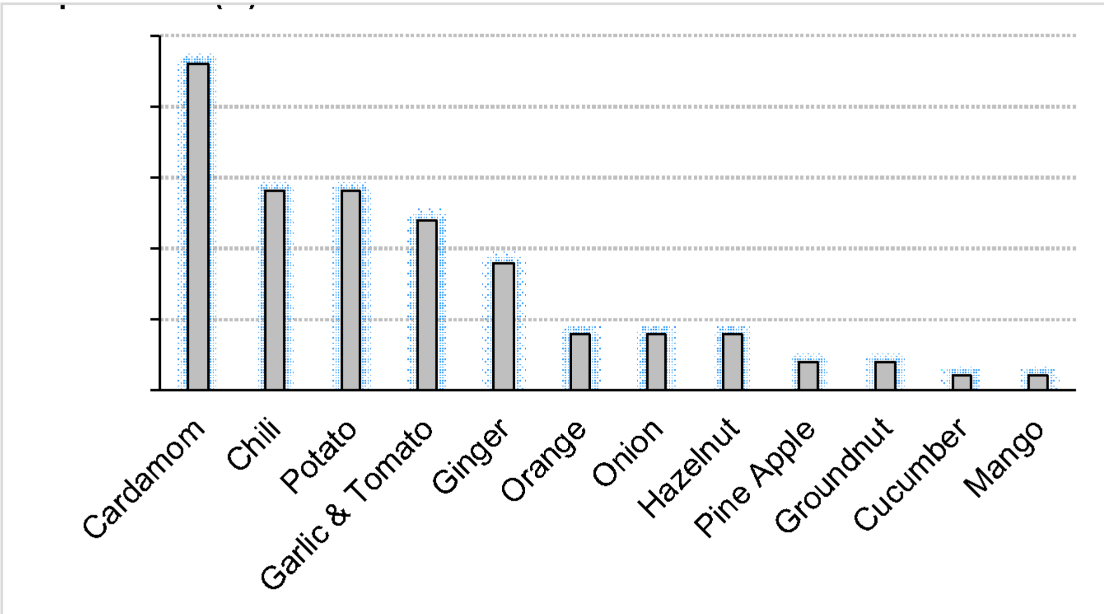


Figure 4: Major cash crops grown by the farmers

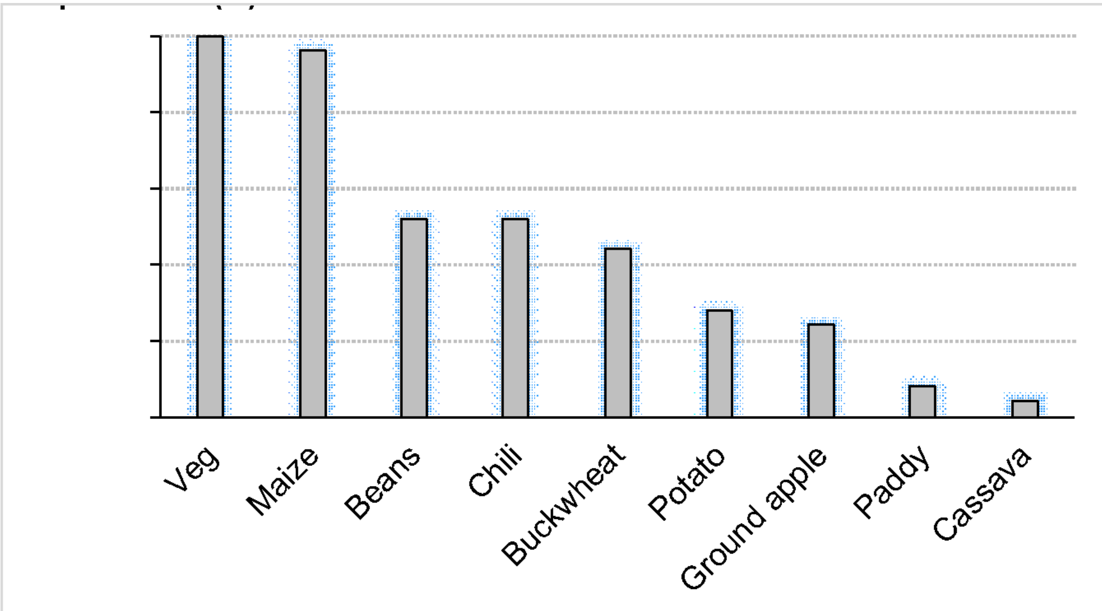


Figure 5: Major food crops grown by the farmers for self-consumption

Common vegetables that the farmers produce for both commercial and self-consumption are chili and potato. The main source of income and the principal fruit grown is cardamom. The least the farmers produce for consumption is cassava and paddy (Figure 5).

Existing traditional crop drying practices in Bhutan

The majority of farmers dry fruits. 56% of total respondents stated that they dry fruit directly in the sun or make use of smoke drying; 44% did not indicate whether they dry crops. About 39% of the informants' dry cardamom and vegetables, 16% dry cardamom only, 12% dry vegetables and fruits, 33% of them did not indicate which crops they dry. They also dry all types of vegetables they grow. All interviewed farmers report that the current open drying system is problematic because it results in damages to the products by fungal growth, insects, and rain. The drying seasons for farmers are in the autumn and winter.

According to an article in BBS (Bhutan Broadcasting Service, 2021), the farmers in Pemagatshel district have been growing cardamom since 2012, and ever since the farmers have struggled without proper equipment to dry cardamom, and currently, they use locally made dryers. These smoke dryers are time-consuming to operate and affects the farmers health negatively due to smoke production.

The farmers report during the interviews that they burn almost a truckload of firewood to dry cardamom every season contributing to deforestation. Additionally, the smoke spoils the quality of the products. Moreover, the majority of interviewed farmers (85%) agreed that it is crucial to dry their farm produce. 44% of farmers dry their farm produce for cash and 40% of them dry for household consumption. There is some evidence to suggest that drying is a somewhat gendered activity with 24% of respondents reporting that only women carried out drying and 33% stating drying is carried out by both men and women. However, drying was primarily an activity carried out by whoever was available at home and undertaken by both men and women.

In terms of training, 68% of the respondents had not received formal training whereas 32% of the farmers had attended training.

Figure 6: Commercial electric dryer in Zhemgang

The most common and prevailing drying practice is a local oven dryer or firewood drying. The local oven dryer is made up of stone and mud with a three-sided wall and one open door to supply the fire. The standard height of the oven is 1.5 m, which is covered by 1.5 to 2m net wire mesh over the fire where capsules are laid on it to dry (see Figure 7). A roof, 1-metre high and arched with simple CGI (Corrugated galvanized iron) sheets is placed above the oven and wire mesh. The farmers report that they change the net wire mesh every year as it gets burnt by fire due to excessive heat. Some even use double-layered mesh to control the dropping of capsule seeds into the fire. Some even make temporary ovens with wooden posts prior to or at the time of harvest. After drying is completed, they dismantled it.

Figure 7: Cardamom drying using firewood

The amount of time farmers spend to dry cardamom depends on the size of the capsules (big and small) and the amount of heat produced by the firewood. Bigger size capsules (cardamom) take 24 hours to dry whereas smaller size capsules take only 12 hours. In one lot, they dry approximately 30 to 50 kg which is determined by the size of the net and oven. After drying, farmers acquire approximately 10 kg cardamoms representing 2-3 times less than the fresh cardamom.

Some informants report that in the past there was a group of farmers who received free electric dryers on a trial basis, but they were found to be uneconomical as the drying cost was more than the selling price of the dried crop. 98% of the respondents are looking for new drying technology and 47% of the farmers are also willing to invest in new technology. This clearly indicates that cardamom growers wish for better dryers in their locality.

4.2 Results Nepal

Socio-economic background of farmers

15 households were interviewed with informants from different ethnic groups, and religious and cultural backgrounds to obtain a more representative sample. The results show that agriculture is the main occupation as 67%[3] of the respondents were involved

[3] The sample size is small but in order to provide an overview of the data collected we use % in the text.

just in agriculture, 27% of the respondents were active both in agriculture and business, and just 6% of the respondents partook in government services.

In Mustang, apple farming was found to be a family occupation where each family member, including the elderly and children, contribute whatever they can to the work on their families farmland. Apart from apples, the major agricultural commodities included apricot, mustard leaf, cauliflower, cabbage, radish, carrot, potatoes, paddy, wheat, peas, and beans. The majority of crops were intended for personal consumption; however, a few of them cultivated considerable amounts to sell to trekkers in their shops and homestays.

With regards to intra-household work division, women are in most cases mainly involved in land preparation, irrigation, and harvesting. Men spent most of their time on other businesses like hotel and trekking. Children and elderly household members were mainly involved in postharvest activities like collecting the apples affected by wind/rain, grading and drying activities.

The respondents were from mixed educational backgrounds, with nearly half of them being illiterate and only a few having passed primary school. A survey on people in Jomsom and a nearby region revealed that the education status of Mustang was below the average i.e. just 47% were literate, the figure was significantly lower than literacy rate of Gandaki Province itself (Pandey and Bhatta, 2020).

Major crops

Apple is the main cash crop for people in Mustang. Apple farming is a family-owned occupation that is passed down to the next generation. It was found that 47% of the respondents had been practicing agriculture for 10 to 20 years, 33% and 20% had been farmers for more than 20 years and below 10 years respectively.

The average production area was estimated to be 1 acre, which represents the figure for medium-scale farmers. The households were organized into three categories: (i) small-scale farmer (production area less than 2680 sq. m), (ii) medium scale farmer (production area in the range of 2680sq. m to 7310sq. m) and (iii) large scale farmer (production area greater than 7310 sq. m) (Pandey and Bhatta, 2020). The farming techniques, productivity, handling, and drying procedures varied according to land holdings and farming scale.

Based on field data, the average production area for large scale apple farmers was 14 Ropani[4] (0.71 ha), which was significantly higher than medium scale (7.5 Ropani) and small scale (4 Ropani). The average apple production for each household in Mustang district was estimated to be 7000 kg annually.

Table 2: Overview on apple farming in Mustang District

Categories	**Average apple production area Ropani (ha)**	**Average number of apple trees**	**Average Production per year kg(Mt)**	**Production Yield (Mt/ha)**
Small Scale	4 (0.20)	100	2610 (2.61)	13.04
Medium Scale	7.5 (0.38)	216	5910 (5.97)	15.71
Large Scale	14 (0.71)	370	12780 (12.78)	17.96

There was a considerable variation in production yield among the three farm categories. It was estimated that the average yield for large scale farms was 17.96 Mt/ha, the value is considerably higher than that for small (13.04 Mt/ha) and medium (15.71 Mt/ha) scale farms (Table 2)[5]. As compared to a previous study by Gayak et al. (2020), the results revealed that the production has increased in recent years. It may be mainly due to people's attraction to apple farming because of the road linkage up to Muktinath. However, most of the respondents highlighted the impact of climate change that causes unpredictable excessive snowfall and rainfall, which directly affect the productivity.

In Mustang, farmers sell fresh apples through three different marketing channels, as shown in Figure 8. A few years back, there was no road linkage in Mustang and farmers used to carry the apples on their backs, travelling for a couple of days just to sell their product directly to the consumer. The unsold apples were used to make popular liquor, ("*Brandy*"), and dried chips. The situation has changed since contractors, and even wholesalers, have started to reach Mustang to buy apples from the orchards. Besides, the domestic market for both fresh and dried apples there is an increasing market linked to influx of tourists and visitors.

---

[4] Land measurement unit in Nepal.

[5] The average value was calculated by dividing the total production yield by the number of households.

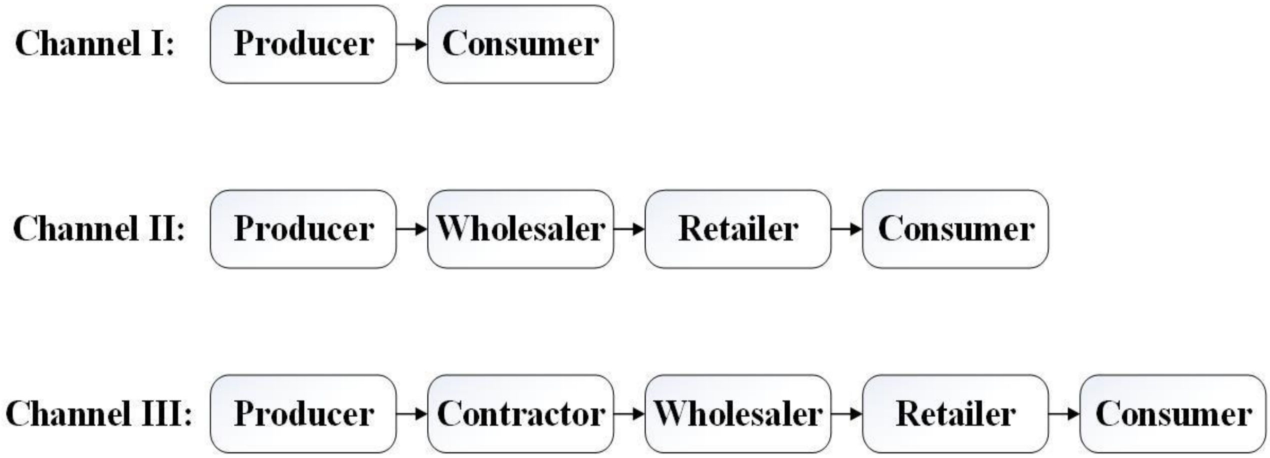


Figure 8: Existing marketing channels

The channels by which the apple reach the market have direct relation to the price farmer gain, i.e. the more agents in between the distribution channel, the lower the payment in the hands of the farmer. Most of the respondents prefer to sell through Channel I and II arrangements (Figure 8). The contractor in between producer and wholesaler buys the apples at a comparatively lower price and then sell to the wholesale stores in Pokhara, Kathmandu and Chitwan at a high profit margin.

Among the three categories of farmers, small scale farmers preferred to sell their product directly to the consumer because their production quantity was low, resulting in weak bargaining power. 54% of the small-scale farmers preferred to sell their product via Channel I, followed by Channel II (35%) and III (13%) respectively. The scenario for medium and large-scale farmers was completely different with maximum preference for Channel II. This was because of their higher production volumes as they could not sell their entire harvest directly to consumers and lack of infrastructures to directly reach the market. However, these larger scale farmers have better bargaining power than small scale farmers and they are able to negotiate a good market value via channel II and III. Regardless of farm size Channel III was the least preferred channel because the contractor offers a lower price to producers.

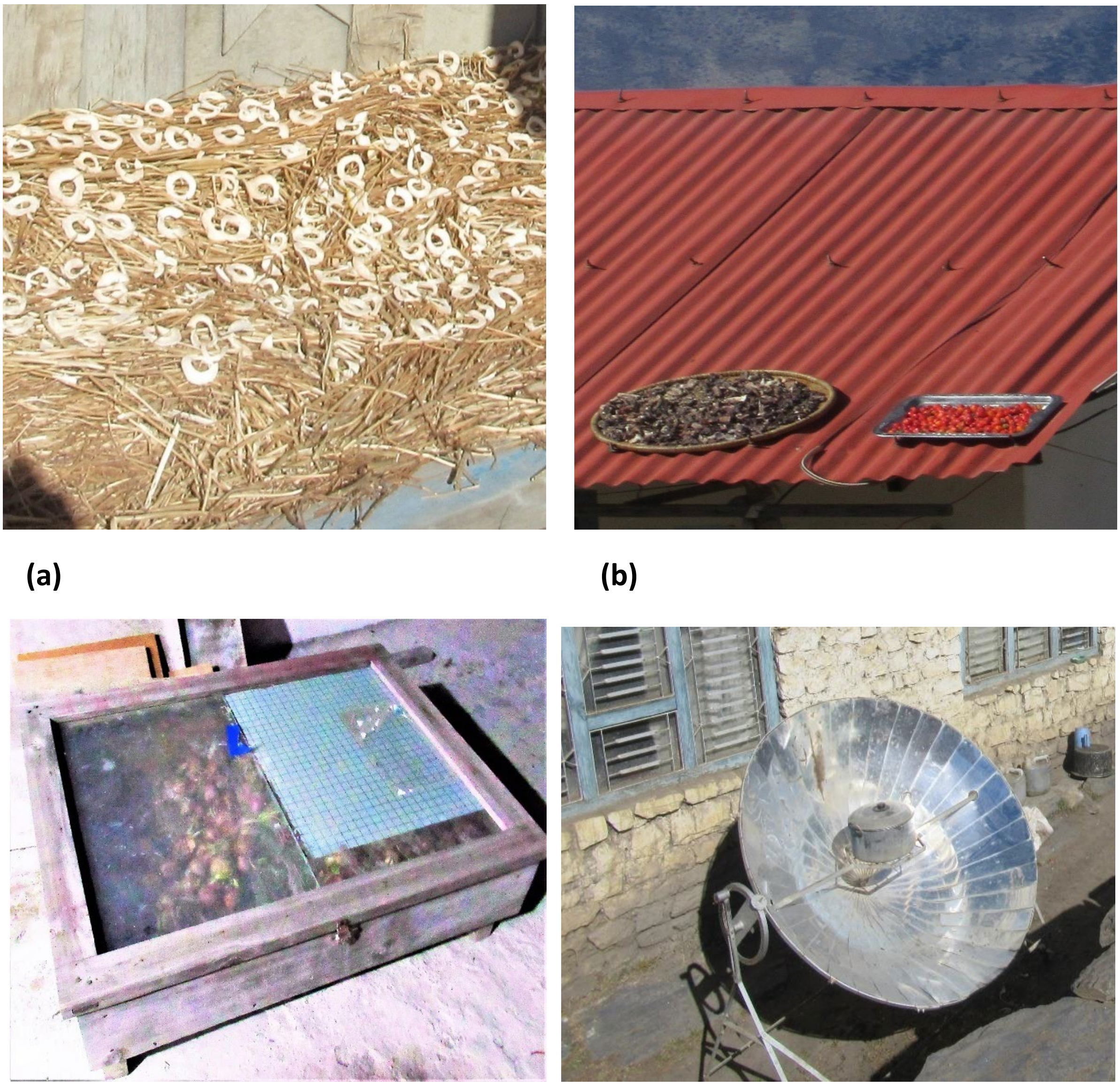
Existing traditional crop drying practices in Nepal

Among the varieties of apple grown in Nepal, such as Red Delicious, Royal Delicious, Golden Delicious, Chocolate, Jonathan, and Richard, most of the farmers prefer to dry Golden Delicious. This is because the market value of other varieties is high compared to Golden Delicious and they are generally preferring to be sold fresh. The farmers usually dry Golden Delicious apples combined with other varieties that fall off the trees prematurely due to wind/rain. The harvesting season begins from early August and ends by late September; however, drying starts earlier than harvesting season to dry the unripen apples affected by the wind/rain.

Most of the respondents combine two drying methods i.e. (i) Open Sun Drying (Figure 9 (a)) and(b) Direct Cabinet Dryer (Figure 9(c)). Firstly, the apples are dried in open sun for two to three days to remove moisture to a certain extent. The heat from open sun drying is insufficient to remove the full necessary moisture content for proper preservation, which means that the product is prone to contamination before it is able to be fully dried. To avoid contamination, the half-dried product from open sun drying is placed inside a direct cabinet dryer to further reduce the moisture content. The product is dried in the direct cabinet dryer for one to two more days to remove moisture. In total, it takes three to four sunny days to get the product to a desired moisture level. The main problems with the prevailing drying method are 1) multiple drying steps, 2) long drying time, 3) dust contamination, and in some extend 4) change in the color of the dried products. The direct cabinet dryers are made from local materials without considering the product characteristics, drying time and loading rate. It has a drying chamber covered by glass on the upper side. Other agriculture commodities like chili, apricot, barley, wheat and more importantly meat are dried on open sun, as shown in Figure 9 (b).

The farmers are aware of existing governmental subsidies for solar cookers, biogas, agricultural plants and equipment. The Government of Nepal also provides 50% subsidy for small dryers and 70% for industrial dryers (MoPe, 2016). However, the farmers were largely unaware of prevailing subsidies on solar dryers. During the fieldwork, it was observed that almost every household has installed a subsidized solar cooker, (Figure 9) but no subsidized solar dryers were installed.

Most of the large-scale farmers consider drying as a crucial business activity. Out of total production, about 28% of the fresh apple were dried, including apples falling off the trees prematurely due to wind and/or rain. Although, large-scale farmers were aware of government subsidies for solar dryers, they had not installed any of the subsidized dryers. Furthermore, it was found that drying was a crucial activity for medium and large-scale farmers to add value to Golden Delicious apples, whose market value is comparatively lower as compared to other varieties.



(a) (b) (c) (d)

Figure 9: (a) Apple on Open Sun Drying, (b) Meat (left) and Chilly (Right) on Open Sun Drying, (c) Direct Cabinet Dryer, and (d) Installed Solar Cooker via subsidy policy

5. Recommendations and conclusions

Based on the fieldwork carried out in Nepal and Bhutan on current drying practices and cultivation of crops we conclude with a set of recommendations for the further development and implementation of innovative solar drying technologies to enhance technology uptake. We divide the types of recommendations into technical and socio-cultural recommendations for solar drying design. We argue that only a combined consideration of the technical and socio-cultural recommendations can foster a successful long-term technology implementation.

5.1 Technical recommendations

Necessity for local adaptation of solar dryers

Cardamon and apple in Bhutan and Nepal respectively, seem to be very relevant cash crops for testing with a high potential to improve their economic value and create more profit. For farmers in both countries, it is important that the drying time will be shortened, secure the quality of the product and that a solar dryer can dry multiple crops (e.g., is an adaptive technology that can meet farmers' changing needs). Adaptation of technology to the local context is also necessary in terms of production of the solar dryer, when the goal is that farmers themselves or other persons locally build the dryers. Thus, the solar dryer should be produced with local materials so that it can also be easily maintained locally. The future work in the project should entail a mapping of available resources and materials in the potential implementation areas for building locally optimized solar dryers.

Study of existing solar dryers in both countries

In both countries open solar drying is undertaken. In Nepal the study showed that cabinet dryers are also implemented. However, we lack more data on experiences with existing solar dryers in both contexts. Hence, it is important to map existing solar drying technologies in both countries and identify the lessons learned from these technologies for optimal design. We recommend a technology assessment study that analyses the design and technical constraints and capabilities of existing solar dryers, which can be useful for the development of the *SolarFood* solar dryers and to learn from positive aspects and avoid repeating previous mistakes.

5.2 Socio- cultural recommendations

Study of adoption barriers with existing solar drying technologies in both countries

This step follows the technology assessment study. When identifying previous implemented solar dryers, it is important to study existing adoption barriers in both countries. Such a study can help framing the technology development and implementation path for solar dryers developed in *SolarFood* and at the same time shed light on other possible barriers for uptake.

Implementation of solar dryers via farmers' cooperatives or other types of farmer organizations

We recommend involving farmer cooperatives and/or other forms of farmer associations in the technology development and dissemination. Farmer organizations can take the responsibility to advice members and other farmers in implementation and assist farmers with financial and non-financial services (offering loans and informing about subsidies). Furthermore, they can cooperate in processing crops for added value. Cooperatives can increase farmers' bargaining power and empower women in forms of micro credits and agricultural advisory support, to mention a few examples. Previous research shows that farmers in Nepal who joined cooperatives have increased their income significantly (Niroja et al. 2015). Furthermore, implementing dryers via farmer organizations can enable the implementation process since they are already involved in food processing. A next step in our research will be to identify farmers' previous experiences with farmer cooperatives or other forms of farmer associations and their interest to working with them for installing solar dryers during the planned fieldwork in September-October 2022. In addition, interviews with farmers associations to find out how far they are interested in testing, co-developing, and disseminating improved solar dryers among their members.

Intra-household need assessment

The interviews conducted in both countries provided an initial needs assessment of solar drying at the household level. Drawing on the large body of work on gender dimensions in agriculture and food systems, there is a need to go beyond the household as the main unit of analysis and to collect data from both men and women within the same household. Such analysis implies paying critical attention to how intra-household dynamics, such as division of labour and responsibilities, time use and control over income and other productive resources, may influence uptake and outcomes of new technologies for different social groups and contexts. In many rural contexts, women not only constitute a major workforce in farming but also bear the brunt of domestic work (Quisumbing et al et al., 2014; FAO, 2011). This disproportionate burden of labour and responsibilities on women may not only constrains their opportunities to benefit from new technologies, but the introduction of such technologies may also exacerbate women's time poverty and thereby reinforce unequal gender relations (Bergman-Lodin, 2012). The next step will be to carry out a qualitative analysis to address intra-household dynamics among farmers in both countries during the next period of fieldwork.

For this, we recommend investigating the presence of women farmer groups in both countries, which has been identified as constraint for technology adoption (Achandi et al 2018). A collaboration with women farmer groups could help to identify challenges that women can face in accessing and using solar dryers and that these can be taken into the consideration for the future technical design and the implementation of solar dryers through relevant local social groups. Furthermore, it can help to identify, which role women can imagine to have in the solar drying process.

Training on designing, building, and using of solar dryers

In both countries there is a lack of experience on designing, building, and operating solar dryers of various types. There have not been any design guidelines, design databases, or quality assurance or monitoring mechanism to enhance the drying efficiency of the product. Hence, it will be important to enable a learning environment in form of a feedback loop with experience being transferred from usage and back to design/building. For this, future research in the project will also have to find out which types of farmers and farming systems are most suitable for solar drying and how far the technology needs to be adapted accordingly.

References

Achandi, E.L., Mujawamariya, G., Agboh-Noameshie, A.R., Gebremariam, S., Rahalivavololona, N., Rodenburg,J. 2018. Women's access to agricultural technologies in rice production and processing hubs: A comparative analysis of Ethiopia, Madagascar and Tanzania, Journal of Rural Studies,60, https://doi.org/10.1016/j.jrurstud.2018.03.011.

Baral, B., Aacharya, A. n.d. Status and drying possibility of apple produced in Mustang of Nepal, Kathmandu University (in press).

Bergman-Lodin, J., Paulson, S., & Mugenyi, M. S. 2012. New seeds, gender norms and labor dynamics in Hoima District, Uganda. Journal of Eastern African Studies, 6(3), 405-422.

Bhattarai DR.2018. Postharvest horticulture in Nepal. Hortic Int J; 2:458–60. https://doi.org/10.15406/hij.2018.02.00096.

Bhattarai, R.R., Rijal, R.K., Mishra, P. 2013. Post-harvest losses in mandarin orange: A case study of Dhankuta District, Nepal. African Journal of Agricultural Research. 8(9), 763-767, DOI 10.5897/AJAR12.2167.

Bhutan Broadcasting Service, 2021. Cardamom growers wish for better dryer http://www.bbs.bt/news/?p=158977 (Retrieved 16.09.2022).

Dauthy, M. E. 1995. Fruit and vegetable processing. Rome: Food and Agriculture Organization of the United Nations, section 5.2. ISBN 92-5-103657-8.

Dhital, PR. 2017. Agricultural Extension in Nepal: Experiences and Issues. Journal of Advances in Agriculture, (7) 3. https://doi.org/10.24297/jaa.v7i3.6287.

Enachescu Dauthy, M., 1995. Fruit and vegetable processing. Rome: Food and Agriculture Organization of the United Nations, section 5.2.

FAO 2011. The State of Food and Agriculture 2010–2011: Women in Agriculture: Closing the Gender Gap for Development. Rome, The Food and Agricultural Organisation of the United Nations.

Faqeerzada, MA. Rahman, A. Joshi, R. Park, E. and Cho, BK. 2018. Postharvest technologies for fruits and vegetables in South Asian countries: a review. Korean Journal of Agricultural Science, 45: 325–53. https://doi.org/10.7744/kjoas.20180050.

Gayak, B., Pandey, S.R., Bhatta, S. 2020. Economics of production and marketing of apple (Malus domestica) in Mustang, Nepal. Int. J.Agric. Environ. Food Sci., 4(4), 483-492.

GC, A., Ghimire, K. 2019. Estimating post-harvest loss at the farm level to enhance food security: A case of Nepal. Int. J. Agric. Environ. Food Sci., 3(3), 127-136.DOI: https://dx.doi.org/10.31015/jaefs.2019.3.3.

Hii, C.L., Jangam, S.V., Ong S.P., Mujumdar, A.S. 2012. Solar Drying: Fundamentals, Applications and Innovations, ISBN: 978-981-07-3336-0.

Integrated Public Use Microdata Series (IPUMS). Demographic and Health Survey 2016, https://microdata.worldbank.org/index.php/catalog/3681; 2021 [accessed 2 September 2021].

Khanal S, Dhital P, Christian S. 2021. Farming the future: Youth enthusiasm and transforming Nepal's economy through agriculture. J Agric Food Syst Community Dev, 1–14. https://doi.org/10.5304/jafscd.2021.102.027.

Kumar, M., Sansaniwal, S.K., Khatak, P. 2016. Progress in solar dryers for drying various commodities, Renewable and Sustainable Energy Reviews, 55, 346-360.

Leon, M.A., Kumar, M., S., Bhattacharya, S.C. 2002. A comprehensive procedure for performance evaluation of solar food dryers, Renewable and Sustainable Energy Reviews, 6(4), 367-393.

MoAC, 2011. A Value Chain Analysis of Apple from Jumla 2011. Ministry of Agriculture and Cooperatives, Department of Agriculture. Retrieved from http://hvap.asdp.gov.np/downloadfile/Value%20Chain%20Analysis%20of%20Apples%20from%20Jumla_1377153352.pdf.

MoAF, 2021, Self-sufficiency and Dietary Energy Supply of Food Crops in Bhutan, Ministry of Agriculture and Forest, Royal Government of Bhutan, available from https://www.doa.gov.bt/wp-content/uploads/2021/11/SSR_DES_version_image-re.pdf

MoALD, 2019. Statistical Information on Nepalese Agriculture 2075/76. Ministry of Agriculture and Livestock Development (MoALD), Singh Durbar, Kathmandu, Nepal. Government of Nepal.

MoPE, 2016. Renewable Energy Subsidy Policy, 2073 BS. Ministry of Population and Environment. Singh Durbar, Kathmandu Nepal. Government of Nepal. Retrieved from https://www.aepc.gov.np/uploads/docs/20180619_RE%20Subsidy%20Policy,%202073%20(English).pdf.

NARC, 2019. Postharvest management of Apple in Nepal 2018/2019. Horticulture Research Division (HRD), Khumaltar, Lalitpur.

Nepali Headlines, 2019. Road link boon to commercial apple farming in Mustang. Retrieved from https://nepaliheadlines.com/road-link-boon-to-commercial-apple-farming-in-mustang/. (Retrieved 05.05.2022).

Niroja, P., Mamoru, I., Muto, Y. 2015. Marketing System of Agricultural Cooperatives in Nepal: A Case Studies of Janagarathi Vegetable and Fruit Producer Agriculture, Cooperative. Review of Integrative Business and Economics Research, 4:4, 337-348.

NSB, 2021, Statistical Yearbook of Bhutan 2021,National Statistics Bureau, Royal Government of Bhutan, available from https://www.nsb.gov.bt/wpcontent/uploads/dlmuploads/2021/10/SYB-2021-Final.pdf

Organic Farm Nepal. 2022. Apple farm in Nepal. http://www.agricultureinnepal.com/apple-farm [accessed 15 July 2022].

Otte, P. P., Tivana, L. D., Phinney, R., Bernardo, R., & Davidsson, H. 2018. The importance of gender roles and relations in rural agricultural technology development: a case study on solar fruit drying in Mozambique. Gender, technology and development, 22(1), 40-58.

Pandey, S.R., Bhatta, S. 2020. Economics of production and marketing of apple (Malus domestica) in Mustang, Nepal. International Journal of Agriculture Environment and Food Sciences, 4 (4): 483-492. DOI: https://doi.org/10.31015/jaefs.2020.4.12

Phinney, R. 2019. Solar Assisted Pervaporation: A Process for the Concentration of Fruit Juices in Membrane Pouches with Solar Energy. (Doctoral Thesis) Lund University, Media-Tryck, Lund ISBN: 978-91-7422-666-9.

Phinney, R., Rayner, M., Sjöholm, I., Tivana, L., Dejmek P. 2015. Solar assisted pervaporation (SAP) for preserving and utilizing fruits in developing countries 3rd Southern African Solar Energy Conference (SASEC), Kruger National Park, 13-15 May, pp. 170-175 Published by Lund University Publications. http://lup.lub.lu.se/record/1ce79ba8-e17b-436c-abb9-06f3bb13a70e

Poverty Alleviation Fund, 2009. Dehydration of Cash Crops and Herbs using Hybrid-Solar Dryer,http://www.pafnepal.org.np/en/pdf/projects/Dehydration%20of%20Cash%20Crops%20and%20Herbs%20using%20Hybrid%20Solar%20Dryer.pdf; [accessed 2 September 2021].

Quisumbing, A.R., Meinzen-Dick, R., Raney, T.L., Croppenstedt, A., Behrman, J.A. and Peterman, A. (Eds.) 2014. Gender in agriculture: closing the knowledge gap. Springer Science and Business.

Rahman M. Shafiur, 2007. Handbook of Food Preservation, 2nd Edition, Pub. Boca Raton DOI https://doi.org/10.1201/9781420017373

Rijal, HB, 2021. Thermal adaptation of buildings and people for energy saving in extreme cold climate of Nepal. Energy Building, 230: 110551. https://doi.org/10.1016/j.enbuild.2020.110551.

Scott, W. 1957. Water relations of food spoilage microorganisms. In G. F. S. E.M. Mrak (Ed.), Advances in food research, 7:83-127. New York: Elsevier.

Simmonds, MSJ. and Howes, MJR. 2015. Profile of Compounds in Different Cultivars of Apple (Malus x domestica). Nutritional Composition of Fruit Cultivars 1–18. https://doi.org/10.1016/B978-0-12-408117-8.00001-5.

Sundén B. 2012. Introduction to Heat Transfer, WIT Press, ISBN 978-1-84564-660-8.

Tarjem, I A., Ragasa, C.; Polar, V., Sylla, A. Teeken, B., Nchanji, E.; Mujawamariya, G.; Mudege, N., Marimo, P. 2021. Tools and methods on gendered design, deployment and evaluation of agricultural technologies. CGIAR GENDER Platform Working Paper #003. Nairobi, Kenya: CGIAR GENDER Platform https://hdl.handle.net/10568/116887

Tiwari, I., Shah, K.K., Tripathi, S., Modi, B., Shrestha, J., Pandey, H.P.,Bhattarai, B.P., & Rajbhandari, B. P. 2020. Study on post-harvest loss on tomato in Kathmandu valley. Journal of Agriculture and Natural Resources, 3(2), 335-352.DOI: https://doi.org/10.3126/janr.v3i2.32545

Udomkun, P. Romuli, S., Schock, S., Mahayothee, B., Sartas, M., Wossen, T., Njukwe, E., Vanlauwe, B., Müller, J. 2020. Review of solar dryers for agricultural products in Asia and Africa: An innovation landscape approach, Journal of Environmental Management 268, https://doi.org/10.1016/j.jenvman.2020.110730

USAID, 2021. Food Assistance Fact Sheet. U.S. Agency for International Development, https://www.usaid.gov/nepal/food-assistance ; 2021 [accessed 2 September 2021].

Wangmo, C., & Dendup, T. 2021. Post-Harvest Handling and Losses of Green Chilies: A Case Study from Bhutan. Indonesian Journal of Social and Environmental Issues (IJSEI), 2(3), 284-292. https://doi.org/10.47540/ijsei.v2i3.329.

Worlddata, 2022a. Bhutan. https://www.worlddata.info/asia/bhutan/index.php [accessed 11.08.2022].

Worlddata, 2022b. Nepal. https://www.worlddata.info/asia/nepal/index.php [accessed 11.08.2022].

Appendix 1

Interview guide Bhutan

1. **Background:**
   1.1. How old are you?

☐ 20-30 ☐ 31-40 ☐ 41-50 ☐ 51-60 ☐ >60

1.2. For how long have you been a farmer?

1.3. Is farming your main income generating activity or are there others as well?
Yes ☐ No ☐ Others ☐

1.4. How long have you been living here?

1.5. What is your household size? **(no of people living)**

1.6. Who makes important decisions in your household related to purchasing agricultural crops/equipment?

1.7. What do you grow? (List 5 commonly grown cash crops and own consumption)?

Own consumption	**Cash crops**

1.8. How big is your farm? **(Decimal)**

1.9. Are you part of an agricultural cooperative or association?
Yes ☐ No ☐

2. **Current drying practice**

2.1 Do you dry fruits?

Yes ☐ No ☐

2.2. If yes, can you show and describe the dying process **(take pictures of existing technologies and equipment)**

2.3. What type of fruits or vegetables do you dry? **List maximum of five with drying time and drying process and pictures.**

2.4. Are there some types of fruits/vegetables that are easier to dry and if yes, which and why?

2.5. Do you face problems with current drying practices? (e.g., too long time, open drying, damage by insects, fungal growth, damage by birds, exposed to rain, excessive heat from sun, etc.)

2.6. Do you do drying all year or is there a special season? **If there is a season when do you do?**

2.7. Is drying a crucial activity for you in your farm business?

Yes ☐ No ☐

2.8. Who does normally the drying in your household?

2.9. What could be improved with the drying process?

2.10. Have you received any training on drying?

2.11. If you don't dry the fruits to preserve them, what do you do with them? Do you preserve them in a different way or does it become food waste?

3. **New drying technology**

3.1 Would you be interested in testing some new drying technologies?

Yes ☐ No ☐

3.2 Are you willing to invest in new drying technology?

Yes ☐ No ☐

3.3 Anything else you would like to mention?

Appendix 2

Interview guide Nepal

General Information	
Family name:	
Location:	
Contact information:	
Age:	
Educational Background:	

Living situation		
With whom do you share your household?		
Household Area:	Production Area:	Commodities:
Is farming your main income-generating activity? **If no, What is?**		
How long have you worked within the agricultural field? ☐ Less than 10 years ☐ Between 10 to 20 years ☐ Above 20 years		

Agricultural production on your farm	
Main fruit crop:	
Main vegetable crop:	

Main grain crop:	

Do you sell your products? **If the answer is yes, please fill in the following fields:**

Yearly Selling Amount (Kg):	Tentative Yearly Worth (NRS):

Are you part of an agricultural cooperative or association? **If yes, please state which one.**

Who makes important decisions in your household related to purchasing crops/equipment?

- ☐ Yourself
- ☐ Spouse
- ☐ Father
- ☐ Mother
- ☐ Grandparents
- ☐ Other (please specify): ………

Marketing channel to sell the product and your preferences:

Solar drying practices
Have you previously heard about solar drying? ☐ Yes ☐ No
Do you know about the subsidies provided by the government for Solar Dryers? ☐ Yes ☐ No
Do you dry fruit and vegetable? ☐ Yes ☐ No
If applicable, what drying method(s) do you use?

☐ Open sun drying ☐ Direct solar dryer ☐ Indirect solar dryer ☐ Mixed mode ☐ Other (please specify): ………
If applicable, what type of fruits or vegetables do you dry: ☐ Highly Perishable ☐ Non-Perishable
If applicable, are there some types of fruits/vegetables/grain that are easier to dry than others?
If applicable, do you dry one specific product or multiple products in the dryer? **Please state which products** ☐ None ☐ One product ☐ Multiple products <u>Product(s) dried:</u>
If applicable, do some of the crops take a shorter time to dry than others? ☐ Yes ☐ No
If applicable, what is the approximate time taken for drying your crops? ☐ Below 5 hrs. ☐ 5 to 10 hrs. ☐ 10 to 15 hrs. ☐ 15 to 20 hrs. ☐ Above 20 hours
Do you dry crops all year around?

- ☐ Yes
- ☐ No

If you answered no at the previous question during which season do you dry crops?

- ☐ Summer
- ☐ Rainy
- ☐ Winter
- ☐ Spring

Is drying a crucial activity for you in your farm business?

- ☐ Yes
- ☐ No

What is the marketplace for your dried product(s)?

- ☐ Excellent
- ☐ Very Good
- ☐ Satisfactory
- ☐ Poor

Who does normally the drying in your household?

- ☐ Yourself
- ☐ Spouse
- ☐ Father
- ☐ Mother
- ☐ Grandparents
- ☐ Children
- ☐ Workers
- ☐ Other (please specify): ………

Have you received any training on drying?

- ☐ Yes
- ☐ No

Do you face any problems with current drying practices? (Example: Duration, Quality, Acceptability on Market)

Quality of dried product
Taste: ☐ Good as compared to fresh ☐ Not better than fresh ☐ Other (please specify): ………
Color: ☐ Not changed ☐ Slightly changed ☐ Completely changed ☐ Other (please specify): ………
Product texture/hardness: ☐ Same as fresh ☐ A bit harder ☐ Excessively hard ☐ Other (please specify): ………
Any further remarks or observation on the quality of the dried product?

Solar dryers
Would you consider using solar dryers as a preservation method for your crops?
What expectation do you have on solar dryers?
What benefits do you see with using solar dryers?

If you do not dry your product(s), what alternative food preservation methods do you use/consider using?

Conclusion
Would you be interested in testing some new drying technologies? **If yes, any specific drying technology you have in mind?** ☐ Yes ☐ No Drying technologies that you would like to try:
Anything else you would like to mention?

FORMÅL

RURALIS - Institutt for rural- og regionalforskning skal gjennom fremragende samfunnsvitenskapelig forskning og forskningsbasert utviklingsarbeid gi kunnskap og idéer for allmenheten, privat næringsliv, offentlig virksomhet og FoU-sektoren, og gjennom det bidra til å skape sosiokulturell, økonomisk og økologisk bærekraftig utvikling i og mellom bygd og by.

RURALIS skal være et nasjonalt senter for å utvikle og ta vare på en teoretisk og metodisk grunnleggende forskningskompetanse i flerfaglige bygdestudier, og fungere som et godt synlig knutepunkt for internasjonal ruralsosiologi.

Ruralis
Institutt for rural- og regionalforskning

Trondheim (hovedkontor):
Universitetssenteret Dragvoll
N-7491 Trondheim
73 82 01 60

Oslo:
Rådhusgata 20
N-0151 Oslo
913 32 277

post@ruralis.no
ruralis.no