From *Supo* to Chimney Dryer: A Pilot Project to Reduce Loss and Improve Drying of Fruits and Vegetables for Women Farmers in Dadeldhura, Nepal

By

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Abstract

Solar drying can reduce fruit and vegetable losses and increase availability for farmers who produce surplus but lack storage. While traditional sun drying in Nepal uses bamboo (e.g. *supo*), improved solar dryers like the chimney dryer are more efficient and hygienic. This project assessed if the chimney dryer is an appropriate and beneficial technology for reducing food loss to disseminate to farmers, especially women, in Dadeldhura district, Nepal. In this study, appropriate was defined as relevant, affordable, locally available, and user-friendly, while benefits were assessed in terms of food availability, quality and safety; time and labor; and income.

Using a convergent mixed methods approach, I constructed three chimney dryers, conducted focus group discussions, key informant interviews, and workshops; made observations in the community; and carried out two experiments to quantitatively compare different drying methods. Qualitative data collection around social impact was guided by the Integrating Gender and Nutrition within Agricultural Extension Services (INGENAES) Gender Technology Assessment.

I found that the chimney dryer was faster, more protected and hygienic, and preserved quality better than sun drying. While the dryer is relatively easy to use, it may require skilled labor to construct, and the design and size can be adapted based on user preference. Although local materials are affordable, any cost may discourage farmer adoption; so, in the future, the technology can be made more affordable through multiple households pooling their resources and sharing a dryer, or through government subsidies.

Because drying is a relatively passive activity with little active time or labor, food safety and nutrition advantages may actually be more important than time saved. However, faster drying is still important for reduced spoilage, which can ultimately save labor and increase food safety and availability. Women will likely gain more than men from reduced time and workload, though concerted efforts will be required to ensure gender equity in value chain development for dried foods. Moreover, because farmers already know how to dry, the entire “dry chain,” including the DryCard™ to measure dryness and moisture-proof storage, should be promoted to prevent spoilage and mycotoxin development.

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List of Abbreviations

BLM	Broadleaf mustard greens
C	Celsius
CA	California
CGEDN	Centre for Green Economy Development Nepal
FAO	Food and Agriculture Organization of the United Nations
FCHV	Female community health volunteer
FGD	Focus group discussion
FS	Field supervisor
GDP	Gross domestic product
HFP	Homestead food production
HKI	Helen Keller International
INGENAES	Integrating Gender and Nutrition within Agricultural Extension Services
KAP	Knowledge, attitudes, and practices
KII	Key informant interview
Kg / g	Kilogram / gram
NARC	Nepal Agricultural Research Council
NGO	Non-governmental organization
NPR / रु	Nepalese rupees
OFSP	Orange-fleshed sweet potato
PE	Polyethylene (plastic)
PI / Co-PI	Principal investigator / Co-principal investigator
PICS	Purdue Improved Crop Storage (bags)
PRA	Participatory rural appraisal
PVC	Polyvinyl chloride (plastic)
RH / ERH	Relative humidity / equilibrium relative humidity
RRA	Rapid rural appraisal
RUWDUC	Rural Women's Development & Unity Centre
TOT	Training of trainers
UCD	University of California, Davis
USAID	United States Agency for International Development
USD	U.S. dollars
VDRC	Vijaya Development Resource Center
VMF	Village model farmer

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1 Introduction

1.1 Nepal project context

Nepal is a small and mountainous landlocked country in South Asia, located between India and China. With biodiverse ecological landscapes and approximately 125 ethnic groups within a population of roughly 29.7 million people, it is highly diverse, both socially and ecologically (Central Intelligence Agency, 2019). Three distinct agroclimatic zones exist in Nepal, delineated by elevation in bands that run northwest to southeast: the terai (or plains) in the south, the mid-hills, and the high Himalayan mountains in the north (FAO, 2011). These topographic zones dictate climatic factors such as temperature, precipitation, and soil quality, and as a result, Nepal is home to a large range of agricultural crops and wide fluctuations in their seasonality. The elevational regions of Nepal have also influenced culture and society in terms of physical road access, distance from markets, population density and urbanization. While rich in cultural and natural capital, Nepal is considered low-income based on more mainstream development indices such as gross domestic product (GDP), with an estimated per capita GDP of $2,700 in 2017 (Central Intelligence Agency, 2019). Agriculture accounts for roughly 27% of GDP and 69% of the labor force (Central Intelligence Agency, 2019).

Irrespective of development, poor diet is the leading cause of disease worldwide, related to six out of the top 11 global disease risk factors (Forouzanfar et al., 2015). Globally, undernutrition is a concern, especially among the 64.6% of poor working adults in agriculture (Castaneda Aguilar et al., 2016). As a low-income country, Nepal has concerning levels of malnutrition, manifesting in childhood stunting rates of 35.8% and 40.8% of women with any anemia (Ministry of Health - MOH/Nepal, New Era Nepal, & ICF, 2017). Chronic malnutrition may inhibit optimal physical growth, as well as impair cognitive development, leading to long-term economic consequences from reduced productivity.

Maternal and child undernutrition has many causes. In Nepal, immediate causes include infectious diseases from poor sanitation and hygiene; limited access to healthcare services; gender inequality; poor maternal, infant and young child feeding practices; and low dietary diversity. In fact, less than half of Nepalese children 6-23 months (47%) receive the minimum number (4 of 7) of food groups (Ministry of Health Nepal et al., 2017). Lack of dietary diversity in rural Nepal is partially a result of a diet that consists mainly of staple foods (e.g. rice and lentils), with very limited amounts of fruits and vegetables and animal source foods because of lack of availability and/or affordability. Dietary diversity has been shown to be associated with child growth (height-for-age Z-score) (Arimond & Ruel, 2004), and dietary diversity among children (Working Group on Infant and Young Child Feeding Indicators, 2006) and women (Arimond et al., 2010) is related to overall micronutrient adequacy of their diets.

While Nepal is a low-income country with concerning levels of malnutrition, especially among women and children, horticultural crops like fruits and vegetables have great potential to ameliorate undernutrition and provide needed income to farming families. The World Health Organization recommends that individuals consume *at least* 400 grams of fruits and vegetables daily (Joint WHO/FAO Expert Consultation, 2003), which can add a diverse portfolio of crucial micronutrients to the diet, including vitamins and minerals, as well as combat overweight and diet-related non-communicable disease. Increasing the production and consumption of fruits and vegetables, which are both high value and high nutrient, is one promising path to attaining healthy diets and increasing farmer incomes throughout the world, including in Nepal.

To understand the potential of improving diets through increasing consumption of fruits and vegetables, I embarked on a pilot project focused on increasing food security, dietary diversity, and availability of healthy foods by introducing chimney solar dryers to dehydrate fresh produce. The pilot project was carried out in conjunction with the existing *Suaahara II* "Good Nutrition" Program, a USAID-funded $63 million five-year (2016-2021) effort to improve the nutrition and health of 1.5 million women and children in forty rural and underserved districts of Nepal. One of the *Suaahara II* objectives is to "improve consumption of nutritious food through increased production, improved post-harvest storage, and processing diverse nutritious food, especially for women farmers from disadvantaged groups" (USAID, 2017). The non-governmental organization (NGO) Helen Keller International (HKI), as managing partner for *Suaahara II*, has been collaborating with communities to increase production of nutritious plant and animal source foods at the household level, through backyard gardens and small farms. This project was carried out in partnership with HKI and their local partner Vijaya Development Resource Center (VDRC). An early part of the project was a small needs assessment through baseline focus group discussions and interviews to better understand local agricultural seasonality, crop availability, and postharvest management of fresh produce in the study area: Dadeldhura district in far western Nepal.

1.2 Horticultural production and reducing postharvest losses of fruits and vegetables

Although fruits and vegetables are excellent sources of micronutrients, in Nepal, their quantities vary throughout the season, based on climatic zone. We conducted a discussion-based seasonal calendar activity in one community in Dadeldhura, which illustrated the seasonal variation in rainfall and crop production (Appendix 1). The months with the most rain (June-September) correspond to the monsoon season in Nepal, with less rain during the shoulder seasons on each end of the monsoon, and almost no rain from October-April. According to *Suaahara* staff members and farmers, common vegetables grown in this area include leafy greens, tomato, radish, cauliflower, carrot, beans, peas, pumpkin, potato, onion, garlic, balsam apple, coriander, and taro, as well as fruits like citrus, guava, and banana, depending on the altitude and temperatures.

In some communities in Dadeldhura, farmers are producing more than enough vegetables, but may lack awareness and/or access to technology to properly handle and store them after harvest. In fact, postharvest losses of fruits and vegetables are exceedingly high in

Nepal, with rates ranging from 20-50% (Gautam & Bhattarai, 2006 as cited in Devkota, Dhakal, Gautam, & Dutta, 2014) or 15-35% (Kaini, 2000; Paudel, 2006), which is consistent with the popular statistic that roughly one third of all food produced for human consumption is lost or wasted (Gustavsson, Cederberg, Sonesson, Van Otterdijk, & Meybeck, 2011). In lower-income countries, it is widely understood that postharvest losses of fresh fruits and vegetables occur earlier in the supply chain because of lack of proper storage technology and scant awareness of postharvest management, with loss typically involving surplus product that cannot be immediately consumed by the household or sold in the market (Gustavsson et al., 2011). A *Suaahara* staff member shared his estimate that for major crops, more than 25% of produce may be lost after harvest in Dadeldhura, mainly due to poor postharvest practices, attributable to both lack of knowledge and suitable technology (e.g. cold storage) (A. Shrestha, personal communication, February 28, 2018).

To supplement published and government data, we conducted some pre-project needs assessments. These needs assessments were used to more accurately describe postharvest challenges and opportunities where we worked. While verifying these food loss claims directly with farmers at the community level in Dadeldhura, I learned that this project represented some of the first postharvest management exposure that these villages have experienced. Due to time and budget constraints, conducting a full-scale baseline postharvest loss assessment and a comprehensive postharvest handling and management training, as originally intended, were not feasible. Instead, I was able to conduct a focus group discussion in one of the villages in the study area (Belapur), themed entirely around postharvest, as well as interview the village's produce collector. Then, I chose to focus the training content specifically on best practices for drying, including nutrition, assessment of sufficient dryness, and storage of dried product.

These postharvest-themed community-level discussions proved extremely useful, as local farmers and the collector helped the project team understand more about the on-the-ground reality of produce losses locally. Farmers in Belapur shared that between 25-35% of their onion crop is lost each season, while others generally lamented that they have to throw "quintals of product" (i.e. hundreds of pounds). Relatively minor contributors to postharvest losses in Belapur include pest attack and disease (e.g. insects on tomato and potato), and natural disasters like landslides, which can prevent products from reaching the market. Fortunately, tomato and potato are fairly easy for farmers in Belapur to sell and get a decent price, though even these crops may spoil after reaching the collection center where 1-1.5 quintals (220-330 lbs.) of potato are lost every season, and 15-20 kg of tomato and 10-15 kg of cauliflower are spoiled each week, according to our discussions with farmers. To provide some context for these losses, the village of Belapur has 1,348 households according to monitoring and evaluation data from HKI (S.N. Acharya, personal communication, December 14, 2018). Moreover, out of convenience, the owner of the collection center ends up throwing this wasted product behind his shop, rather than feeding it to livestock or properly composting (though he has heard of composting, he does not actively practice it).

Price fluctuations seem to be a main factor in the high loss rates of fruits and vegetables in Dadeldhura, including for onion, potato, tomato, and cauliflower. Both women farmers and men produce collectors shared that they are forced to throw hundreds of pounds of produce away because there is not a good market price. According to the man who runs the collection center in Belapur, "The price of produce today may be 50 NPR, but may fall the next day, which means vegetables cannot be transported immediately after collection." My co-principal investigator and translator further explained, "For instance, if he buys potatoes for 40 NPR/kg from farmers today and the price falls to 30 NPR in the Dadeldhura market tomorrow, this would not be profitable for him…he would lose 10 NPR per kg." While it would be in his interest to hold onto the produce until the prices go back up, because he lacks proper cold storage, the product spoils, and he is forced to discard it.

A related component of the price of produce is a saturated market. In these villages, many community members are producing the same products (e.g. onion) for a relatively small customer base, which drives down prices. In fact, several people expressed that onion has the highest lost after harvesting and when asked why, women responded that "it can't be sold in the market" and "no one buys onion." Thus, while lack of reliable transportation can occasionally be an issue (especially for collectors who are transporting the produce), price fluctuations are a more significant contributing factor to postharvest losses in Dadeldhura.

According to Belapur's produce collector, he sometimes has trouble explaining this economic phenomenon to the local farmers. He exclaimed, "The villagers also don't understand that when they have to sell in bulk, the price will be reduced. They don't understand supply and demand." In an attempt to elucidate the situation, he described calling the Dadeldhura market in the presence of the growers so they know he is not trying to cheat them out of money. Some farmers will then sell to him at a lower price, while others decide to keep the products for their home consumption or give them away to family or neighbors. According to the women farmers, however, they are well aware of the dynamics of the market. The village model farmer (VMF) in Belapur noted that "all community [members] produce the same product at the same time so the market is saturated to some extent," and another woman farmer said, "I don't plant more onion. I plant just sufficient for my home. This year I didn't plant even for household consumption. It can't be sold, so I don't want to waste my efforts and time." Farmers appear savvier and more economically conscious than the collector gives them credit for and are adjusting their crop planning accordingly. Despite this apparent misunderstanding, the collection center owner believes that better tracking of market prices could be one way to reduce postharvest losses. He said he should constantly follow the market price in Dadeldhura, though he already calls the market once a day to inquire about produce prices. Moreover, because agriculture in Belapur is not highly commercialized, local production is not always stable, resulting in an inconsistent supply. Thus, the collector believes if farming was done commercially, he might be able to secure a reliable market all the time.

But is waste better than want? Despite more than a third of food products being wasted, when we asked the women farmers in Belapur if they are satisfied with this quantity of loss, they replied, “there is less loss, so we are okay. At least we don’t have to buy.” This comment indicates that they would rather have surplus and waste than under-produce and have to purchase food from the market. Farmers in Belapur also tend to feed lost product to livestock such as water buffalo, including that which may be infested by pests, disease or mold or simply a dried food product they do not want to eat. Farmers and collectors are clearly at the mercy of price fluctuations and saturated markets because they lack the means to properly store produce until prices rise again. Overall, because of price fluctuations, high losses and lack of preservation methods, the availability of these nutritious foods is restricted.

1.3 Postharvest management and drying to reduce loss and increase consumption

Reducing postharvest losses is one strategy that governments, non-governmental organizations, and other stakeholders can prioritize to increase fruit and vegetable consumption and improve farmer incomes, and some solutions are already being implemented. For instance, the Government of Nepal is constructing a cold storage facility close to the Dadeldhura market for potatoes. The *Suaahara* staff member who served as our focus group discussion moderator explained the development to the farmers:

> “if you produced a large scale of potatoes, and if you can’t sell it just after harvesting, then you can store it in cold storage by paying money and resell it when there is high market price. PMAMP [Prime Minister Agriculture Modernization Project] has built it for the sake of farmers. You can store your potatoes there by paying a small amount of money depending upon your [need]. It is better to store there and sell after you get [a higher] market price than letting potatoes spoil.”

The farmers in Belapur were surprised to hear about this development and immediately asked if they could use the cold storage for their surplus onion crop. This interest indicates the need for additional cold storage facilities, which could also be financed by the government.

Perhaps more feasible than large-scale cold storage, alternative and more affordable options for reducing postharvest include different forms of home food preservation. Pickling and fermenting are common practices in Nepal, especially for radish (e.g. *sukuti*) and leafy greens (e.g. *gundruk*). Some farmers also process their products, consuming and selling items like lemon juice, ghee (clarified butter), and honey. Value addition is especially popular for sugarcane, which can be transformed into juice, jaggary (a product of unrefined cane sugar), and molasses and sold in the market, while processing appears less prevalent for other horticultural products.

Solar drying is another highly promising solution to address food losses and increase food availability. Drying is an ancient food preservation method that can effectively decrease postharvest losses, especially in settings like rural Nepal where proper cold storage is not very feasible. Effective drying or dehydration involves removing most of the water in fruits and vegetables, as water is required for microbes to grow (Borgstrom, 1968). Final moisture content should be around 5-10% for vegetables (Condorí, Duran, Echazú, & Altobelli, 2017; Harrison & Andress, n.d.) and 7-20% for fruit (FAO, 2007; Kumar, Sansaniwal, & Khatak, 2016). Fruits and vegetables can be dried for use in multiple forms, including whole, sliced, as a powder, or as a leather (Barrett, 2002; Ratti & Mujumdar, 1996). Drying is a relatively low-cost, viable alternative to cold storage that allows fruits and vegetables to be consumed throughout the year, making valuable micronutrients available to vulnerable populations during the lean season. In fact, properly dried, packaged, and stored food products can last up to one year or more at room temperature (Barrett, 2002; 5,110,609, 1992).

1.4 Current drying practices in Dadeldhura

In many places around the world, drying has traditionally been done outside in open air, either on the ground or on roofs (Chua & Chou, 2003), and Nepal is similar. Drying is already a popular and widespread postharvest activity practiced by farmers in Dadeldhura, with the current practice of open-air sun drying done commonly by women who learned from their mothers and grandmothers in villages where drying has been practiced for generations. Dadeldhura is a productive district for vegetable crops, so it makes sense that the popular products for drying include common vegetables such as chili pepper, radish, leafy greens, cauliflower, balsam apple, pumpkin and taro. Through our baseline focus group discussions, we learned that women in the villages of Bagarkot, Belapur, and Pokhara in Dadeldhura are using a variety of materials for drying produce including bamboo (e.g. *nanglo* or *supo* baskets, the latter is pictured in Figure 1a, as well as plastic tarps, cloth, or even on rooftops without any drying material under the product: Figure 1c). Because farmers will leave the food outside and uncovered for several days at a time, sometimes through the nights without bringing it inside, this practice leaves the product exposed to the elements like dirt, dust, rain, flies, animals and children (Figure 1d). This finding is consistent with the literature, which deems open-air sun drying as unhygienic, because it leaves product vulnerable to contamination by debris such as rocks, dirt, insects and other pests and can also have moisture issues through hardening of the product skin or unexpected rainstorms (Chua & Chou, 2003).

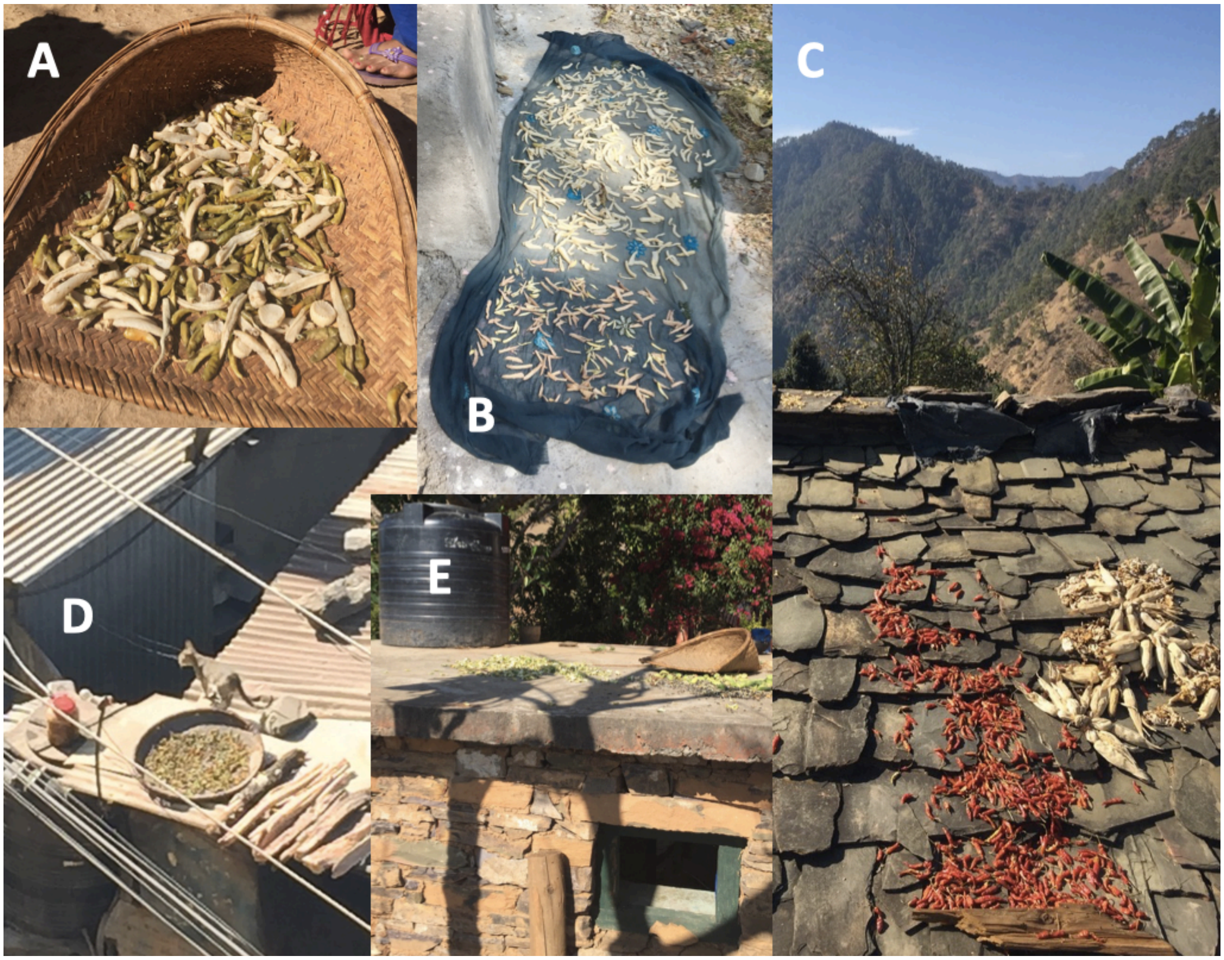

Figure 1. Traditional sun drying in Dadeldhura: a. Drying radish and chili pepper co-mingled in a supo bamboo basket; b. Balsam apple being dried on a scarf; c. Chili pepper and corn being dried on a slate rooftop in Belapur; d. A cat walking next to product being dried on a nanglo (round bamboo basket) on a rooftop in Amargadhi; e. Balsam apple being dried on a rooftop of a toilet. Photos taken by Lauren Howe, 2018.

These practices are not only unhygienic (for example, Figure 1e shows product drying on the roof of a toilet structure), but can lead to spoilage due to slower drying (especially under cloudy conditions), as well as quality loss. The VMF in Bagarkot said, “we dry many types of vegetables. If the weather is sunny, it’s good, but if there is not good sunshine, all the produce is spoiled.” Despite this observation, the women we spoke with are generally content with this current method; as one woman, the community health volunteer in Belapur said, “we spread [the food] on the roof top, and we don’t have to look after it, so we are satisfied.” A sentiment that was succinctly captured by the VMF in Pokhara: “we are following this [traditional sun drying] method; we don’t know any other method, that’s why we like this method.”

1.5 Improved solar drying

Despite a general sense of satisfaction with current drying methods, some community members expressed a desire for improved solar drying. The VMF from Pokhara said, “any method that is easy and takes less time…if we can dry more and, in less time, it would be better…it would be better if we can reduce [the drying time] from 4 days to one day.” However, few women we spoke with had specific ideas for how to improve the drying process. The VMF from Belapur explained that using material under the product when they place it on the roof could be one form of improvement (though many communities are already doing this with plastic, cloth or bamboo). Moreover, upon further discussion with the women, especially around sanitation, they began to understand the benefits of improved solar drying.

It is important to differentiate between improved solar drying and traditional sun drying. “Solar drying” or “dehydration” also uses the sun’s energy but is aided by technology or equipment to facilitate the drying process and protect the product (Chua & Chou, 2003). Benefits of solar drying as compared to open-air sun drying include: shorter drying times and higher efficiency by trapping heat and the ability to increase the heat collection area; increased hygiene by drying in a protected area, safe from pests; production of more nutritious foods that are dried at optimal temperatures for shorter time periods, which reduces nutrient degradation (Chua & Chou, 2003). In considering improved drying methods and technologies that are appropriate for low- and middle-income country settings or small-scale operations, critical factors include initial affordability and startup costs; local availability of materials; ease of operation, maintenance, and repair; and ability to promote improved drying through proper air movement (Chua & Chou, 2003).

Various factors determine the amount of time it takes for a product to dry. Higher air temperature (Karathanos & Belessiotis, 1997), higher air speed past the product (Eissen, Mühlbauer, & Kutzbach, 1985), lower relative humidity (Ekechukwu & Norton, 1997), and increased product surface area to volume (Youcef-Ali, Messaoudi, Desmons, Abene, & Le Ray, 2001) all result in faster drying. Solar dryer designs can be divided into two categories: active and passive (Chua & Chou, 2003). Unlike active solar dryers, passive dryers, often in a cabinet-style, do not utilize additional equipment such as fans to increase airflow, but simply rely on the sun's rays passing through a transparent barrier (e.g. plastic or glass) and the natural convection to move warm air past the product (Chua & Chou, 2003).

1.6 The chimney solar dryer

Although drying in Nepal has typically been done through traditional open-air methods using bamboo containers like *supo* or *nanglo*, this process can also be achieved using improved solar dryers like the University of California, Davis-designed chimney dryer (Figure 2). An improved postharvest technology, the chimney dryer is an efficient model that is small-scale and relatively affordable. It is an example of a passive dryer that traps heat with its large drying table, and which is covered with heat-absorbent black cloth or plastic. The chimney design promotes moisture removal through constant airflow and high air speeds around the product, as the warm, less dense air moves across the trays, up and out of the chimney, accelerating the drying process more than cabinet-style dryers (Horticulture Innovation Lab, 2018a) (Figure 2).

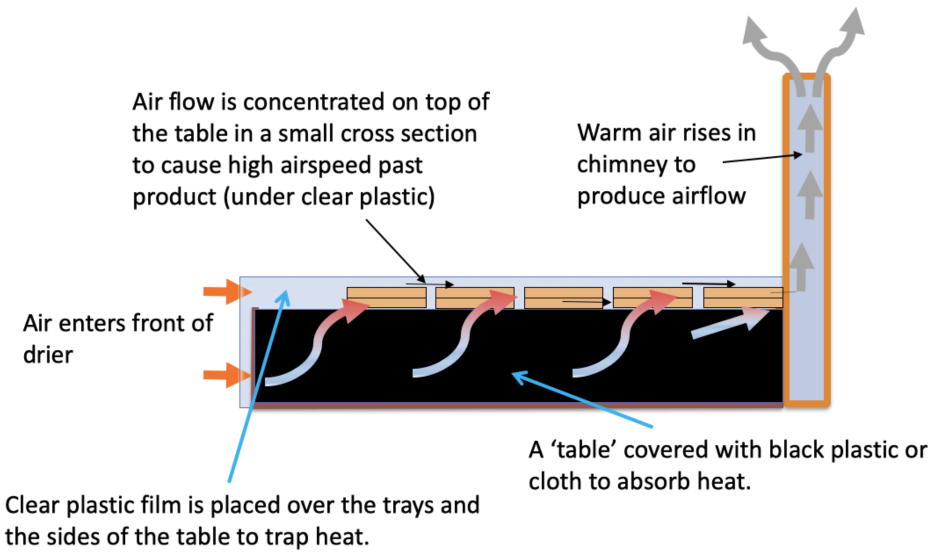

Figure 2. Diagram of the chimney solar dryer, an improved dryer designed by a team at the Horticulture Innovation Lab at UC Davis. Illustration created by Michael Reid, 2016.

A benefit of many passive solar dryers, including the chimney dryer, is that they can be constructed with local materials such as wood, bamboo, plastic, and cloth. The chimney dryer also has a flexible design, with table length and table height that can be adjusted based on user needs. It can also achieve more uniform drying through its utilization of the stacked trays lined with mesh, which promote airflow around all sides of the product, resulting in good air-particle contact (Horticulture Innovation Lab, 2018a). The trays can also be repositioned during drying to promote more uniform final product moisture content. The chimney dryer has been built and tested in several countries, including Zambia, Guinea, Tanzania, Rwanda, Guatemala, Honduras, Thailand, and Cambodia. Research in Bangladesh shows the profitability of the chimney dryer, particularly for fish and high-value crops including chili pepper, peanut, and mung bean (Horticulture Innovation Lab, 2017). In 2018, the USAID-funded and UC Davis-based Horticulture Innovation Lab published a manual and instructional videos (Appendix 2), which provide background information, building instructions and tips for troubleshooting the dryer. The main components of the chimney solar dryer include (Figure 3):

1. A drying table covered with black plastic or fabric
2. A chimney covered with clear plastic with an opening at the drying table

3. Mesh drying trays to hold the produce
4. Clear greenhouse-grade polyethylene (PE) plastic film that covers the trays and the drying table and is sealed to the chimney, which allows air to enter the dryer at the front, removing moisture as it flows over the product, and then warm moist air escapes up and out of the chimney

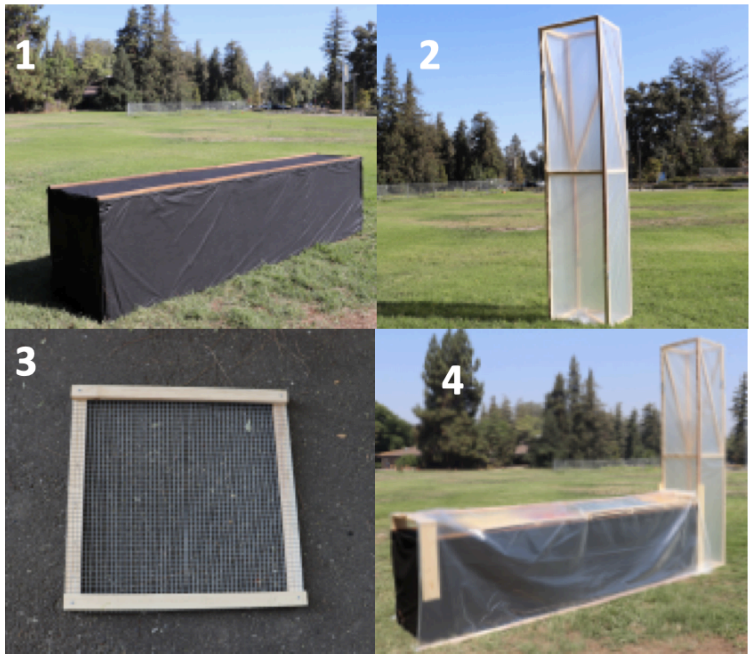

Figure 3. Main components of the chimney dryer: 1. A drying table covered with black plastic or fabric. 2. A chimney covered with clear plastic with an opening at the drying table. 3. Mesh-covered drying trays to hold the produce. 4. Clear polyethylene (PE) plastic film that covers the trays and the drying table and is sealed to the chimney. Photos taken by Brenda Dawson, 2017.

In addition to the faster drying time, there are several other perceived benefits of the chimney dryer that I set out to verify during this pilot study. These benefits include more hygienic drying as a result of plastic covering the food and the table elevating it off the ground, which can ultimately lead to safer food that is not contaminated by the elements such as flies, dirt, animals, and rain. Another facet of improved solar drying using the chimney dryer includes improved quality of dried products, including color, texture, and presumably nutrients.

Moisture is required for microorganisms to function, and product dryness is arguably the most important factor to maintain the quality of dried food products in storage (Bradford et al., 2018). Thus, besides drying product, measuring dryness and knowing when product is dry enough to store is a critical piece of the overall drying process. During our baseline FGDs, I learned that the current local method for measuring dryness is bending, tearing, or crushing the food product by hand. This method is obviously free but not 100% reliable. A more accurate method is to measure relative humidity (RH) of the air surrounding a product, which is a good indicator of the product's dryness. RH must be less than around 62% to ensure safe and extended storage of dried products; otherwise, microorganisms like bacteria and mold may develop (Semenuik, 1954 as cited in Roberts, 1972). This contamination is a food safety and public health hazard because mold can produce toxic and carcinogenic substances known as mycotoxins (e.g. aflatoxin), which have been linked to cancer, compromised immunity, and stunting and are estimated to affect up to 4.5 billion people worldwide (Gong et al., 2002; Williams et al., 2004).

1.7 Measuring dryness and the DryCard™

Researchers at UC Davis invented the DryCard™, a low-cost and reusable device that signals if products have been sufficiently dried to prevent the growth of mold during storage. The DryCard (Figure 4) is an affordable and helpful tool, especially for less experienced or resource-limited individuals who may not have a quick and reliable way to measure RH (Bradford et al., 2018). The DryCard costs about $0.10-0.50 to make but can be sold for $1-1.50 USD. It includes a cobalt chloride humidity indicator paper strip that changes color depending on the equilibrium relative humidity (ERH) inside a container: when RH is less than 65%, the paper will turn mauve or blue and it is dry enough and safe to store, but if the RH is greater than 65%, the paper will turn pink, indicating that the product is not dry enough to safely store. To help improve the dryness measuring component, I introduced the DryCard as part of our training activities.

Figure 4. The DryCard™, a low-cost and reusable device invented by researchers at UC Davis that signals if products have been sufficiently dried to prevent the growth of mold during storage. Photo taken in Nepal by Lauren Howe, 2018.

1.8 Nutrition and consumption of dried foods

Food preservation, processing, and storage can impact the nutritional content of foods, as different macro and micronutrients have varying stability depending on the processing method (Henry & Massey, 2001). Drying and the application of heat can cause the degradation of some nutrients, especially vitamins C, A, E and B (e.g. thiamin, niacin, and riboflavin), due to oxidation and other chemical reactions (Perera, 2005). Beta-carotene, a precursor to vitamin A, has been especially shown to decrease upon drying vegetables including carrot, broccoli, and spinach (Park, 1987). In contrast, iron, caloric and fiber content remain constant, although more concentrated due to a reduction in mass (Perera, 2005). Changes in macronutrient contents, including proteins, lipids, and carbohydrates, may manifest in color and texture differences, off or rancid flavors, and an overall reduction in quality (Perera, 2005).

There are certain practices that can be paired with drying to help preserve nutrients, which we shared with farmers during our training activities. For instance, minimizing the peeling of fruits and vegetables, while still maintaining palatability, can help retain vitamins and minerals, especially vitamins C and B (Henry & Massey, 2001). Most notable for this pilot study, utilizing improved solar dryers in lieu of open-air drying can prevent direct exposure to ultraviolet light and thus prevent degradation of some nutrients, especially carotenoids (Mwanri, Kogi-Makau, & Laswai, 2011). Although dehydrating fruits and vegetables can lead to some nutrient loss, the potential for solar drying to increase the consumption of these nutrient-rich foods by rendering them available year-round, especially during the lean season, should not be overlooked. Moreover, it should be noted that even the nutritional content of fresh fruits and vegetables also tends to degrade with time and if consumption is delayed by several hours after harvest without proper temperature management, this practice can result in significant nutrient losses (Barrett, 2007).

While eating dried foods is a secondary choice compared to consuming fresh produce, dried fruits and vegetables do play an important role in the household diets of local farmers in Dadeldhura. Farming families there tend to consume dried produce during the lean seasons (e.g. during the dry months of *Chaitra* and *Baisakh* or March and April when rainfall is low, during *Poush*, *Magh* and *Falgun* or December through March when temperatures are extremely cold) or times of very heavy rainfall when fresh produce is limited. During the lean seasons, farmers may resort to eating dried foods weekly or even daily. Belapur seems to have more of a true lean season compared to Bagarkot, possibly due to Belapur's more remote location, harsher climate, and lack of irrigation. In Belapur, for six months out of the year (September-March), farming families consume dried foods around once a week, and because no fresh foods are available from April-June, they also rely on dried foods during this lean season. According to the women farmers in Belapur, they are always able to feed their families three meals a day, but the quantity and quality of the meals may change because when some vegetables are not available year-round, they will make substitutions. In general, dried foods appear to play an important role in the household diets of the women we spoke with, manifesting in the consumption of dried foods every day during some months.

It should be noted, however, that the sensory properties of dried foods are quite different compared to fresh. One woman in Dadeldhura even said "like when we dry [food] through smoking, it tastes smoky, similarly [the food] tastes sunny if we dry in the sun." Producers and consumers of dried food products are rightly concerned with various aspects of quality, including food safety, texture, flavor, aroma, color, nutrition, shelf life and convenience (Perera, 2005). Food, especially sliced products, may undergo changes in appearance, including color (e.g. browning) and shape (e.g. shriveling and loss of structure), as a result of the various biochemical and physical processes associated with drying (Perera, 2005). Increased porosity, related to shrinkage and loss of structural integrity, may result in a different texture (e.g. hard, chewy, or rubbery), which may or may not be desirable for consumers depending on the specific dried product (Perera, 2005).

There are several ways to improve the palatability of dried foods, many of which are already being practiced by farming families in Dadeldhura.[1] Using radish as an example, they first soak the dried product in warm water, then fry it in oil or add it to soup, *dal* (lentils), *tarkari* (curry), or *achar* (pickle), oftentimes mixing it with fresh vegetables if they are available.

[1] It should be noted that the original project proposal incorrectly assumed that women do not feel very capable or comfortable incorporating dried foods into household meals, and one of the original short-term outcomes of this project was around increasing willingness and desire by family members to consume dried produce. This assumption and outcome were based on limited Internet-based communications with the partner NGO team before traveling to Nepal and proved to be rather misplaced. All farmers we spoke with in Dadeldhura are already regularly consuming dried foods as part of their diet, especially during the lean season, and every member of their household consumes dried foods when they are incorporated into a family meal. Thus, the notion of needing to convince people in the local farming communities to consume dried foods or increasing their confidence in preparing dried foods was irrelevant, though potentially important for urban consumers who may not be accustomed to incorporating dried foods into their regular diets. Thus, this project is only likely to influence drying and storage practices, but not necessarily the food dishes or recipes used, which are already well established and accepted. However, this project may trigger new ideas for foods to dry, and new ways to prepare dried foods (e.g. as snacks).

In fact, women expressed that rehydrating for a longer period of time can reduce the chewy texture considerably.

1.9 An early success story in Nepal

Unexpectedly, the chimney dryers we built in Dadeldhura district were not the first ones constructed in Nepal. An organization called Centre for Green Economy Development Nepal (CGEDN), in a joint venture with Integrated Development Society Nepal, found the Chimney Dryer Manual online through a simple Google search during the summer of 2018. They reached out to the Horticulture Innovation Lab explaining that they had discovered the manual and were promoting the technology among farmers in Shivapuri Nagarjun National Park, two hours north of Kathmandu, as a way to demonstrate different alternative sources of green energy. Their solar dryer project was developed under the Asian Development Bank/Bagmati River Basin Improvement Project for members of the Bufferzone user-group Committee of Shivapuri Nagarjun National Park to dry their food products. CGEDN staff emailed the Horticulture Innovation Lab photos of the chimney dryer they had built using local materials in Mulkarka village in the national park and asked us a variety of questions about the design. We noticed that they constructed a much smaller version of the dryer, shorter in length and height.

I was fortunate to have had the opportunity to meet CGEDN's field staff who took me into Mulkarka village during my first couple of weeks in Nepal to observe their chimney dryer in action. Here, I learned that one farming family had already replicated the demonstration dryer and even made design modifications on their own dryer at home, including securing the clear plastic to the sides of the drying table, sliding the trays in and out from the front, and adding a mesh screen door at the front of the dryer to keep out pests (Figure 5).

Figure 5. A farming couple in Mulkarka Village built and modified their own chimney dryer. Modifications included securing the clear plastic to the sides of the drying table, sliding the trays in and out from the front, and adding a mesh screen door at the front of the dryer to keep out pests. Photos taken by Lauren Howe, 2018.

This farming couple was using the dryer to dehydrate apple, soya bean, and mushroom, and reported that mushrooms used to take 3-4 days to dry in the open sun, and now, they only take 24 hours. They were very pleased with the technology and were preparing to train other community members in its construction and use.

Although surprising, this visit and early success story proved to be a tremendous benefit to the pilot project in Dadeldhura. Through questions, photos, and videos, I had the chance to document these farmers' experiences with the dryer, their local modifications to the design and materials, and how it is working for them. I was then able to use this story to further promote the chimney dryer to partner NGOs and farmers in Dadeldhura. Having a successful experience to share from within their own country was much more relevant, poignant, and convincing than showing photos of farmers in East Africa using the dryer. These photos and farmers' experiences served as evidence that this technology is already present in Nepal, albeit on a limited basis.

Overall, this literature review and baseline needs assessment through focus group discussions established that fruits and vegetables grow abundantly in Dadeldhura, where farmers have to manage surplus production that they cannot consume at home or sell in the market. Thus, drying produce, especially for home consumption during the lean season, is a common practice among smallholder farmers in Bagarkot and Belapur. Drying is an effective and low-cost form of food preservation that allows farmers to extend the shelf life of produce in communities where cold storage is unattainable. Traditional open-air sun drying methods, however, leave product exposed to the elements, which can result in compromised food safety, quality, nutrition, and ultimately wastage. If accepted by these communities, improved solar drying with appropriate technologies like the chimney solar dryer has great potential to reduce food loss and increase consumption of nutritious fruits and vegetables.

2 Study description

2.1 Positionality statement

As a graduate student in International Agricultural Development and a student researcher at the Horticulture Innovation Lab, the institution responsible for developing the chimney solar dryer, I came into this research with certain lived experiences and personal biases. Interacting with the chimney solar dryer was one of my first professional experiences with the Horticulture Innovation Lab, including constructing one at our demonstration center garden when I first arrived at the UC Davis campus in August of 2017. Since then, I have built a chimney dryer with Nepali refugees in July 2018 at the International Rescue Committee New Roots Farm in Sacramento, California, as well as utilized the dryer on campus during the summer of 2018 to run preliminary experiments and dry produce to carry to Nepal. I actively promoted the chimney solar dryer among international and community development practitioners and organizations from East to West Africa. The Horticulture Innovation Lab was interested in testing the chimney dryer construction manual, so I brought that intention to the research, as well as objectives of international nutrition researchers at UC Davis who hoped to gather preliminary data around dryer feasibility to inform future randomized controlled trials. Thus, I am bringing these previous experiences, predispositions about the benefits of the technology, and research priorities into this project.

There are additional personal background and demographic characteristics that are worth pointing out that have likely influenced my engagement with the project and our targeted communities in terms of research agenda setting, power dynamics, and impacting the outcomes of this research. I am a 28-year-old, Chinese-American woman from a middle-class background. During my Bachelor's degree, I studied environmental studies, with a focus on sustainable food systems and women and gender studies. A deep personal commitment to environmental sustainability and social justice and equity undoubtedly drove me to pursue this project, as it involves utilizing renewable solar energy to reduce food waste and increase food security for marginalized populations, especially women, in a lower-income country. However, because I do not speak Nepali, I needed to rely heavily on my local partners for translation and project logistical support, which generated a disconnect between myself as the principal investigator and the communities I was serving. However, being a woman of color and of Asian descent, in particular, may have assisted with cultural integration, as many people in Nepal pointed out that I look Nepali, especially in cultural dress. I hope that the efforts I made to culturally integrate through learning Nepali greetings and wearing *Dhaka kurtas* (a piece of traditional clothing) earned some respect and trust from the local communities, especially the women. Lastly, while efforts can be made to remove power dynamics from research, being from the academic sector in the United States may have automatically influenced my interactions with project partner organizations and community participants. In an attempt to overcome power imbalances in this research, I tried to defer as much as possible to my local partners in determining which approaches would be most culturally-appropriate, sensitive, and respectful.

2.2 Objective and research questions

Improved drying has the potential to reduce food loss, improve food safety, and increase household access to diverse and nutrient-rich foods year-round (especially for women and children). Thus, the overall objective of this pilot project was to improve the drying process of fruits and vegetables for farmers, namely women, in the Dadeldhura district of Nepal through the introduction of the chimney solar dryer. To develop a complete understanding of the potential benefits and challenges of the chimney dryer, I used a convergent mixed methods approach by collecting, analyzing, and integrating data from both interviews (individual and group) and quantitative experiments.

This study aimed to answer the following primary research question: "Is the chimney dryer an appropriate and beneficial technology to disseminate to Dadeldhura's farmers, especially women, for drying fruits and vegetables?" Here, I defined appropriate as relevant, affordable, locally-available, and user-friendly; and assessed benefits in terms of food availability, quality and safety; time and labor; and income. Associated qualitative sub-questions included:

1. How will the chimney dryer impact people differently, based on their gender or social status (e.g. position in family)?
2. Is the DryCard™ an appropriate technology to measure sufficient dryness for safe storage in Nepal?
3. How can farmers improve their current storage practices?
4. What role can other stakeholders (e.g. government, NGOs, private sector, etc.) play in supporting dissemination of the chimney dryer, DryCard, and improved storage practices?
5. What is the potential for selling dried foods as an additional source of income for farmers?

6. What challenges may exist and what kind of support would farmers need to overcome these barriers?
7. What role can other stakeholders (e.g. government, NGOs, private sector, etc.) play in developing a market for dried products?

To answer these questions, I used a mixed methods approach. The qualitative methods (focus group discussions and key informant interviews) aimed to understand more about farmers' current drying and storage knowledge, attitudes, and practices (KAP); farm and household-related gender dynamics; and potential for selling dried products; especially for women. The quantitative experiments compared the performance of different drying methods to answer the question: "Which drying method is faster?" as well as make observations about hygiene and food quality. The different drying methods compared included the UC Davis-designed chimney dryer, the Nepal Agricultural Research Council (NARC)-designed cabinet-style solar dryer (previously promoted by *Suaahara*), and traditional sun drying on bamboo (*nanglo* and *supo*) for different horticultural crops. I hypothesized that the chimney dryer would perform the best because it has the unique characteristic of increased airspeed past the product.

The reason for collecting both qualitative and quantitative data was to generate a more holistic understanding of the implications of introducing the chimney dryer in Dadeldhura. I want to promote improved solar drying only if a) it empirically works better than traditional sun drying (which is free for farmers) in the Dadeldhura environment and b) if it is deemed appropriate (i.e. relevant, affordable, locally-available, user-friendly) and beneficial (in terms of food availability, quality and safety; time and labor; and income) by stakeholders, especially farmers. Thus, the mixed methods research question became: "How do the qualitative data in the form of stakeholder opinions and the quantitative findings regarding chimney dryer performance align or contradict one another?" If the quantitative experiment reveals that the cabinet dryer is in fact more efficient and effective than the chimney dryer, these results would not dramatically alter the outcome of the study, as the findings from the qualitative data collection can be easily applied to the cabinet dryer instead of the chimney dryer, as both are improved drying methods. However, if there was no difference among the performance of the traditional sun drying method, the cabinet dryer, and the chimney dryer, then the findings from the interviews would have to be considered more carefully, and the conclusions and final recommendations may change. Either way, the results of this pilot study will be useful for development practitioners, non-governmental organizations, government agencies, researchers, and private sector actors who are interested in advancing appropriate technologies to reduce food loss and increase the availability of nutritious foods, while reducing workload and increasing income for farming families (especially women) in low and middle-income countries.

2.3 Description of targeted communities and participants in Nepal

This research project builds on the *Suaahara II* programmatic focus on nutrition and gender empowerment, as data were collected around the opportunities and challenges of building, utilizing, and training farmers, namely women, on the chimney dryer. Currently, women are the main members of their households engaged in drying activities. The seasonal calendar activity we conducted as a baseline needs assessment (Appendix 1) revealed that in general, women have much larger workloads than the men in their communities. The main responsibilities of men are around tillage, field preparation, and dry-land irrigation, only during two months of the year. While both men and women participate in the harvest, women are additionally responsible for planting, weeding, drying, and all household work, which takes place year-round. When I followed up with the women after the activity, the staff moderator shared that the women are well aware of the unequal distribution of work and are very accustomed to it. It is common in their communities, especially because many husbands are outside the home working so women simply have no other option but to fill the labor gaps, which may include taking on roles traditionally held by men such as land preparation and irrigation. This trend is consistent with the literature, which points to large-scale rural migration, especially among Nepali men, many who work outside the home, traveling to India or Gulf countries, and send remittances back to their families in Nepal (The World Bank, 2018).

Thus, the target beneficiaries of this project were mainly women. Participants included village model farmers (VMFs) within the *Suaahara II* Program, who are women generally selected from "1,000 days" households (homes that have either pregnant women or children under the age of two) based on their agricultural performance, leadership, and their central location. VMFs already have land, irrigation systems, and a supportive family environment, which allows them to create a demonstration plot on their property. VMFs from each community participated in the training and interview activities. This project also targeted other "1,000 days mother-farmers" and general homestead food production (HFP) group members who are currently receiving training from HKI on how to grow fruits and vegetables and raise poultry. The overall group has mixed literacy levels and some income-generation activities. In total at the community level, 55 individuals participated in focus group discussions and training activities, including twenty-one 1,000 days mother-farmers, 19 women general group members, four women village model farmers (VMFs), and three women community health volunteers (FCHVs). Lastly, in addition to these women, six men farmers and two men carpenters were involved in the construction and training activities to promote additional buy-in and long-term sustainability of the technology at the village level.

Per selection by HKI based on current project activities and priorities, this research was carried out in Dadeldhura district, a hilly district in the remote far-western part of Nepal (Figure 6). The far west is well known for being underdeveloped compared to other districts in the country with almost half its population (45%) in the lowest equity quintile and only 1% in the highest equity quintile, according to HKI reporting data (S.N. Acharya, personal communication, December 14, 2018). Equity quantiles are a composite measure of household living standards, calculated from ownership of household assets and household characteristics. Despite the far west being much less developed than the rest of Nepal, according to one key informant, Dadeldhura may have more NGOs than any other district, and it is a common saying that there are more NGOs than households. It is also a district that is highly productive in the areas of vegetables, rice, and dairy products compared to other districts in Nepal.

Figure 6. Dadeldhura district (pictured in red) in far western Nepal was selected as the research site for this study on improved solar drying. Image from https://commons.wikimedia.org/wiki/File:Dadeldhura_district_location.png

This research was conducted in two communities in Dadeldhura district, pre-selected by HKI: Bagarkot and Belapur (Figure 7). The first municipality, Bagarkot, is an area where there are still high amounts of surplus produce after household consumption, with relatively easy access to local markets to sell agricultural products. As this municipality is located very close to the district headquarters where most NGOs and government offices are located, community members may be more used to project support and subsidies, as indicated in multiple interviews. According to HKI monitoring and evaluation data, of the 785 households in Bagarkot, 68% fall below the middle equity quintile. Regarding caste or ethnic group, 74.3% of households fall into the high castes of Brahmin or Chhetri, 7.1% are disadvantaged Janajati (indigenous, outside the Hindu caste system), and 18.6% are members of the lowest caste: Dalit (S.N. Acharya, personal communication, December 14, 2018).

The second community involved in this project was Belapur. Belapur is a municipality in the upper belt of the mountain region where vegetable production is not possible throughout the year. Because this area is located farther from the district headquarters of Dadeldhura (approximately two hours driving, half of which is on an unpaved dirt road), households there are less accustomed to project support compared to Bagarkot. Belapur is also relatively more disadvantaged economically compared to Bagarkot as well, with 86% of the 1,348 households falling below the middle equity quintile. The demographic profile of the caste or ethnic groups, however, is relatively similarly, with an equivalent proportion of households (73.8%) falling into the Brahmin or Chhetri caste, and 26% being Dalit (S.N. Acharya, personal communication, December 14, 2018).

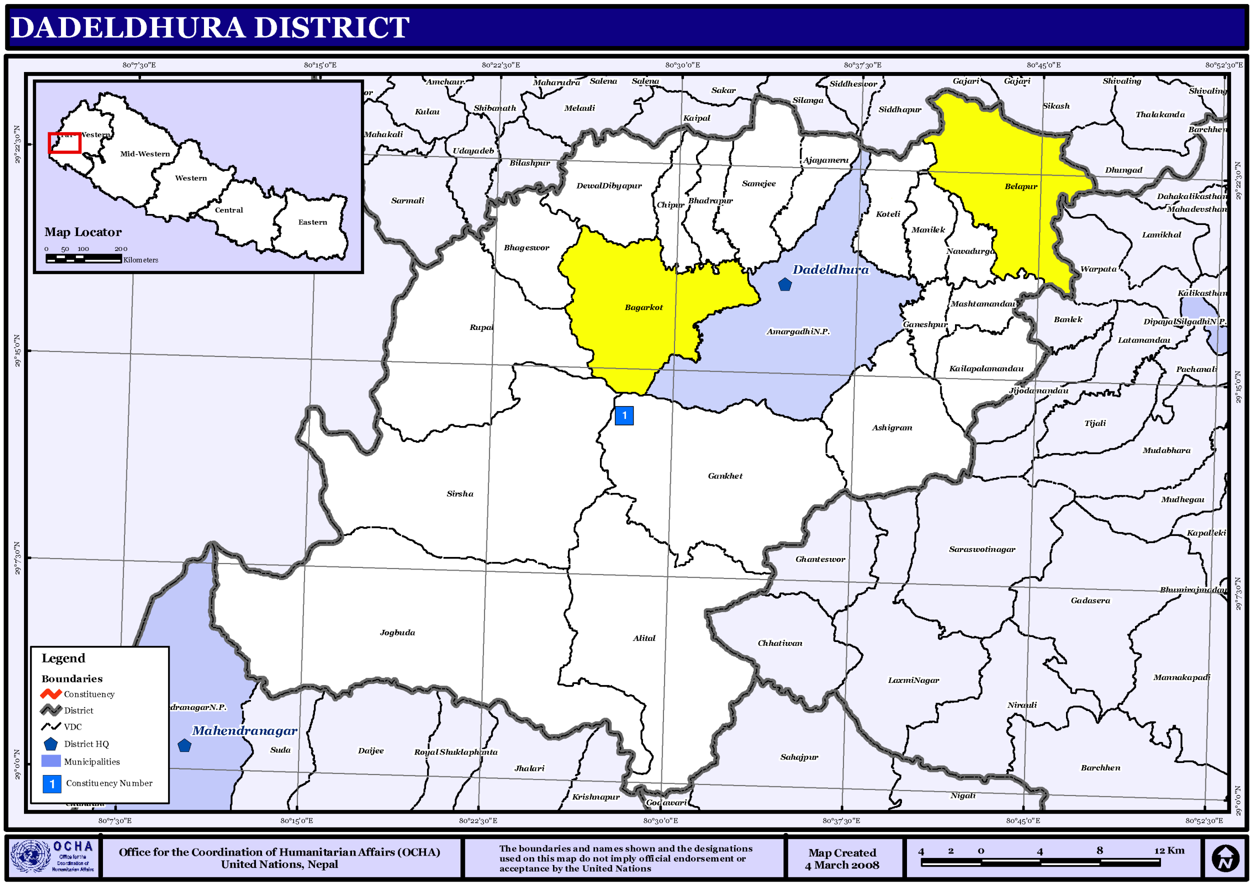

Figure 7. Study sites of Bagarkot and Belapur (pictured in yellow) in Dadeldhura district. Map modified from https://commons.wikimedia.org/wiki/File:NepalDadeldhuraDistrictmap.png, public domain.

I originally planned to conduct the activities in four communities in Dadeldhura. However, upon further discussion with the project partners, it became clear that this scope was too ambitious for the three-month timeframe and allotted budget, and that two communities, Bagarkot and Belapur, would be more realistic and feasible. As a result, the total number of community members we planned to train decreased, though we were still able to construct four dryers as originally planned (two chimney dryers at the community level, and a demonstration chimney dryer and cabinet dryer, both at the district headquarters).

3 Qualitative methods

3.1 Research context and location

Postharvest loss is an issue that Helen Keller International (HKI) was just beginning to incorporate as part of their *Suaahara II* efforts. In February 2018, HKI conducted a training on postharvest management, processing, preservation, and packaging of fruits and vegetables for their agriculture team from 40 districts in Nepal. HKI is currently collaborating with the Nepal Agricultural Research Council (NARC), an autonomous organization that conducts agricultural research to improve economic outcomes. NARC demonstrated the cabinet solar dryer model, another type of solar dryer that is common in lower-income countries. To build upon this effort, HKI was very interested in piloting the chimney dryer and potentially incorporating it into ongoing *Suaahara II* activities, which are funded through 2021. This pilot project involved carpenters from local communities, who will become experts in constructing the chimney dryer, and can continue to build them even after *Suaahara II* wraps up. Although we only worked with a small number of women farmers in the pilot phase, there is the potential to introduce the chimney dryers to many more farmers who are currently participating in *Suaahara II*. In the long-term, this type of intervention could make a substantial contribution to reducing postharvest losses, increasing access to fruits and vegetables year-round, and improving dietary diversity and micronutrient intakes among women and young children.

Working in partnership with HKI and a partner NGO, Vijaya Development Resource Center (VDRC), under the *Suaahara II* Program, improved solar dryers (the UC Davis-designed chimney solar dryer and the Nepal Agricultural Research Council-designed cabinet dryer) were constructed. Qualitative data collection techniques included focus group discussions (FGDs), key informant interviews (KIIs), and participatory action research methods (e.g. seasonal calendar). Training workshops for both trainers and farmers were also conducted on dryer construction, usage, nutritional benefits, storage and preparation methods of dried produce.

These activities were implemented in two rural communities, Bagarkot and Belapur, in Dadeldhura district in far west Nepal. In a convergent-design mixed methods approach, two experiments were conducted that quantitatively compared the performance of three drying methods (traditional, cabinet dryer, and chimney dryer).

The research and in-country project activities were conducted from October-December 2018, after the monsoon season and before the onset of the most frigid winter temperatures. Agricultural seasonality impacts the crops available for harvesting and drying, and during the fall season, these crops included leafy greens such as broadleaf mustard, cauliflower, tomatoes, radish, taro, and balsam apple.

3.2 INGENAES Gender Technology Assessment

In addition to field testing the chimney dryer in Nepal, the second major objective of this research was to improve the chimney dryer design and dissemination to be more gender-sensitive and gender-responsive by implementing the USAID INGENAES Gender Technology Assessment. INGENAES is a program whose acronym stands for "Integrating Gender and Nutrition within Agricultural Extension Services." The technology assessment evaluates the impact of a technology (either a "hard" or "soft" technology, as well as improved management practices) on three domains: food (availability, quality and safety); time and workload; and income and asset generation (Manfre, Rubin, & Nordehn, 2017). This technology assessment was piloted from 2015-2017 in Nepal, Bangladesh, Zambia, and Sierra Leone, utilizing a variety of different technologies and improved management practices from conservation or minimum-tillage agriculture to treadle pumps. The assessment was introduced in Nepal in December 2016 during a workshop titled "Addressing Gender Issues in Technology Design, Use and Dissemination" led by Cultural Practice (the firm that created the Gender Technology Assessment). For the chimney dryer pilot project in Nepal, elements of the technology assessment were used as a preliminary gender and social impact evaluation to better understand gendered implications of introducing the chimney dryer on dimensions of time use, food security, and income.

More specifically, this assessment aimed to improve understanding of how the dryer will impact the daily lives of users, especially women, in terms of food, time and workload, and income generation. We also sought to better understand how gender may affect dryer usage, as a gendered analysis has the potential to lead to modifying the dryer design or dissemination process. Furthermore, exploring the gender implications of and dynamics around the dryer may also enable future adaptations to better suit the needs of women. This assessment is the most appropriate tool to evaluate the chimney solar dryer and answer our research question because it incorporates gender dynamics, food and nutrition-related indicators, and aspects of rural livelihoods.

3.3 Data collection: focus group discussions

Focus group discussions (FGDs) were one of the primary qualitative data collection methods utilized in this study. Employing the INGENAES Gender Technology Assessment Toolkit and its interview templates, I compiled all of the questions for the FGDs (Appendix 3), which were translated into Nepali by the co-principal investigator (co-PI). The actual discussions were then moderated by an HFP Marketing Officer for *Suaahara II* and supported by the co-PI, who recorded, took notes, translated, and transcribed responses, which I later coded using a qualitative data analysis software called MaxQDA.

To obtain baseline information around current drying knowledge, attitudes, and practices (KAP), an FGD was carried out in both Bagarkot and Belapur prior to the chimney dryer construction and training activities. Unlike a situation analysis for planning purposes, drying KAP-related questions were used in an FGD in lieu of a baseline survey as "part of monitoring and evaluation of the project or intervention…conducted at the beginning of the implementation phase" (Fautsch Macías & Glasauer, 2014). In addition to inquiring about the drying practices, questions were also asked around measuring dryness, storage of dried produce, preparation and consumption of dried foods, nutrition of dried foods, selling dried foods, and feelings around improved solar drying and the chimney dryer specifically. Some of the FGD questions were also aimed at revealing gender dynamics related to drying, selling, control of income, and household decision making (i.e. household roles by gender). See Appendix 3 for a full list of interview questions.

The baseline focus group discussion questions were piloted in the village of Pokhara, which is located in Amargadhi municipality, nearby the district headquarters of Dadeldhura. A group of seven women, including one village model farmer (VMF), one female community health volunteer (FCHV), and five 1,000 days mother-farmers participated in this pilot discussion. Note that although this was only a pilot discussion, data from this conversation were deemed useful and have been included in the analysis and conclusions. In Bagarkot, around 7-10 women participated (some arrived late and others left early), including one VMF, one FCHV, one mother-in-law, and seven 1,000 days mother-farmers. In Belapur, six women participated in the baseline focus group discussion, including one VMF, one FCHV, two 1,000 days mothers, and two mother-farmers who participate in the *Suaahara* HFP program but whose children are older than two years. Moreover, an FGD on current postharvest losses, management and value addition was carried out in Belapur with the same group of women as part of the baseline data collection.

Approximately two weeks after the construction and dryer trainings, endline focus group discussions were conducted in Bagarkot and Belapur. Due to the limited time between baseline and endline data collection, only one person in each community had actually used the dryers, so the endline FGDs focused more on perceived benefits (e.g. *potential* impacts on sanitation, workload, time, food availability, and income generation), as well as anticipated changes to drying practices and future adoption of the chimney dryer. The endline discussions also inquired about measuring dryness, including the newly introduced DryCard technology and utilization of improved storage methods. Six women from Bagarkot and four women from

Belapur who participated in the baseline FGD and community-level training also attended the endline FGD. An all-male FGD with four men was also conducted in Belapur during the final visits to the field site as part of an increased effort to engage men and household decision makers in the project. These men attended the community-level training on how to use the chimney dryer and during the FGD, they were asked about their households' traditional drying practices, opinions of the dryer (including the materials and design), perceived benefits related to sanitation, time, workload, food availability, and income generation and control, as well as any challenges and future adoption. In total, eight focus group discussions were conducted.

It should be noted that this project originally targeted only 1,000 days mother-farmers who are participating in the *Suaahara* HFP program. We planned to include these 1,000 days mothers in our FGDs and training workshops and believed that if we invited men, they would dominate the activities or the women would not feel comfortable sharing or participating. However, as the project progressed, we realized the critical importance of involving husbands and in-laws in some of our project activities, as they are often the heads of household and primary decision-makers, especially when it comes to controlling income or investing in new technologies. This idea came from one of the Monitoring, Evaluation and Research Officers for *Suaahara II* who suggested that in addition to the FGDs with the women, we should conduct some key informant interviews with male heads of household, as their engagement and opinions will be crucial for the sustainability of the dryers in the community. We were not able to include these additional family members in the baseline assessment, but incorporated them in training activities and solicited their views towards the end of the project as part of the endline data collection, using purposive sampling. Thus, while our FGD participants were mainly women, one entirely male FGD was carried out as part of the endline activities in Belapur. Excluding men from project activities is not beneficial, has the potential to raise animosity and conflict among households, and "[o]n the contrary, evidence suggests that getting men's support is critical, and often necessary for the success of gender-responsive projects" (Ragasa, 2012).

3.4 Data collection: key informant interviews

Fourteen key informant interviews (KIIs) were conducted with a variety of stakeholders including the chimney dryer designers based at UC Davis; Dadeldhura-based ward-level and district-level government representatives; partner NGOs; produce collectors; carpenters; and the first chimney dryer users. My co-PI and I carried out all of the KIIs in English, and due to time and budgetary constraints, detailed notes were taken in lieu of recording and transcribing for the majority of the interviews. I used the same qualitative data analysis software, MaxQDA, to code and identify themes within the KII notes.

As previously mentioned, the questions for the FGDs and KIIs were informed by the USAID INGENAES Gender Technology Assessment to explore the gender-related implications of the dryer, in terms of workload, time, and income generation. To complement the aforementioned focus on gendered impacts, the USAID Agricultural Scalability Assessment Tool for Assessing and Improving the Scaling Potential of Agricultural Technologies also informed the interview questions to begin to assess the potential for scaling the chimney solar dryer in Nepal in the future (Kohl & Foy, 2018). With the exception of the interviews with the designers, which were conducted before traveling to Nepal, we carried out these interviews throughout the three-month project period in the field. The majority of the interviews were conducted towards the end of the fieldwork due to scheduling availability of both the researchers and key informants. The individuals we interviewed were mainly men and included:

1. **Chimney solar dryer designers** (two men): The team from UC Davis designed the chimney solar dryer from 2010-2012.
2. **Staff at Dadeldhura's Agriculture Knowledge Center:** Senior Agriculture Development Officer (man); two Junior Technicians / Agricultural Assistants (both women)
3. **The Executive Director of a rural development organization with an office in Dadeldhura** (woman)
4. **A local resident in Amargadhi who helped with drying experiment** (woman)
5. **A produce collector from Bagarkot** (man)
6. **Bagarkot's first chimney dryer user** (man)
7. **A Junior Agriculture Technician Assistant/Extensionist for Bagarkot** (man)

8. **The husband of Belapur's first chimney dryer user** (man)
9. **The collection center/shop owner in Belapur** (man)
10. **The Ward Chairperson of one of the villages we worked in** (man)
11. **A carpenter from Bagarkot** (man)
12. **A carpenter from Belapur** (man)
13. **The Executive Director of one of the partner NGOs** (man)
14. ***Suaahara* II program staff member** (man)

3.5 Data collection: observation

In addition to focus group discussions and key informant interviews, I made observations during farm and household visits. The primary focus of the observations was to better understand the crops farmers are growing, their current household storage methods for dried foods (i.e. containers and location of containers in the home), and the kitchen facilities for preparing dried foods. We conducted household and farm visits during the baseline activities in Belapur, after the initial focus group discussion and before the chimney dryer training workshops. In Bagarkot, household and farm observations were done after the training workshops but before the endline FGDs. I felt that it was important to include community observation to supplement and validate the information collected during the FGDs.

3.6 Data collection: participatory rural appraisal

In addition to the focus group discussions, one Participatory Rural Appraisal (PRA) method was utilized. PRA methods were developed from Rapid Rural Appraisal (RRA) methods, with the goal being visualized analyses in which communities represent information on their own terms (Cornwall & Jewkes, 1995). These methods typically include participatory mapping, timelines, flow diagrams, and seasonal calendars, to name a few. Ideally, these activities allow for more information than would be available from a conversation alone. I chose to use a seasonal calendar activity to understand how agricultural practices, income, expenses, and workload vary throughout the year. I decided to employ this method as an additional form of data collection partway through the project, which is why we only conducted this activity in Belapur rather than both communities. This activity was informed by a guide for planning and implementing participatory natural resource management projects (Catholic Relief Services, USAID, & Modernizing Extension and Advisory Services (MEAS) Project under the University of Illinois at Urbana Champaign, 2002). According to this guide, "this exercise enables participants to describe and analyze their farming and other activities throughout the year. It builds an understanding of the farming system, and shows when it may be possible to make improvements in natural resource management."

We attempted to utilize this form of PRA and visual analysis by asking women in Belapur about seasonal rainfall, the main crops they grow (and when they plant, harvest, and dry each crop), the labor responsibilities of men and women, food availability, income sources, crop prices, and consumption of dried foods. Overall, the activity provided valuable information for framing our understanding of seasonal variations in Belapur, but was less participatory than I aimed for because instead of having the women draw the calendar, the facilitator drew it based on participant responses. Following the seasonal calendar activity, we transitioned into the focus group discussion specifically about postharvest management practices and value addition.

3.7 Data collection: feasibility and cost calculations

A key component to technology adoption is feasibility related to cost and affordability. We kept track of the cost of the major materials and carpenter labor required to build the chimney dryers to help determine if this is truly a low-cost technology. The Horticulture Innovation Lab estimates that chimney solar dryers should not cost more than $200 USD, but recognizes that material availability and prices will vary based on location. HKI sent me a very detailed cost estimate in July 2018 before I arrived in Nepal based on background research conducted by the field team (Table 1). Guided by the Chimney Solar Dryer Manual, HKI estimated that one full-size chimney dryer with a 12-foot-long table and 10 trays would cost around 18,000 NPR or about $160-$170 USD with the following estimated cost breakdown:

Table 1. Chimney dryer cost estimate in western Nepal from July 2018, calculated by HKI.

Item	NPR	USD
Clear plastic (for the chimney and table)	रु1,240	$11.48

Food grade plastic/metal mesh for 10 trays	रु3,000	$27.78
Black plastic or fabric (to cover the table)	रु600	$5.56
Wood (for the dryer table, chimney, trays, and support pieces)	रु10,249	$94.90
Total	**रु18,089**	**$167.49***

*Conversion rate from July 2018

Thus, while we were in the field, I tracked the costs of the different chimney dryer construction materials to determine if the actual costs were within our estimates, and more importantly, if farmers deemed the projected costs to be financially feasible.

3.8 Supplemental activities: construction and training

Towards the end of the baseline focus group discussions, we shared with participants that we would work with them to construct chimney dryers in their communities. The construction and training activities were a necessary part of this pilot project to begin to assess people's competence with building, as well as their perceptions and projected use of the technology. We began with carrying out a three-day Training of Trainers (TOT) workshop in Amargadhi, the district headquarters for Dadeldhura. We trained 20 trainers on how to build and use the chimney solar dryer including *Suaahara* staff members, local carpenters (one from Bagarkot and one from Belapur), local government officials, partner NGOs, and village model farmers or lead farmers from nearby villages. We conducted the TOT workshop at the office grounds of one of *Suaahara* II's partner NGOs, and the chimney solar dryer we built will likely be used for future demonstration and training activities. For this TOT, we initially planned to have a local furniture shop prepare enough wood to build two chimney dryers, so that there would be sufficient tasks for the workshop participants to break up into two groups. Unfortunately, likely due to the festival season and lack of commitment and prioritization, the furniture shop did not prepare enough wood in time, so we were only able to construct one dryer. Typically, the dryers can be built in less than a day (usually 4-6 hours), but due to delays in material arrival, it took us about 1.5 days to complete the build, even with the help of local carpenters.

After construction, all participants engaged in two days of training on how to utilize the chimney solar dryers. While drying is a relatively simple food preservation process, there are some nuances and technical facets that we wanted to share with farmers to improve their final product. For instance, the quality of dried food products starts in the field with sanitary management practices, proper harvesting based on desired maturity, and optimal and hygienic postharvest handling and storage. It is important to start with high quality raw material, including removing contaminated food products (e.g. mold-infected, rotten, damaged or diseased) and maintaining a sanitary environment (e.g. clean equipment and washed hands) during processing (Perera, 2005). Using clean water with chlorine bleach to generate an acid, or adding alkaline detergents to sanitize processing surfaces (e.g. equipment, utensils, and trays) and wash fruits and vegetables is recommended (Barrett, 2002), while care should be taken to not damage the product's tender skin (Brett, Cox, Simmons, & Anstee, 1996). Peeling, pitting, and slicing can also be performed, which can accelerate the rate of drying by increasing the product surface area (Esper & Mühlbauer, 1998). Trays should be loaded quickly as the produce is sliced, with only minimal or slight product overlap, while ensuring efficient utilization of space (Brett et al., 1996; George, Mcgruder, & Torgerson, 2007; Horticulture Innovation Lab, 2018a). Products of similar sizes or drying time should be dried together, while foods with strong aromas (e.g. onion and pepper) should be dried separately (Swanson & McCurdy, 1995). However, with the chimney dryer, it is possible to put the trays with onion close to the chimney and other items near the air entrance to prevent odor contamination (J. Thompson, personal communication, April 29, 2019).

Monitoring drying temperature is crucial for maintaining product quality. Although heat is required to remove moisture, excessively high temperatures can degrade a food product's nutritional content (Bolin & Stafford, 1974) and flavor (Augustus Leon, Kumar, & Bhattacharya, 2002), whereas temperatures that are too low (e.g. from cloudy conditions or during the night) can promote spoilage by slowing air circulation, promoting microbial activity, and extending drying times (Esper & Mühlbauer, 1998). Furthermore, shortened drying time may mean less exposure to heat damage and increased product quality, including minimizing nutrient loss (e.g. vitamin A) (Clydesdale et al., 1991). Optimal drying temperatures and times will vary depending on the product. Uniform final moisture content is another desirable quality of any dehydration method (Tiwari, 2016).

Thus, extension materials were necessary to transmit some of this technical information, not only related to the drying process, but also about how to build and use the chimney solar dryer. A full translation of the Horticulture Innovation Lab Chimney Dryer Manual (Appendix 2) was produced in Nepali, and was distributed to training participants and partner NGOs across Nepal. Based on the Chimney Dryer Manual, I created a supplemental a 60-page training facilitator manual for anyone seeking to lead a training on how to use the chimney solar dryer and teach the principles of drying foods using passive solar energy. This training facilitator manual was also translated into Nepali, and it has been distributed to a number of individuals and organizations across Nepal. The facilitator training manual includes 15 learning sessions that can be carried out over the course of two days:

1. Pre-training baseline survey
2. Handwashing and utensil cleaning
3. Selecting products for drying
4. Preparing products for drying
5. Filling trays, loading the dryer, covering with plastic, checking the seal and ensuring airflow
6. Dryer location and orientation
7. What are the benefits of drying fruits and vegetables?
8. How the chimney dryer works
9. Weather, temperature, and drying time
10. Measuring dryness of product
11. Storage containers and conditions
12. Nutrition of dried fruits and vegetables
13. Tasting, culinary uses/recipes, and market sales
14. Community planning for future chimney dryer usage and maintenance
15. Post-training Survey and Closeout

This training manual also includes suggestions for scheduling the training, a full list of required materials, and background information on principles of adult learning. This training aims to be a dynamic, group-based learning experience, grounded in principles of adult education such as respecting learners' existing knowledge and experiences, making the topic useful and immediately relevant for learners, providing feedback and praise in a safe learning environment where learners' opinions are respected and questions and discussion are welcomed, and where the instructor establishes themselves as a co-learner along with participants. The training also has achievement-based objectives and a pre-post survey to evaluate learning before and after the training activities.

A component of the extension work that was not initially planned for but was tremendously successful was the design of pictorial training aids that explain the benefits of the chimney solar dryer compared to traditional sun drying using culturally appropriate illustrations and Nepali captions (Appendix 5). A local graphic design company in Kathmandu, Qurien Pvt. Ltd., was commissioned to create these pictorial cards, which proved effective in a range of settings from PowerPoint presentations to meetings with government officials to focus group discussions with women farmers. However, color printing was not feasible in the field, so I had to print the pictorial images in color in Kathmandu and bring them to Dadeldhura. In general, printing training material, especially the chimney dryer construction manual, was a challenge. The black and white printing quality was subpar locally, so some of the details in the diagrams were obscured, which made it difficult to convey some concepts.

Both the TOT and the community-level workshops covered the same aforementioned topics, including handwashing, produce selection, preparation and placing sliced product onto the drying trays (Figure 8), loading the trays into the dryer (Figure 9), and ensuring the plastic was properly sealed (Figure 10). We briefed participants on how to select the best location and orientation for the dryers (south facing), the benefits of drying fruits and vegetables, and we reviewed how the chimney dryer works, with an emphasis on how weather and temperature impact drying time.

Figure 8. Training participants preparing the product for drying, including cutting and placing on drying trays. Photos taken by Lauren Howe, 2018.

Figure 9. Training participants loading the dryer with product on trays. Photos taken by Lauren Howe, 2018.

Figure 10. Training participants sealing the plastic on the dryer. Photos taken by Lauren Howe, 2018.

The last day of the training was focused on measuring product dryness using both traditional methods of bending and tearing product and a more accurate method of using the DryCard, as well as safe and effective storage containers and conditions. We briefly discussed the nutrition of dried fruits and vegetables compared to fresh, and the nutrition of produce dried in the chimney dryer compared to open-air sun drying.

There were a number of components of the training that were more effective than others. For instance, training participants were excited to see the weight change of the products, so using a scale to demonstrate water loss seemed to be a successful learning tool. Moreover, we pivoted the training plan and tried to engage the learners to take charge of their own learning as much as possible. For instance, we provided money to the women in the TOT group to shop for produce so they could select the fruits and vegetables they were interested in drying. During this TOT, attendees also had the opportunity to taste dried product that I brought from the Horticulture Innovation Lab demonstration garden in California during my chimney dryer activities on the UC Davis campus during the previous summer, which was interactive, tactile, and fun. While tasting, we discussed possible culinary uses and potential for market sales. Lastly, we had participants divide into groups for the community planning portion to determine a framework for rotational usage and maintenance among the group. The *Community planning for future chimney dryer usage and maintenance* learning session provided valuable written and conversational data, which I analyzed to understand farmers' plans to share the dryer as a group and pay for any repairs.

All three training workshops involved a pre-post survey. These questions aimed to understand people's knowledge, attitudes, practices (KAP) and confidence around drying, consumption of dried foods, sanitation and food safety, the basic operational principles of the chimney dryer, measuring dryness, storage, nutrition, and future use. We had originally planned to administer this survey as a hand-raising exercise to accommodate lower literacy levels, but decided to distribute it as a written survey last minute, with the goal of gathering more useful data around pre-post KAP, especially on an individual level. However, this late decision resulted in a survey that we did not have time to validate or pre-test in Nepali with community members. As a result, I have chosen to not analyze these survey data, but instead keep it in the training facilitator manual as a tool for future trainers to assess if they are successfully imparting knowledge around these key topics to participants.

I facilitated the TOT, while other members of the research team, including the HFP marketing officer, co-PI, and *Suaahara* field supervisor collaborated to facilitate the community-level trainings in Bagarkot and Belapur. At the community-level in Bagarkot and Belapur, the project team and I constructed one chimney dryer in each village on the demonstration plots of a village model farmer (VMF), to serve as an example in the community. We purchased the materials to build the dryers, including clear plastic and wire mesh in Dhangadhi, about a five-hour drive from Dadeldhura. We sourced the black fabric and cloth and all the wood in Dadeldhura. All materials, however, can be purchased in Dadeldhura and then taken to the villages. Figure 11 provides an overview of the mixed methods utilized in this research project.

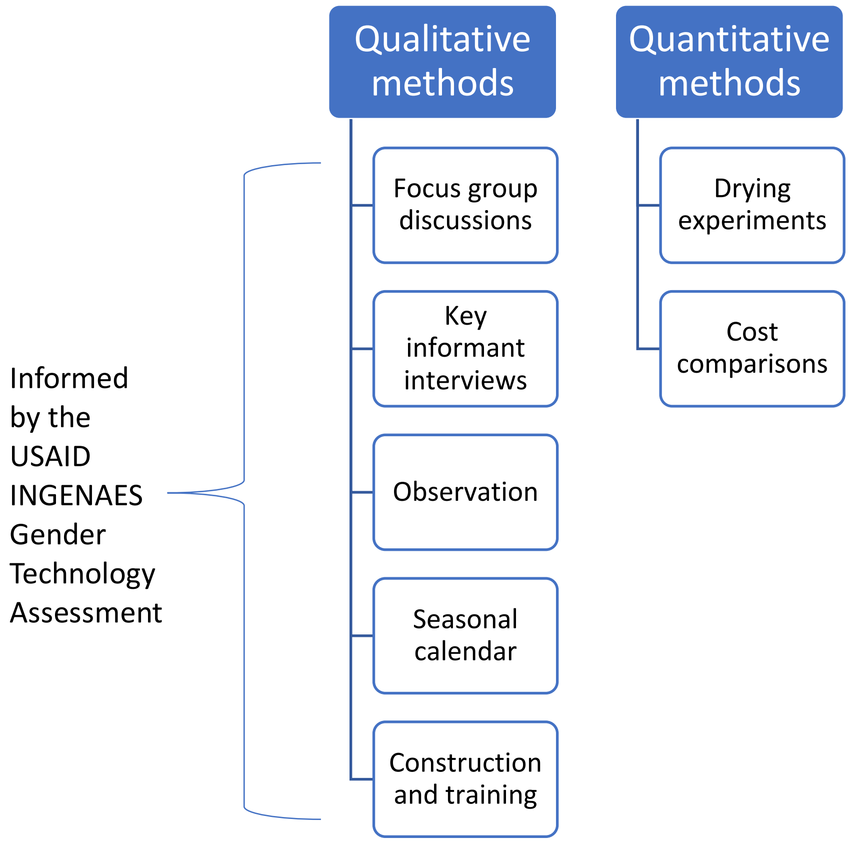

Figure 11. An overview of the mixed methods used in this research project

4 Results of qualitative data collection

4.1 Relevance and interest in the chimney dryer

Although I embarked on this project with a preconceived notion of the benefits of the chimney dryer, the data collection and results did validate these views. During the baseline focus group discussions, the women were generally interested in the chimney solar dryer. One of the mother-farmers in Belapur said, “Who wouldn’t be interested to learn a new thing?” This comment indicates a general excitement that could have been generated by any novel technology. Interest in the chimney dryer specifically, however, was also expressed by both farmers' verbalized intentions and actions. For instance, during the endline FGD in Belapur, the VMF commented on another farmer in her community: "Although she is far from here, she is going to bring her produce here for drying before they build their own. So, community people even far from here want to bring their produce here for drying." The woman responded by saying "it takes one hour for me to come here but I am going to bring my produce here." At baseline, another woman asked if they can use the dryer to make potato chips, indicating a desire to create value added products that can be sold for a higher price in the market.

In terms of actions as an indicator of interest, because the time between the baseline and endline focus group discussions was only a few weeks, the actual number of people who had used the chimney dryer in each community was also limited. Only one person in each village had used the dryer on their own in the interim. Surprisingly, Bagarkot's first user was a man who did not attend the training. When interviewed, he said:

> "I heard that *Suaahara* built a dryer for drying the vegetables. After hearing, I was so curious about that, and one day I came to see the dryer. I saw many varieties of vegetables drying in the dryer. I thought it was a good method, and I also thought about drying vegetables in it."

In response to his expressed interest, the VMF trained him, and he became the village's first user, drying around 5-6 kg of cauliflower.

This man was relatively young (32-years-old), married with one son, a member of a higher cast (Chhetri), and more educated than many of his neighbors, having achieved above secondary education. To make a living alongside farming, he also holds a government job as a teacher and has a relatively large landholding compared to his neighbors (25-30 ropani or about 1.5 hectares). When we spoke with this man, he said, "There are some benefits of the dryer compared to open sun drying. It's better…protected from insects, dust, and animals." This perceived benefit around protection and hygiene was not surprising, but we were very curious to understand his experience with the dryer in terms of time required. He responded by saying, "I think [drying 5-6 kg of cauliflower] would take more than 10 days if I dried in the sun." After some subsequent clarification, it became clear that it was about 3-4 days faster for drying cauliflower based on his experience. He also explained:

> "if the market price of fresh products is too low, at that time, we can dry and sell it, and for dried, we can get higher prices also. Another reason is the color and shape are also preserved in the products dried in the dryer, so consumers may be attracted to it and will encourage people to eat it, even if they have not tried dried vegetables before."

His last comment is particularly astute given that many farmers are interested in selling their dried product if there is a viable market, so selling an attractive, higher quality product will be key for building a customer base.

In Belapur, there was also one user between the time of baseline and endline. She is a 34-year-old woman who was not part of the initial focus group discussion, but a member of the farmers' group. She has four children, is also part of the Chhetri caste, which dominates this region, and is illiterate. She holds 10 ropani of land (a little over an acre), and her household's main source of income is agriculture. Unfortunately, we were unable to interview her because she was away at a health training. We spoke with her husband, but he was not well informed. The difference in both pilot sites' first users is interesting. I was expecting members of the core FGD to be the first users of the chimney dryer in their communities, but in both instances, this was not the case. Some of the FGD members noted that it is difficult to deny a neighbor who expresses interest in using a technology and will typically put others before themselves.

In addition to interest expressed by the farmers, a number of other stakeholders we spoke with, including produce collectors, partner NGOs and local government representatives, expressed that the chimney dryer could be a relevant technology to meet community drying needs, but with some specific stipulations. First and foremost, the fact that we were able to carry out this project in partnership with HKI and their partner organization VDRC indicates their shared organizational commitment and interest in reducing postharvest losses and promoting increased food safety and security among local farmers. When I asked one of my key collaborators at HKI if he thinks traditional sun drying is effective and his thoughts on the potential for the chimney dryer, he responded:

> "traditional drying is useful, but farmers are not well aware of the moisture content…during winter, there is not enough sunshine, so [traditional sun] drying is not enough to dry and store [product] for a long duration. Traditional drying requires much longer time than improved methods…Quality and aroma deteriorates. For a semi-commercially oriented farmer, I think [the chimney dryer] is an effective method because they can dry and store for another season or add value to sell to the market."

For him, the possible benefits of the chimney dryer seem to be associated with more thorough drying and quality retention, particularly benefitting commercially-oriented farmers. In response to the same questions, a high-level NGO administrator also emphasized affordability, user-friendliness, and hygiene:

> "Technology should replace [traditional sun drying] because of hygiene and cost effectiveness…Traditional practices are very time consuming, more than 15 days, and no one can trust [them] because of hygiene…[the chimney dryer is] absolutely a great idea, but it should be cost effective and user friendly. If the technology is not user friendly, people won't be ready to adapt it. If it is expensive, then farmers won't be willing to pay for the drying system because their current tradition is free of cost. If we talk about nutrition, we have to explain why the dryer is required. If we think about these things, it can be good for the community."

I should note that neither of these two partners interviewed had actually seen the chimney solar dryer in person, as they were located in their respective office headquarters far from Dadeldhura, so their impressions were based on seeing extension materials and hearing my explanation of the chimney dryer. In contrast, as someone who actually saw the dryer being constructed and used in Dadeldhura, the Executive Director from one of the partner NGOs with a local field office, expressed her desired to use the dryer as a demonstration technology for future district-level training activities. She believed that because the chimney dryer is a new technology in Dadeldhura, farmers need to be

> "made aware about drying products to prevent postharvest loss first and after that, we can disseminate the technology…once they are aware, they will demand [financial] support from the ward (local government) themselves. So, it is first important to make people aware of the technology."

In a similar cautious fashion, an agricultural extension agent from Bagarkot who attended about an hour of the community-level training shared that his first impression of the chimney dryer is that "it is a more advanced technology than [the farmers] need," noting that "farmers are not so advanced to adopt the technology, but it's good that they had the opportunity to learn." After this training, he reported back to his supervisor, who reacted positively because at least the farmers are learning from us.

4.2 Construction, materials, and ease of use

"While constructing it, even without the experience, it seems like we can build it ourselves by following the design and utilizing some of the locally available resources." –User in Bagarkot

To understand the potential for wider chimney dryer adoption in the future, I needed to understand the perceived advantages and challenges related to construction, materials, and user-friendliness. From multiple building experiences in Nepal and in the U.S., it became clear that working with a carpenter or skilled laborer is the most efficient and least stressful mechanism for constructing the dryer, especially when it comes to cutting and joining the wood. For example, one partner NGO representative who participated in the TOT noted, "we need skilled manpower to construct [the chimney dryer] because all people are not used to carpentry work, cutting the plastic, knowing the dimensions of plastic." Thus, although it is possible for a layperson to build, having knowledge of and experience with tools and building materials is a benefit. Some farmers we spoke with were interested in building their own dryers, while others prefer purchasing a ready-made dryer, which further makes the case for building the capacity of local carpenters to be able to build chimney dryers autonomously.

The materials required to construct a chimney solar dryer are readily available in the local community, according to farmers and government representatives. Because we were uncertain if we could procure the necessary materials in Dadeldhura, we did not actually acquire all of the supplies (e.g. clear plastic and wire mesh) locally, but rather purchased them in Dhangadhi, a city on the terai (plains) of Nepal near the Indian border, before traveling to Dadeldhura. However, local farmers said, "we can buy everything here," "there is no problem for wood either," and "we can get wood from the community forest."

It should be noted, however, that while materials may be available locally, the quality and integrity of the materials may be questionable and subpar. For example, we were only able to find 0.075 mm clear plastic for the chimney and table, whereas the Horticulture Innovation Lab recommends clear greenhouse-grade polyethylene (PE) plastic, at a thickness of 0.10 – 0.15 mm. As a result of only being able to find thinner plastic, we experienced ripping and small holes soon after constructing the dryers. We also recommend only using PE plastic and refraining from using polyvinyl chloride (PVC) plastic, the latter which will not transmit the infrared radiation necessary to heat the interior of the dryer. Similarly, while stainless steel (or plastic) mesh is best to prevent rusting, we could not be certain that the mesh we purchased was stainless steel, as the shopkeepers did not know themselves. The black surface on the chimney dryer for heat absorption can be achieved through wrapping the table in either black fabric or black plastic. We tried both, and were not able to quantify or compare the performance, though the plastic was much cheaper than the high-quality fabric we purchased. Another person suggested painting corrugated tin with black paint as a method for heat absorption, which could be tried in the future, though it would be important to ensure that the paint does not contain lead or any other contaminants that could be transferred to the food. We built three dryers with black fabric and one with black plastic, and further testing is necessary to determine which covering is more effective at absorbing heat.

In addition, other materials could be used to construct the table such as plywood or plastic produce crates, rather than the perfectly cut and joined lumber. Overall, local materials (e.g. community forest, bamboo, scrap wood on the farm, etc.) should be used whenever possible to keep costs low. Furthermore, an agricultural extensionist from Bagarkot noted that while materials may be readily available, affordable, and easy to transport, farmers may still be unwilling to pay for things in full out of their own pockets. This opinion is crucial, especially since one of our communities (Bagarkot) is located very close to the district headquarters, is frequently supported by NGOs and government subsidies, and may have built up a dependence for aid. Thus, despite the relative affordability of the technology, cost may still be a prohibitive factor in the dissemination and budgetary support through subsidized materials or a public-private partnership/cost share might be necessary for wider uptake of the chimney dryers.

4.3 Dryer size, capacity, and modifying the design

The size of the dryer and the required space are important facets of this technology that were met with varying reactions. One of the HKI *Suaahara* staff members initially responded:

> "Small landholding is always a challenge, so in this sense, smaller is better…For subsistence farmers, it may take up too much space. I have not seen the physical chimney dryer, but have seen the cabinet dryer, which is low cost and takes up little space. In this sense, maybe the cabinet dryer is more appropriate for small landholding farmers. But then I thought that the chimney dryer might be faster because of air flow and circulation, maybe more than the cabinet dryer. Maybe it's better for larger farmers."

During a discussion following the Training of Trainers activity after which we constructed a standard 12-foot-long dryer, one of the participants commented,

> "the size of the table should be different. There should be more than one standard size, like if a small size could be prepared containing only two trays for household purposes. It would be better if the size of the table is reduced in the community level."

He also asked if the height of the table could also be reduced. In the same discussion, a VDRC staff person who served as field support for this research said "the size is so big that community people can't store it inside, [so] the plastic may rip…This [full] size is better for commercial use but may not be useful for the community." *Suaahara* Field Supervisors (FSs) agreed:

> **FS from Bagarkot:** As it is new technology, I found this really very nice, but it may be difficult for community people to adopt the dimensions [length, breadth and height] according to the manual, but they can make smaller. Smaller is better, as community people may lack this long piece of land.
>
> **FS from Belapur:** Yes, in the community, it's hard to find this long compound.

Even a VMF from Pokhara (a nearby village that was used to pre-test the FGD questions) who attended the TOT said, "this technology is appropriate for farmers like us. We can't make this big size but we can make smaller one."

In response to this feedback, I suggested that we build a cabinet dryer, which is much smaller and more portable, to test alongside the chimney dryer. If the models ended up performing comparably, then the final technology recommendation would be based on farmers' preferences for usability, including size and cost, as the main goal of this research is to improve the drying process for farmers, namely women. However, it should be noted that the chimney dryer tended to outperform the cabinet dryer, which will be discussed more in depth in the drying experiment section. Following this initial TOT and after constructing multiple size chimney dryers and a cabinet dryer, the farmer-carpenter in Bagarkot said "for less quantity, [the cabinet dryer] is better because it is small and portable," but after building the smaller size chimney dryer with the 8-foot-long table, he said, "this size is handy…comfortable and appropriate for local level use…it was easy to build and materials needed were also less compared to the big [dryer].”

Most of the farmers at the community level did not see the full-size dryer built at the district headquarters and reacted positively to the 8-foot-long chimney dryer built at the community level. In Belapur at endline, men farmers said, “this size is appropriate for individual use at this time.” Producers also expressed willingness to devote a portion of their landholding for the dryer and did not seem concerned about space constraints. Men farmers in the endline FGD in Belapur said, “space is okay. We have sufficient land to provide so it doesn’t matter” and one of the more vocal participants confirmed, “there is no shortage of land for the dryer.” Women in the same community reacted similarly at endline. When asked if they were concerned about the chimney dryer taking up space on their agricultural field, one woman lamented, “look at these vegetables that we planted, they are dying due to water stress,” and the VMF stated, “there is no rain and no irrigation facility, so space doesn’t matter.” A third woman chimed in: “we can provide the space…we just want to use this technology.” I should note that although we planned to ask about it during the endline FGD, we did not get a chance to inquire about perceptions of the dryer size and space required with farmers in Bagarkot.

Related to dryer size is drying capacity and the ability to accommodate product. When asked at endline if they felt that the 8-foot-long dryer was an appropriate size for their use, one man in Belapur said, “it depends on the type of vegetables” and another, “if we have large production then this size is small but for now this size is okay. And it depends on our production.” A third man chimed in about the smaller chimney dryer:

> “in the season of large production of vegetables, bigger is better…like when there is the season of cauliflower, all the cauliflower sprouts at the same time. In such conditions, we should dry all the cauliflower at the same time. At that time, this size may be small but for off season, this size is appropriate.”

Thus, there are many factors such as crop, seasonality, and production volume that contextualize which dryer size would be most appropriate. From a community-wide perspective, the VMF in Belapur expressed, “I think bigger is better for whole community use because we are waiting for our turn and our turn would come faster if the size was bigger…this [8-foot-long] size is good for 2-3 households.” It is likely that more than three households will use this dryer, as more than 10 families located nearby participated in the community-level training. During the training, the Field Supervisor who supports these farmers advised them that “there might be more people near to you who are also going to use. You should also include them [in the community use plan].”

In comparing the chimney solar dryer to the traditional method, one potential drawback is drying capacity. The current traditional method of sun drying has a virtually unlimited capacity as it really just depends on how many bamboo mats, plastic tarps, or roof space a farmer has on their land. In contrast, the chimney solar dryer has a fixed capacity (6-10 trays), depending on the size of the drying table. In terms of drawbacks, the first user in Bagarkot, the male teacher noted, “We can dry increased quantity through sun drying, but in the solar dryer, the size is fixed, so quantity is also fixed.” However, one of the women farmers in Belapur said:

> “If we relate the quantity and time and compare between both methods, I think the quantity that can be dried in the sun is equal to the quantity that can be dried in chimney solar dryer. Because we can pull out the produce twice from the solar dryer in the same amount of time [as the] roof.”

Compared to the essentially unlimited capacity of sun drying, the limited capacity, especially of the smaller chimney dryer, is a valid potential concern for farmers who are interested in commercial drying. For commercial or shared use, the consensus is that the original size (12-foot-long table) is better. However, for many farmers who intend to use it for limited household use, the reduced size (8-foot-long table) will likely work well.

4.4 Ease of use

In terms of chimney dryer usage once it is constructed, this technology is relatively easy to use. One user in Bagarkot said, "after learning the skill, nothing was difficult" and the first user in Bagarkot, the male teacher said:

> "Yes. Although the building procedure seems hard, the using procedure is quite easy…Opening the dryer was the easiest and the most difficult was learning how much quantity is adequate to fill in the trays, and how frequently the trays should be rotated."

This user did not attend the training, which might explain why he was unsure of how much to fill the trays and rotation frequency. However, his comment raises an important point that these nuanced facets of the drying process should be clarified in any training activities to reduce barriers to usage. Other women farmers in the endline FGDs also said that the dryer is easy to use, and especially helpful because they "don't have to look after [the food product] because it's protected…from dust and children," and "there is no tension of our goats eating the products left for drying when we put products inside the dryer." While the dryer is fairly low-tech and relatively simple to use, there are key aspects like ensuring that the plastic is properly sealed around the back of the dryer near the chimney and along the sides. If the plastic is not secured, then air will not flow optimally across the product. During the training activities, both at the trainer and community levels, I observed that participants struggled to adequately secure the plastic, which could be cumbersome with the bicycle tire tube, scrap wood, and other pieces used to create the seal.

Besides the act of physically using the dryer, another aspect of ease of use is related to logistics around sharing the dryer. I expected that sharing the dryer among multiple households and planning for community usage might be a more challenging aspect of using the dryer. However, farmers thought they would have no issues creating a schedule or devising a plan for sharing. For example, both villages are committed to following a dryer-usage schedule in which community members rotate and take turns. During the community-use planning session in

Belapur, one group intended to have two users share the dryer simultaneously, each using three trays, and even wrote, "we will give time for the people who are out of our group and interested [to use the dryer] without bringing conflict." The plan in Bagarkot included at least three farmers using the dryer in one rotation, and in Belapur, the rotation would be based on "need, time and weather." The VMF in Belapur even said that "sharing [among] 2-4 households in the group is better because everybody may not have enough product to dry all the time." Besides more efficient use of the dryer, the benefit of collective usage is around shared labor and cost, the latter which will be discussed more in the next section. One of the women farmers in Belapur said, "Although I am far, [the village model farmer] will take care of my produce and will rotate those trays once a day," which has potential to spread the workload across multiple community members. However, there is the potential for too many households to be sharing one dryer. In Bagarkot, the women farmers said that between 20-30 families are located nearby, and the *Suaahara* staff person cautioned them that "if all the community people tried to dry in one dryer, your turn won't come even once a year."

4.5 Dryer affordability and cost recovery

Affordability represents a critical component of technology adoption. My partners and I assessed the cost of the chimney dryers first hand by building three in Dadeldhura. Because we were unsure of the availability of the construction materials in Dadeldhura, we purchased the clear plastic and stainless-steel mesh for all three chimney dryers in Dhangadhi (a city on the *terai* near the border with India that we flew into from Kathmandu before driving to the field site). We wanted to test different materials for the black covering over the table, so we purchased black plastic for the chimney dryer that we constructed for demonstration purposes at the partner NGO office, and black cloth for both of the chimney dryers constructed in Bagarkot and Belapur. We purchased the wood and bamboo in Dadeldhura from a few different furniture shops, as well as local farmers in the communities who were growing bamboo. Costs of carpenter labor varied according to the number of people who worked on preparing the wood and actually constructing the dryers, as well as the number of days required. Thus, we had three different actual cost schemes for each chimney dryer we built in Dadeldhura and have added an additional "most affordable combination" scheme (in both Nepalese Rupees and U.S. Dollars) to show the most affordable possible scenario for constructing a chimney dryer in Dadeldhura, based on our actual costs (Table 2).

Table 2. Nepal chimney dryer costs from October-November 2018 based on construction of three different dryers.

Item	**RUWDUC** (12-foot-long table, 10 trays)	**Bagarkot** (8-foot-long table, 6 trays)	**Belapur** (8-foot-long table, 6 trays)	**Most affordable combination** (8-foot-long table, 6 trays) NPR ($USD)
Clear plastic	रु560	रु560	रु560	रु560 ($4.78)
Metal mesh	रु1,400	रु840	रु840	रु840 ($7.38)
Black fabric/plastic	रु836 (plastic)	रु1,260 (fabric)	रु1,260 (fabric)	रु836 (plastic) ($7.35)
Wood/bamboo	रु15,400	रु7,700	रु8,900	रु7,700 ($67.68)
Carpenter labor	Included in wood above	रु6,000 (2 people)	रु3,300 (1 person)	रु3,300 ($29)
Total	**रु18,196 ($159.93*)**	**रु16,450 ($144.58*)**	**रु14,860 ($130.61*)**	**रु13,236 ($116.33*)**

*Conversion rate from February 3, 2019

In comparing the estimates provided in July 2018 (Table 1) with the actual costs in October-November 2018 (Table 2), the clear plastic was less than half the estimated cost (560 NPR compared to 1,240 NPR). The metal mesh was less than half the price of HKI's initial estimate (1,400 NPR compared to 3,000 NPR). Both the black plastic and black cloth, however, were more expensive than we had initially budgeted for by (836 NPR for the black plastic and 1,260 NPR for the black fabric, compared to the 600 NPR estimated). The wood was also more expensive than the initial budget for a full size 12-foot-long dryer: 15,400 NPR compared to 10,249 NPR, though it is unclear from the initial cost estimates provided by HKI if these included carpenter labor. However, for a full-size dryer, the actual total costs were very close to the initial overall estimate due to the price differences across all the different materials: रु18,196 compared to रु18,089, which is equivalent to about $1 USD. Thus, when seeking to build a smaller dryer with a table that is only 8-feet-long instead of 12-feet-long and only has six trays instead of 10 trays, the costs decrease significantly, and the most affordable combination of material and labor costs result in a dryer that is only रु13,236 or $116.33. However, it should be noted that if the cost was compared based on the actual square meters of drying area rather than total cost, the larger dryers are likely more cost effective when factoring in carpenter labor.

Besides maximizing the use of the chimney dryer through households sharing, constructing chimney dryers as a small group also makes the technology more affordable. In addition to seeking budget support from the local government or NGOs, women discussed pooling resources from their women's groups or sharing the dryers in groups of 3-6 households. For example, during the endline FGD in Bagarkot, we asked the women if anyone was interested in building a chimney dryer in their own home, and they said:

> **Farmer #1:** we can't think alone…
>
> **Farmer #2:** we can't build alone but we can build in the group of 3-4 families.
>
> **VMF:** if 4-5 families are interested, then we can build and share one.
>
> **Moderator:** so, you prefer sharing in a 4-5-person group to building individually?
>
> **VMF:** five families a dryer is perfect.
>
> **Moderator:** 1000-2000 [NPR], if you have enough wood you don't even need 5000 [NPR] to invest.
>
> **Farmer #1 and VMF:** we already have one for our use. If one is built up the village and one down the village, then we can use easily.
>
> **Farmer #2:** it is better to share one than building individually.

In general, estimates for farmers' willingness to pay were similar across stakeholders (Table 3).

Table 3. Perceptions of willingness to pay for a chimney solar dryer based on focus group discussions and key informant interviews.

Stakeholder	Willingness to pay in NPR	Equivalent USD*
Woman farmer in Belapur	8,000-10,000	$72-90
VMF in Belapur	7,000-8,000	$63-72
Man user in Bagarkot	5,000-10,000	$45-90
Husband of first user in Belapur	8,000-10,000	$72-90
Man farmer in Belapur	"I can use my own wood but I have to buy fabric, plastic etc. from the market…If I can get all materials except wood, I can spend 1,000-1,500"	$9-14
Suaahara staff person	Up to 10,000 for an individual	$90
Range for an individual household in Dadeldhura based on above data	**1,000-10,000**	**$9-90**
Average for an individual household in Dadeldhura based on above data	**7,375**	**$67**

*Conversion rate from May 5, 2019

There were also several quotations from partner NGO staff members that illustrate their perceptions of affordability and community members' willingness to pay for a chimney dryer:

> **Partner NGO staff member:** 5,000 ($45 USD) is not a joke for community people.
>
> **Field Supervisor for Belapur:** I think it is hard to afford personally. It is suitable for mass production and collection centers.
>
> ***Suaahara* staff person*:*** Up to 25-30k ($225-271 USD) at the group level.
>
> **Senior administrator at a partner NGO:** It depends on the exact community…[some ethnic groups] can afford 15-20k ($235-180 USD). If you go in the north of the far west [e.g. Dadeldhura], then people are poorer.

I should note that when we asked the women in Belapur, many agreed that they could not estimate their household's willingness to pay:

> **Farmer #1:** I am not sure.
>
> **Farmer #2:** we should first ask and discuss in our family.
>
> **Farmer #3:** if family is convinced, we are interested to spend.

Separately, even one of the men farmers in Belapur noted that "we can't decide alone so we have to ask in [our farmer] group." In Bagarkot, women expressed variation across families:

> **Farmer #1:** in some families, they give permission. In some, they don't allow.
>
> **Farmer #2:** if [the chimney dryer] costs 10-15,000 [NPR], they will say it is better to sun dry than to invest.
>
> **Farmer #1**: in some families, they don't have enough money to spend.

Knowing that the solar dryer might be too expensive for individual households to pay for, I inquired with one of the staff people from HKI about how people will pay for the dryer, including for building and repair, and if there are credit or financing mechanisms available. He responded:

> "If individual farmers think that this will give them sufficient returns from the investment in building the dryer and producing dried foods, they would definitely value it. They need to be convinced about the benefits and agree, then they would be ready to use their own funds to pay. Some can finance themselves, others might need microfinance or credit services. But the fact is that farmers need to be fully agreement that it will give sufficient returns…selling the product and getting money. They have their own traditional practice – people prefer to sell fresh, especially those who are nearby a market. Drying and storage is drudgerous work and takes space, so we need to convince them that if they build a dryer and produce dried product, they can sell and earn money, more than just selling fresh."

This sentiment that farmers need to be convinced was shared by the Executive Director of one of the partner NGOs:

> "One thing we should think about is how the dryer can benefit the community. If they invest 15,000 [NPR] and they can earn this money in 3-5 months, they would be willing to pay for the dryer by getting a microloan from a microfinance bank or cooperative, [which is] very accessible. But we have to convey and show them the benefits…

> nutritional value, financial benefits…Specifically, farmers are thinking about the financial benefit and cost benefit analysis – how many months will it take for them to recover income."

This return on investment estimate was corroborated by a farmer's calculations as well. When we asked Bagarkot's first user how many years or seasons it would take for him to recover the cost of constructing a chimney solar dryer of his own. He responded by saying:

> "If I dried continuously and the weather is clear, I can dry 5 times a month. Then for 6 months, this would be 30 times. And in one shift, if I will be able to get 1 kg of dried food, then that would be 30 kg dried product in 6 months. If we get a reasonable price for that 30 kg of dried products, then the cost will be recovered in six months only. If the cost [of the chimney dryer] is under 10,000 NPR, it will be recovered in six months."

We were not able to verify his calculations, but he seemed confident and unconcerned about the cost of the dryer, with the caveat that he would be able to earn a good price for his dried product.

Besides households pooling resources and sharing dryers, government subsidies are another option that emerged. For example, the ward chair from Belapur attended our training and expressed his willingness to provide a 50% subsidy for 100 dryers in this community, which would cover all 500-600 families in the village if they share. However, some would argue for caution with regard to subsidies. According to one of the chimney dryer designers:

> "This is a great example of the disadvantage of using incentives to foster change. Good, contextually appropriate ideas do not need incentives…subsidies can be a real detriment to developing viable local businesses because they condition farmers to expect a subsidized price in the future when subsidies end. The government's role needs to be carefully limited. I favor the government promoting the value of the dry chain and not becoming part of business efforts."

We definitely encountered different opinions with regard to governments or NGOs provisioning monetary support for the chimney dryer, versus the role that the private sector can play in promoting this technology.

4.6 Food availability, quality and safety

4.6.1 Food availability.

Food availability, quality and safety make up the first domain of the INGENAES Gender Technology Assessment. During the baseline FGD in Bagarkot, one woman forecasted, "I think we can dry *more* products in [the chimney dryer], that's why we won't have to spoil the vegetables when the market is saturated" (emphasis added). Even though her comment does not capture the relatively limited capacity of the chimney dryer compared to traditional sun drying, it does reflect a sentiment that more product could potentially be dried and less lost over all. Similarly, at endline, a different farmer in Bagarkot commented that the chimney dryer "will make our life easier because it will increase the availability of food" and another said, "vegetables will always be available for eating" when asked about the consequences of adopting the chimney dryer. We also asked farmers in Belapur how they thought the dryer might change the food available for household consumption, and the VMF responded that the chimney dryer "makes a difference because we can sell, as well as we can consume more…we are used to drying other vegetables, but we didn't know we can dry tomatoes also… now we can consume tomatoes in the dry season." Other women chimed in by saying "consumption and availability in the dry season will increase significantly." This series of comments is more of a reflection on the larger chimney dryer training activities, which elucidated new drying techniques, as well as different crops to dry. One of the men farmers from Belapur also explained how the chimney dryer will increase food availability: "consumption will be increased because there won't be spoilage of dried food as before."

4.6.2 Food quality.

In addition to the quantity of food available for consumption, there was also the belief among some community members that the chimney-dried foods are higher quality, including more colorful, tastier and more nutritious than the sun-dried product. My partners and I dried orange-fleshed sweet potato (OFSP) during the community-level training in Bagarkot. After one day of drying (despite the fact that the product had not yet completely dried), the differences in color were very noticeable, with the chimney-dried product maintaining a bright orange color compared to the sun-dried OFSP (Figure 12), which could be an indicator of beta-carotene retention and thus improved nutrition. Farmers and NGO partners were equally impressed by this difference.

Figure 12. Orange-fleshed sweet potato dried in the open sun (left) and chimney dryer (right) in Nepal, demonstrating color retention from product being dried in the chimney dryer. Photo taken by Lauren Howe, 2018.

Another example was the man user in Bagarkot who said that one of the advantages of the chimney dryer compared to traditional drying was that "the original color…and shape are preserved in the products dried in the dryer, so consumers may be attracted to it. [This] will encourage people to eat it, even if they have not tried dried vegetables before." Separately, men in Belapur agreed at endline that "color will also be preserved" for foods dried in the chimney dryer, and that "nutrients will be less compared to fresh but more than open sun-dried vegetables." The village model farmers in both study sites shared similar sentiments:

> **VMF from Belapur:** it's good that there is no color change in the dried products obtained from the dryer. Now I don't want to eat the products that I dried before on the roof…[The product dried in the chimney dryer is] cleaner, more nutritious and color is preserved. That's why I don't want to eat the products that I previously dried in the sun. We have compared.
>
> **VMF from Bagarkot:** we just started using the chimney solar dryer, and we liked the taste. So, we can incorporate the dried products in our daily diet…[Chimney-dried product] will be tastier and nutritious …There won't be as many nutrients as in fresh, but it's better than that of open sun-dried products.

Likewise, the first man user in Bagarkot stated, "I tasted the dried cauliflower, and the taste was also good." Related to taste, our moderator asked how the chimney dryer would affect consumption practices, and one of the woman farmers in Belapur tried the dried products from the training and said, "the dried products obtained from dryer are tastier." Although the farmers seem convinced, neither nutrition retention nor taste were quantified during this study, so the actual degree to which chimney-dried product is more nutritious or palatable than sun-dried remains to be measured. However, for the purposes of technology adoption, this quantification may not be immediately necessary, as shifting farmers' perceptions is arguably just as important as generating scientifically-valid results for the community to change their practices.

4.6.3 Food safety.

Food safety is the third component of this INGENAES Gender Technology Assessment domain. As was discovered during the initial community assessment, it is quite common for dried products that are exposed in the open sun to come into contact with flies, dirt, and animals. This realization came to light during the baseline FGD in Belapur during which farmers expressed being unaware that their previous method of open-air sun drying was unsanitary due to contamination from pests and weather. A woman farmer said, “we were unknowingly following an unhygienic method, but now we are aware,” and the female community health volunteer chimed in by saying, “we will improve our practices for our health.” These feelings carried over through endline when one young mother-farmer in Belapur said, the chimney dryer keeps food “protected from dust and smoke. Animals can’t eat, birds can’t contaminate by their feces, that’s why it is sanitary and protected.” Separately, during the FGD made up of men in Belapur, one farmer said, “it will make a big difference because [the food in the chimney dryer] is protected from dust…there won’t be any contamination by birds’ urine and feces. That’s why it is protected.” Furthermore, these feelings were not just isolated to Belapur, but also expressed by farmers in Bagarkot, almost verbatim. During our endline focus group discussion in Bagarkot, when asked what has encouraged the farmers to use the dryer, one woman said, the product “is protected from dust, flies…in open drying, flies contaminate the products.” In response to what types of changes the chimney dryer might bring to their lives, women here said, “when we used to dry in *nanglo* and *supo*, there was tension about the dust and animals. But in the chimney solar dryer, [the food] is protected” while they are working in the field, and “we should only check if it is completely dried or not, otherwise we are carefree.” The parallel sentiments echoed by both women and men in both villages indicate that interest in the technology seems to be driven by common motives, including improved drying, food safety and hygiene. However, it is possible that farmers were simply repeating content from the training rather than speaking from personal observation and actual experience, a nuance that was impossible to tease out.

4.7 Time and workload

One of the initial areas of interest in my research question was how the chimney dryer will impact time and workload of the users, especially women, which is the second domain of the INGENAES Gender Technology Assessment. It was expected that these solar dryers would improve the drying process, making it faster and more hygienic than the traditional method of open-air sun drying. Moreover, since women are typically the household food managers, the primary individuals carrying out drying activities in their communities, and were targeted by *Suaahara* as the main participants in our training activities, it was expected that they would experience the benefits of the chimney dryer relatively more than other members of the household in terms of time and workload. Because the time between baseline and endline was so limited, we mainly assessed people's *perceptions* of time and workload effects.

Related to gender, multiple people, including men and women, thought that women would benefit more than men from the reduced workload because women are the primary dryers. For example, an agricultural extensionist from Bagarkot said, "As women are engaged in field work all day, they don't have to pay attention to the product they have left for drying regarding animals and insects." Although he did not attend our training in the community, his instincts about the benefits of the dryer were very much aligned with the opinions of the women farmers we trained and interviewed, who ubiquitously agreed that they would benefit the most. For example, during the endline FGD, a woman farmer in Bagarkot anticipated that "[The chimney dryer] will make our lives easier because…our time will be saved because our products will be dried soon." Similarly, the Executive Director of one of the partner NGOs said that "[benefits] are equal for male and female, but the workload of females can be reduced." And although a man, the first user in Bagarkot did experience time savings firsthand, expressing his belief that he saved about 3-4 days in drying his 5-6 kg of cauliflower. Our team also showed time savings of several hours (which varied by food product) in running our comparative drying experiments, which will be further discussed in a later section. Thus, time saved is a true benefit of the chimney dryer compared to traditional sun drying, especially knowing that product can spoil more easily if left out for days at a time under cloudy or suboptimal drying conditions. Moreover, farmers can leave their product in the dryer all day, and even potentially during the evenings, with minimal stress. They might only need to devote 5-10 minutes a day to rotate the trays, which we expect will only add minimum tasks to women's existing workload.

Furthermore, the chimney dryer may actually save time because of the mesh trays, which allow air to circulate on all sides of the product. This air circulation helps ensure uniform drying, preventing users from having to turn or flip the food products piece by piece as they might with traditional sun drying on a solid surface where product does not receive airflow from the bottom.

In addition to women benefiting, other farmers responded to our question of who they thought would benefit the most from the improved solar dryer. One farmer said, "My parents because they dry and have to pay attention 3+ times a day…to turn those pieces, that would disturb them in their other work." Another commented from a long-term standpoint that "if [the chimney dryer] will be profitable, then I will separate some part for savings for my children." Similarly related to long-term community adoption, the village model farmer in Bagarkot noted:

> "Once we get the chance to dry in the solar dryer, the improved method, this practice will be transferred to future generations. The whole family will learn how to use the chimney solar dryer. We can teach our children to use the solar dryer for drying vegetables, so the use of the chimney solar dryer will increase."

We were encouraged by the foresight and optimism of the farmers when presented with this new technology.

4.8 Reactions to the DryCard

Farmers in Dadeldhura reacted very positively to the DryCard as a technique to supplement their traditional practices. In fact, men farmers in Belapur said they would be willing to spend 500-1,000 NPR for a DryCard ($4-9 USD). *Suaahara* program staff were surprised by farmers' willingness to pay and noted that this was likely an over-exaggeration, but still a positive sign, especially considering that the DryCard costs much less than their willingness to pay estimate. Similarly, the VMF in Belapur was interested in distributing more DryCards to fellow community members when we followed up with her in the endline FGD. A key result of this research is the development of a partnership between the Horticulture

Innovation Lab and local agricultural entrepreneurs who own a company called R&D Innovative Solution. Having submitted a viable and approved business plan, R&D Innovative Solution is now the first manufacturer of DryCards in Nepal, which means that farmers will hopefully be able to purchase this technology locally, including HKI, which plans to run future studies related to aflatoxin development, using the DryCard.

4.9 Storage of dried foods

Following sufficient drying initially, product should be cooled and then properly stored in cool, dry, and dark conditions to extend shelf-life, as inadequate storage (subject to light, high temperatures and high moisture) can lead to the degradation of product quality and safety (Perera, 2005). To combat the development of mycotoxins, prevent insect damage, and extend the shelf life of dried product, hermetic packaging (e.g. airtight plastic bags or containers) is critical because it is moisture, oxygen, and microbe-proof (Bradford et al., 2018). Although some microorganisms can survive in low oxygen environments, hermetic storage restricts the growth of many microorganisms and prevents insects from damaging the product, as these pests generally require both moisture and oxygen to respire and function (Roberts, 1972). In addition to reducing aflatoxin development and insect infestation, hermetic storage has helped overcome the common problems of spoilage, expensive refrigeration, and the need to apply pesticides or fumigants during storage, as well as helping to maintain desirable flavor and aroma by reducing oxygen exposure and absorption of ambient odors (De Bruin, Navarro, Villers, & Wagh, 2012; Perera, 2005). Dried food products should be stored in small quantities to reduce widespread contamination (Brett et al., 1996), and in dry, dark, and cool conditions to extend the shelf life and maintain the quality of dried products (Perera, 2005).

Through baseline FGDs, we learned that current storage methods of dried products are largely in plastic bags or cloth sacks (Figure 13).

Figure 13. Local storage containers for dried food products in Dadeldhura, Nepal: a. cloth bag that does not seal; b. plastic bag that does not seal; c. natural storage in a woven leaf; d. black plastic with a tear in it; e. clear plastic that has been tied off to close; f. open clay pot. Photos taken by Lauren Howe, 2018.

These methods are affordable (or even free), but suboptimal because they are not moisture-proof, which can lead to mold growth. To solve this problem, product needs to be sufficiently dried and properly stored. Farmers already know how to dry, even if their current method is not the most efficient or sanitary. Proper storage practices, however, needed to be promoted. Through our training activities, we emphasized the usage of plastic jars, like the ones that are currently used to store and sell candy and sweets. These jars are reusable and sturdier than polyethylene bags, and readily available, which will increase shelf-life of dried products. We also spoke with local shopkeepers in Belapur, encouraging them to sell plastic containers, which could be made available to local community members at around 20 NPR (around $0.18 USD). As a result, some farmers in Belapur have already changed their storage practices by buying and using airtight containers. In one case, a man farmer in Belapur went out and bought plastic jars immediately after our endline FGD.

4.10 Income generation and market opportunities

If product is adequately dried after harvest, dryness is measured as sufficient for long-term storage without mold growth, and proper storage is maintained, then a logical next step beyond household consumption would be marketing the dried foods. In fact, drying can facilitate the storage, transport, and marketing of fruits and vegetables, especially during the lean season, because the process reduces the product weight and bulk by removing water (Barrett, 2002). I was interested in assessing whether farmers in Dadeldhura were currently selling their dried produce or if this potential existed, which aligns with the INGENAES Gender Technology Assessment in that income and asset generation are the third domain of inquiry, after food availability and quality, and time and workload.

Although home consumption could potentially take priority, especially within the context of nutrition-specific programs, one of our desired short-term outcomes in the project was to increase the desire to sell surplus dried product and raise awareness of potential markets. Through observation during in-person visits, I discovered that some dried foods were already being sold in major cities, especially at Nepali superstores like *Bhatbhateni*, but the farmers we spoke with in Dadeldhura were not currently participating in these supply chains, though many were interested in selling dried foods. This new market opportunity would allow them to dry small quantities at a time, then wait and store it until they have enough dried quantity to aggregate or until market prices increase. Red chili peppers are one key example in Dadeldhura (and across Nepal), as many farmers are producing this crop on a relatively large scale, which leads to low prices. One farmer in Pokhara, a small village outside Amargadhi noted that, “we can get either 15-50 rupees or otherwise it falls to 5 rupees per kg [of fresh product]. In such condition, drying would be more profitable. We can sell dried chilies at 500 rupees per kg.”

Because farmers could potentially earn a much higher income from selling value-added dried product, the incentive to sell fresh may be reduced.

Many stakeholders agree that drying is an effective alternative to product spoilage when prices are low, especially for commercial farmers growing in bulk. Moreover, produce collectors and collection centers may often have higher postharvest losses than individual households, so there may be more potential for the chimney dryer to benefit them. For instance, Belapur's produce collector believed drying could amend the scenario of high postharvest losses due to price fluctuations, as an alternative to disposing of fresh produce behind his shop when prices are low. Farmers could sell him their dried products, which he could then keep in his shop until prices increase. He specifically pointed out that "broadleaf mustard greens would be good dried and sold, as would tomato, radish, and balsam apple because production is high and more is spoiled." The collector pointed out that one kilogram of fresh balsam apple might fetch only 30-35 NPR, but he could potentially sell a kilogram of dried balsam apple for more than 100 NPR. Although we were not able to calculate the conversion rate based on the quantity of dried versus fresh produce, the idea behind his statement was that he believed dried product is considered value added and could thus generate more income than fresh. Furthermore, partially damaged or overripe produce is typically unsellable but can be dried and provide additional income for anyone willing to invest the resources into drying.

Successful sales, however, are dependent upon consumer demand and a reliable customer base or market. Through our key informant interviews and focus group discussions, we learned about a number of possible marketing opportunities for dried foods in Nepal. For example, according to a staff member from a partner NGO whom we interviewed, "In big cities like Kathmandu or Pokhara, the number of conscious buyers…people who are aware of health, ingredients, calories, and read food labels…is growing, but it is still a small number of people and a niche market. However, they are shopping in big markets like *Bhatbhateni*." This view was supported by a *Suaahara* staff member who independently said, consumers in "other market centers might think dried foods are healthy, organic, and nutritious and are ready to buy." While cooking dried produce requires the additional step of rehydrating, if the dried products are already washed, cut and sliced, they can be considered a convenience food that may require less active preparation. Thus, marketing dried foods as convenience foods to middle class or wealthier "conscious consumers" in Kathmandu and other population centers could be a potential option. Other sales outlets include direct sales to government workers, restaurants, hotels, and even tourists. Nepal has a large trekking industry where tourists come from all over the world to hike in the Himalayan mountains. Thus, selling dried foods to trekkers is a promising option, given the lightweight, portable, and convenient nature of dried foods. For this outlet to be promising, however, there needs to be transportation or traders to bring the dried foods from Dadeldhura to the trekking hotspots.

Dried foods should also be considered for general snack foods. I observed and confirmed through our FGDs that in Nepal, salty and crunchy foods are popular for snacks, including popcorn, peanuts, and soybeans. While there is not currently a strong tradition or practice of consuming dried fruits or vegetables as snack foods in Nepal, there is a burgeoning interest in consuming dried fruit in urban centers, which could be also promoted in rural areas, especially for children. Changing consumption patterns within communities can be challenging and acceptability of dried fruits and vegetables as snacks between meals would require intentional marketing efforts. While spending time in Dadeldhura, I noticed that a lot of fruit is being grown, including banana, fig, guava, mango and tomato, none of which were being dried by farmers. In one of our trainings, we dried tomatoes, and it was many farmers' first time tasting them. Thus, dried fruit is an especially viable healthy snack option for both children and adults.

Through our extension activities, we were able to expose community members to "new" foods and increase their knowledge about what is possible to dry. As a result of our informal tasting, some farmers were excited to start drying tomato after the next harvest. In terms of expanding people's palates through community activities, it is promising to both introduce new foods for drying and eating, but also demonstrate examples of dried product that is already familiar (e.g. radish and leafy greens). For example, farmers in Belapur enjoy eating dried balsam apple, which they believe has a taste and texture that resembles meat or fish when it is rehydrated and cooked, which was revealed during the FGDs. This semblance may satisfy cravings for these savory and relatively uncommon animal source foods.

Another potential marketing opportunity could be promoting dried foods as specialty, value added products that are culturally familiar or significant. For instance, when asked if local consumers would accept dried fruits and vegetables in terms of taste, texture, appearance, cooking, culture, and processing standards, a staff person from VDRC noted:

> "If the fresh vegetable is readily available, people don't want to buy dried product. But certain vegetables like *gundruk [*fermented and dried leafy greens], *sinki* [made from fermented and dried radish] used for soup and noodles also have this flavor, *mula ko achar* [dried radish pickle], *masaura* [dried balls of black lentil paste and chopped vegetables]…these dried products are always demanded, and there isn't enough supply. This could be an interesting market opportunity…both restaurants and individual consumers would be interested in buying. In certain franchise-type restaurants, they specialize in making pickle from *sinki* and must have this, individuals too…In my opinion, we should separate two types [of dried foods]: one product is processed and has a changed taste like *sinki* or *gundruk,* which isn't just dried but has a different flavor. These are changing tastes from processing and people definitely like [them], but if we compare fresh to dried cauliflower, then people don't like this."

Thus, not all dried foods have equal palatability, with certain value added, fermented, or otherwise additionally processed dried foods having more consumer appeal than plain dried foods without any further flavoring. Making simple dried foods palatable for a wider audience necessitates consumer marketing and education on the nutritional benefits and culinary uses, as well as taste testing and recipe development. The aforementioned specialty foods: *gundruk,* *sinki*, *masaura* and *mula ko achar* all include dried vegetables and are already sold in superstores and small wet markets. These well-known examples can be further promoted as traditional and value-added foods. Another example is *sisnu* or stinging nettle, which has been widely regarded and in high demand as a health food supplement that claims to address a number of ailments, including diabetes. This underutilized plant grows abundantly throughout Dadeldhura and can be dried and crushed into powder, an idea revealed during one of our KIIs.

According to our interviews, there are several other components of marketing that could be considered in terms of scaling up the production and sales of dried foods. These additional ideas include media campaigns, partnering with agricultural entrepreneurs, and seeking investment and buy-in from super stores like *Bhatbhateni*, which reach many urban consumers and can promote a demand-driven "pull approach" (Garloch, 2015). Farmer cooperatives are another option that could be pursued for collective drying and marketing of dried products.

If a market is developed, then selling dried product has the potential to increase household income. However, returning to the INGENAES Gender Technology Assessment as the guiding framework, a question of interest emerges: to *whom* in the household does the income accrue? According to an interview with a *Suaahara* staff member:

> "If the household head is a man and he is still in Nepal, then he will definitely be involved in selling. He has no restrictions to go to the market and sell, as the economy is controlled by men. Men are interested in selling the dried product but not doing the drying. If they see this is an income generating thing, they will get involved in selling later."

This comment reveals concurrent social dynamics in Nepal, including trends towards male migration outside Nepal, and the fact that men generally have more social freedom and decision-making power compared to women, especially in public and economic spaces. During our FGDs, we learned that husbands or in-laws in tend to be the primary decision makers and heads of household in Dadeldhura as well, and as such, they often control the income. As one agricultural extensionist from Bagarkot noted, “Males are more likely to be early adopters [of the chimney dryer] because they are more up to date with the news, invited to attend trainings, and exposed to new technologies.” He agreed that trainings for the dryer could be mixed gender, however, men involvement with women is better because men have the decision-making power. He continued:

> “It can be a good employment opportunity for males if they start drying commercially… Females can also start commercially selling but they need support from their husbands and families as they are not so used to business and should be made aware about the market and benefits.”

His viewpoint was supported by FGDs, during which men agreed that the “whole family” would benefit from the chimney dryer, but one man in Belapur notably said, “if income is generated, males will benefit.” The most immediate and tangible employment gain, however, may be felt by local carpenters, who are men, as this project can support them in the long-term with the knowledge and skills to construct chimney dryers for other farmers in their villages.

5 Quantitative methods: drying experiments

Conducting the two comparative drying experiments was very successful, as well as useful for the *Suaahara* team. Although not originally part of the project or research plan, this activity was in response to some staff questions as to why the chimney dryer is the best drying alternative. One organizational partner asked about the substitute technology for the chimney dryer, and I explained about the cabinet-style dryer, a version of which has been adopted on a limited basis by *Suaahara* field offices (e.g. in the remote high Himalayan district of Mustang for drying apple). This cabinet dryer was designed by NARC and promoted as part of a *Suaahara* postharvest training last February 2018. However, budget cuts prevented them from rolling out the cabinet dryers to more districts. Furthermore, we received preliminary feedback from local NGOs and training participants during the Training of Trainers workshop that the chimney solar dryer in its current dimensions might actually be too big for most Nepali farmers' household drying needs. Thus, constructing the cabinet dryer and comparing the performance with the chimney dryer and traditional method became crucial for the NGO to understand which dryer they should invest in at the community level in the future.

Using instruments brought from UC Davis, I was able to show graphs of temperature, relative humidity and weight change across all three drying methods (traditional sun drying, cabinet dryer, and chimney dryer). Although the chimney dryer did not reach temperatures as high as the Horticulture Innovation Lab expected, it still dried products (e.g. tomato, balsam apple, leafy greens, and radish) faster than both other methods. Moreover, the chimney dryer has a greater drying capacity than the cabinet dryer and can be built for about the same cost (around $100 USD). Below, I go into greater detail for each experiment.

5.1 Description of drying experiment #1

To complement the qualitative methods of focus group discussions and key informant interviews, we also conducted two quasi-experiments to quantitatively compare the performance of different solar drying methods. We had three treatments:

1. Traditional method (either *nanglo* or *supo* bamboo basket) – **CONTROL GROUP**
2. Cabinet dryer (direct/integral dryer)
3. Chimney dryer (mixed mode: direct and indirect/distributed dryer with airflow)

For these experiments, the research question was: which drying method (traditional, cabinet dryer, or chimney dryer) dries product the fastest? I hypothesized that the chimney dryer would dry product faster than the cabinet dryer (because of airflow), and both the chimney dryer and the cabinet dryer would dry product faster than the traditional method (because of higher drying temperature in the cabinet and chimney dryers). I also made some observations about the general state of each drying method in terms of sanitation, but the main focus was on time required to complete the drying process for each method.

The independent variables in this experiment included the food product and the drying method. The dependent variables included drying time, weight of the product, temperature (inside and outside the dryers), relative humidity (RH, inside the solar dryers and the outside or ambient RH), the product dryness as measured by equilibrium relative humidity (ERH) using the DryCard, airspeed past the product, and solar radiation (estimated by luminosity). The weight of the product was measured using a digital scale (smallest interval of measurement was 1 gram, maximum 5,000 grams). I used HOBO® U12 external data loggers, which can measure temperature and RH, each with an additional temperature probe (placed inside the cabinet dryer and chimney dryer), and one that could measure temperature, RH, and luminosity (placed on the bamboo mat to collect ambient data). Airspeed was observed in the chimney dryer using a piece of tissue paper, but airflow was not measured in the cabinet dryer because it is not part of the design. General ambient weather conditions were also recorded from the Earth Null School online database (Earth.nullschool.net), which provides data on surface temperature, relative humidity, and windspeed based on geographic coordinates.

I found it particularly important for this experiment to consult closely with my Nepali colleagues and the local community to determine which products to dry, product preparation method, quantity of product, and general drying cultural practices (e.g. how many times they would check on the product, how to measure sufficient dryness, norms around bringing the product inside overnight, etc.). The goal of my discussions with local contacts was to mimic typical drying practices as closely as possible to measure the performance of the improved solar dryers (the cabinet and chimney dryer) under typical or “normal” drying conditions.

Ultimately, for this first experiment, my partners and I decided to dry radish and broadleaf mustard greens (BLM). We started the experiment on November 16, 2018, and finished it after 2.5 days on November 18, having to terminate the experiment early due to a field visit. We worked with a local woman who helped us purchase and prepare the produce (Figure 14). As previously mentioned, the purpose of collaborating with a local woman was that her local knowledge around typical slicing thickness, quantity dried at one time, and measuring sufficient dryness would help inform us about the control group (the traditional drying method on the bamboo baskets), as well as ensure that all the treatments were uniform in product quantity and preparation. We started by purchasing six kilograms of radish (assuming about two kilograms per drying method) and three kilograms of BLM (assuming about one kilogram per drying method). We purchased the produce around 10:30 AM and started washing and preparing the produce around 10:45 AM. The study site was located on the office grounds of RUWDUC, one of *Suaahara*'s partner NGOs in Amargadhi where we hosted the Training of Trainers workshop. The office is located in a part of town called *Tufandada*, which means "windy hill" in Nepali.

Figure 14. A local woman in Amargadhi slicing radish for the first of two solar drying experiments in the fall of 2018 in Dadeldhura, Nepal. Photo taken by Lauren Howe.

Figure 15. Broadleaf mustard greens sliced into thin ribbons on a supo (left) and radish thinly sliced on a nanglo (right), part of a solar drying experiment in November 2018 in Amargadhi, Dadeldhura, Nepal. Photo taken by Lauren Howe.

By noon, all the radish was sliced into thin coins and by 12:45 PM, all the leafy greens were cut into thin ribbons (Figure 15). I first asked the local woman to put a typical amount of radish on the *nanglo* (a round, flat bamboo basket), and after she placed it, I removed it for weighing, and it was about 500 grams. Because we did not want to overload the *nanglo* with too much product, which would severely inhibit the drying process, we used this quantity as a benchmark for loading the cabinet and chimney dryer trays. Thus, to mimic the traditional drying process as closely as possible, we used 500 grams of radish for each drying method. After preparing the BLM, the woman had to leave the experiment site to tend to some personal matters, so I followed her lead and placed enough thinly sliced BLM to fill the *supo* (a deeper bamboo basket) with only minor product overlap. This quantity was close to 250 grams, so we placed 250 grams of BLM on each drying method. In total, we had one tray of each product for each drying method (Figure 16):

- One *nanglo* with 500 g of sliced radish
- One cabinet dryer tray with 500 g of sliced radish
- One chimney dryer tray with 500 g of sliced radish
- One *supo* with 250 g of thinly sliced broadleaf mustard greens
- One cabinet dryer tray with 250 g of thinly sliced broadleaf mustard greens
- One chimney dryer tray with 250 g of thinly sliced broadleaf mustard greens

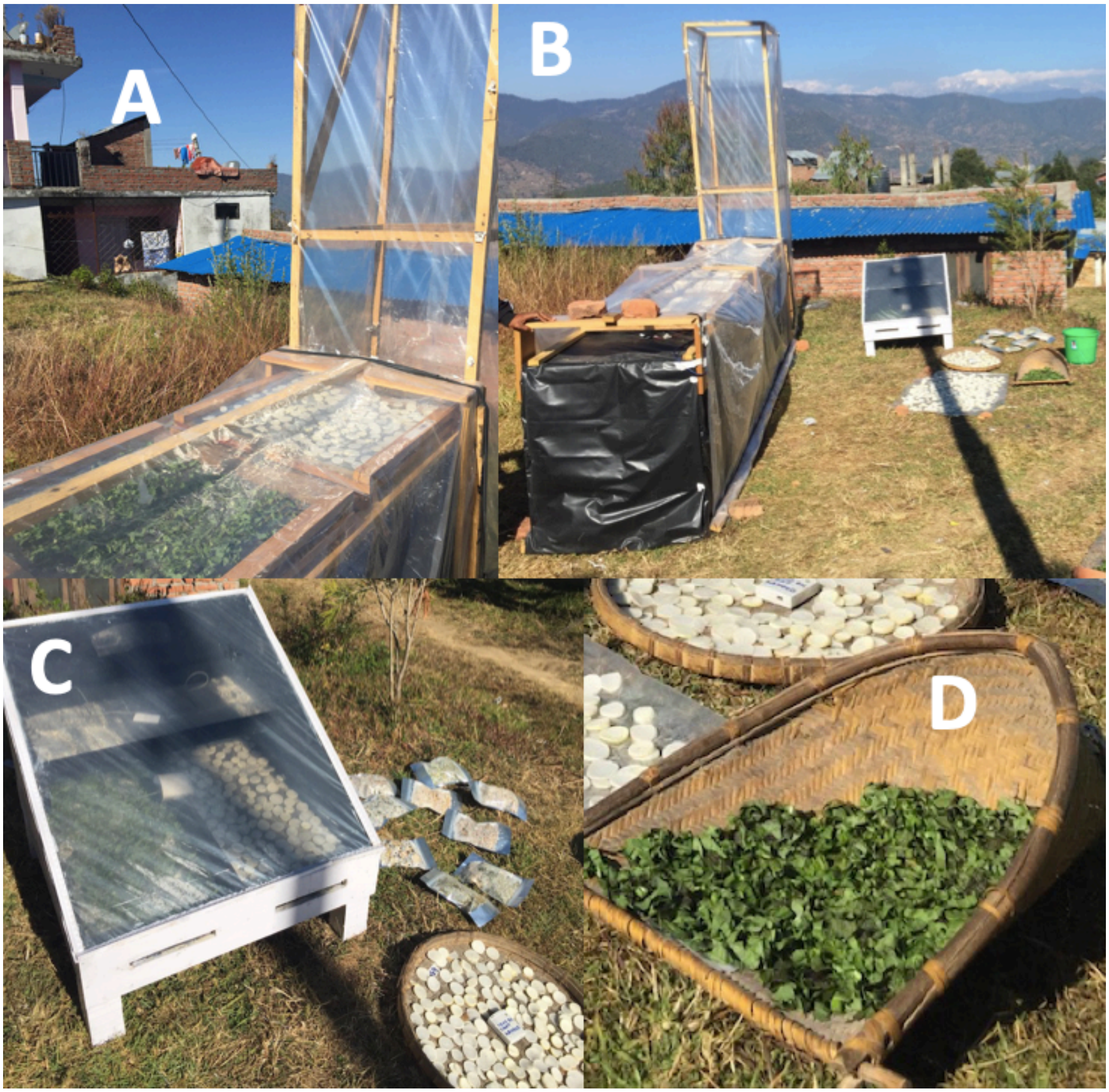

Figure 16. Experimental setup for experiment #1 with radish and broadleaf mustard greens during a drying experiment in Dadeldhura, Nepal in November 2018. a. chimney dryer; b. chimney dryer next to the cabinet dryer and nanglo and supo on the ground; c. cabinet dryer with nanglo; d. supo in the foreground and nanglo in the background. Photos taken by Lauren Howe.

After washing and cutting, we put the products into the dryers around 1 PM and began recording the drying conditions at 1:30 PM. Less than an hour into the drying process, the local woman came back to the study site and at 2:10 PM, she inspected the *nanglo* and meticulously turned each radish coin. At 3:06 PM, we moved the *nanglo* and *supo* into the sun down the hill because the sun was setting and shadows were beginning to reach the bamboo baskets. At this time, the cabinet dryer was shaded and the front end of chimney dryer was shaded as well (though the back portion with the product was still in the sun). At 3:20 PM, we moved the cabinet dryer into the sun and at 3:35 PM, we moved the *nanglo* back up the hill to the sun next to the cabinet dryer. On this first day, we did not rotate the trays because it was only three hours of drying. Based on the local woman's typical practice, which is to bring the *nanglo* with the product inside between 4-5 PM when the sun has set enough to virtually suspend the drying process, we removed the product at 4 PM to weigh it. For this first experiment, during the intermediary weigh-ins (i.e. not the very first at the beginning of the experiment or very last at the end of the experiment), product weights were taken by weighing the entire tray with the product and subtracting the tray weights, which was deemed a less time-consuming method than removing all of the product and replacing it during each weighing session.

Overnight, we put the *nanglo* with the radish into a shed that was covered, but had a screen door that was exposed to the outside conditions. We decided to leave the trays with the product in the chimney and cabinet dryers overnight since they were covered by plastic.

The data measuring devices were set up in the following configuration (Figure 17):

- The HOBO data logger that measures temperature, RH, and light was placed on the *nanglo* with the radish (Figure 17a)
- One HOBO data logger that measures temperature and RH was placed on the lower level of the cabinet dryer between both trays with radish and BLM, with a temperature probe placed on the top tray of the cabinet dryer, which was empty (Figure 17b)
- One HOBO data logger that measures temperature and RH was placed in the center of the chimney dryer table with a temperature probe extended to the back of the table between the last two trays (Figure 17c)

For this first experiment, all HOBOs were logging data in five-minute intervals continuously for the entire experiment.

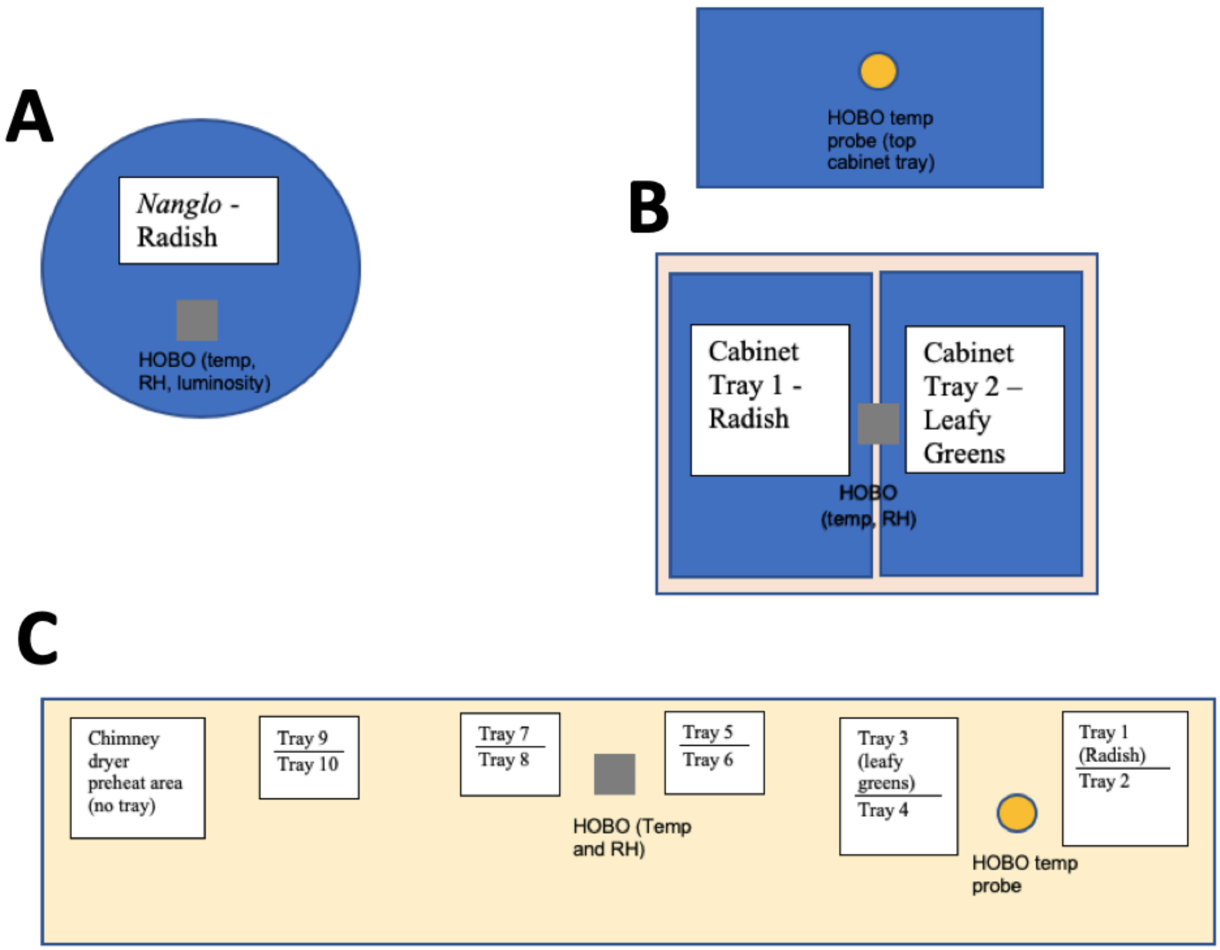

Figure 17. Illustration of instrument placement in solar drying experiments in Dadeldhura, Nepal in the fall of 2018 (a: nanglo; b: cabinet dryer with a top and bottom tray; c: chimney dryer with five tray locations). Created by Lauren Howe, 2018.

For descriptive analysis and data reporting purposes, the temperature averages for the cabinet and chimney dryers were calculated by averaging the temperature readings from the main HOBO unit and the temperature probe. In the case of the cabinet dryer, this meant averaging temperature readings from the bottom tray where the main HOBO unit was with the temperature readings from the top tray where the temperature probe was located (Figure 17b). For the chimney dryer, this meant averaging temperature readings from the main HOBO unit in the middle of the chimney dryer table with those from the temperature probe located at the back of the drying table closer to the chimney (Figure 17c). For both experiments, we used pieces of cardboard as solar shields (Figure 18) to cover the HOBO data loggers and their temperature probes, with the exception of the HOBO that was outside and measures luminosity. The reason for utilizing solar shields was to more accurately measure the ambient temperatures inside the dryers and having solar radiation come into contact with the sensors, even indirectly after passing through the clear plastic, would have significantly increased the temperature readings.

Figure 18. Solar shield (cardboard) covering the HOBO, pictured with broadleaf mustard greens inside a cabinet dryer in a drying experiment in Dadeldhura, Nepal in November 2018. Photo taken by Lauren Howe.

The experiment continued for a full day on November 17, 2018. I arrived on site at 7:38 AM and observed significant condensation development outside on the grass, inside both the cabinet and chimney dryers, and outside on the plastic of both dryers. I opened the plastic on the chimney dryer and spread it over the grass to dry, opened the back door of the cabinet dryer, and took the *nanglo* and *supo* out of the shed and placed them back in the sun near the cabinet dryer. At 8 AM, I rotated the trays inside both the cabinet and chimney dryers (for the cabinet dryer, I swapped the leafy green tray with the radish tray from left to right and for the chimney dryer, I rotated the trays from front to back with the leafy greens now closer to the chimney instead of the radish), and left the dryers open until the water evaporated more from the interior plastic. At 8:25 AM, I moved the cabinet so it was facing the sun (but the back door was still open), and by 9 AM, I closed both dryers despite the fact that all the moisture had still not fully evaporated. At 10:45 AM, I moved the bamboo baskets slightly to stay in the sun, and at noon, I removed the trays and took the weight of the product. By 12:30 PM, the products were back inside the dryers and the dryers were properly closed. At 2:53 PM, I moved the bamboo containers and cabinet dryer to stay in the sun and by 3 PM, the front two-thirds of the chimney dryer was shaded. In fact, by 3:45 PM, the entire chimney dryer was in full shade and the cabinet dryer needed to be moved again to stay in the sun. I took product weight at 4:30 PM now that all drying methods were shaded.

After removing the product from the dryers after the second day, I stored them inside overnight. I put the BLM from the cabinet and chimney dryer into sealed containers with DryCards and kept the BLM from the *supo* into an open container because it was clearly not finished drying (pieces felt moist to the touch). I placed the radish from the cabinet and *nanglo* into open plastic bags (also clearly not dry yet), and put the radish from the chimney dryer into a sealed bag with DryCard, as I suspected it might be done drying but was not certain.

On the third and final day of the experiment (November 18, 2018), I arrived to the study site at 7:45 AM to find a significant amount of condensation inside the dryers (but fortunately, the products were taken inside overnight). I uncovered the chimney dryer and opened the cabinet dryer so the water could evaporate from inside. At this time, there was noticeable cloud coverage and a light breeze. Between 8-9 AM, I weighed the product and by 9:18 AM, the dryers were closed and all the product resumed drying. Around 9:30 AM, the clouds had lifted, and at 12:30 PM, I opened the dryers and took the mid-day weights. By 1 PM, I re-closed the cabinet and chimney dryers after rotating the trays again. Final product weight was taken at 4:15 PM and by 4:40 PM, all the instruments were removed.

5.2 Description of drying experiment #2

A second quantitative experiment was conducted from December 4-12, 2018 (with December 7 and 11 skipped due to field visits for qualitative data collection). The same three drying methods were compared: *supo* (traditional bamboo basket), cabinet dryer, and chimney dryer, at the same drying site (the office of the partner NGO RUWDUC). In this experiment, a *supo* was used for all three products instead of a *nanglo* due to availability. Based on popularity among farmers and advice from the *Suaahara* team, we dried three crops: cauliflower, balsam apple, and tomato. We purchased the products around 9:30 AM, and then began preparing them that morning with the assistance of the same local woman with washing and cutting, as well as a support staff person from RUWDUC. We first removed the large outer leaves of the cauliflower for washing, then after washing, we removed smaller florets for drying, which the woman then cut into even smaller pieces (Figure 19). We sliced the balsam apple into thin strips and cut the tomatoes into thin wedges (Figure 19).

Figure 19. Local woman preparing cauliflower, balsam apple, and tomato for drying experiment #2, which took place in Dadeldhura, Nepal in December 2018. Photo taken by Lauren Howe.

I asked the local woman to place the "normal" amount of each product in one *supo*, and then I weighed this amount and put equal amounts onto the cabinet dryer and chimney dryer trays. Thus, the experiment began with the following product amounts and arrangements:

- One *supo* with 270 g of cauliflower
- One cabinet dryer tray with 270 g of cauliflower
- One chimney dryer tray with 270 g of cauliflower
- One *supo* with 150 g of balsam apple
- One cabinet dryer tray with 150 g of balsam apple
- One chimney dryer tray with 150 g of balsam apple
- One *supo* with 400 g of tomato
- One cabinet dryer tray with 400 g of tomato
- One chimney dryer tray with 400 g of tomato

The locations of the data measuring devices were the same as the previous experiment, with the HOBO data logger that measures temperature, RH, and light placed on the *supo* the entire time. One HOBO data logger that measures temperature and RH was placed on the lower level of the cabinet dryer between both trays, with a temperature probe placed on the top tray of the cabinet dryer. One HOBO data logger that measures temperature and RH was placed in the center of the chimney dryer table with a temperature probe extended to the back of the table between the last two trays (approximately 330 cm from the front of the table). Solar shields were also used on all HOBOs and temperature probes, except the one that measures luminosity, which was placed outside on the *supo* and left unobstructed.

By 1 PM on the first day (December 4), all the products were placed for drying, which is the same time that the HOBOs started logging data. After about three hours of drying at 4:30 PM, we took product out of the dryers and off of the *supo* for weighing. All product was brought inside overnight and stored in unsealed plastic bags during the second experiment, after learning about the condensation that develops inside the dryers overnight during the first experiment.

On day 2 (December 5), I reached the experiment site at 9 AM and by 10 AM, all the product was placed back in their drying positions. Weights were taken and trays were rotated at 1:15 PM, and final weights were taken at 5 PM.

On the third day (December 6), products were placed back in their drying locations by 9:30 AM and at 1 PM, we opened the dryers to rotate the trays and flipped all the product pieces on the *supo* individually so they would dry more evenly (in alignment with traditional drying practices), but we did not weigh the product during midday due to time constraints and to increase the drying time, since it took approximately 30-60 minutes to remove, weigh, and re-place all the products in their respective locations. At 2:15 PM on the third day (December 6), it appeared that all the balsam apple was close to being finished, so I removed it from all the drying methods, weighed it and used the DryCard to measure the dryness. During the weigh in, a small piece was accidentally dropped from both the cabinet and chimney dryer trays, though the lost weight was likely negligible. At this time, the balsam apple that was being dried in the chimney dryer was completely finished (the DryCard was blue and indicated RH less than 65%), while the balsam apple from the cabinet dryer and *supo* were still not completely dried so we put them out again the next day. The cauliflower and tomato weights were taken at 5 PM. All product was stored inside overnight, and we did not dry on December 7, 2018 due to other obligations.

On December 8, I re-commenced another full day of drying, which was the fourth day of the experiment. Product weights were taken in the morning and by 10 AM, all of the products were placed in their respective drying locations. At 1 PM, I weighed the product and had to re-weigh it several times for accuracy due to the presence of children around the drying site who were leaning on the weighing surface and disturbing the scale. At this time, I suspected that the balsam apple from the cabinet dryer and *supo* were sufficiently dried, so I tested them with the DryCard and confirmed that they were indeed finished. I incorrectly assumed that the tomatoes being dried in the chimney dryer were finished, so I removed them at 1 PM for a DryCard test, but they were actually still a little wet. Thus, I missed the last three hours of afternoon drying time for the chimney dryer tomatoes and put them back out the next morning. It is possible that a negligible amount of cauliflower may have dropped during the weighing process. By 1:30 PM, the products were back in their drying locations and final weights were taken at 5 PM. We repeated this process for day 5 (December 9) where products were put in by 9:30 AM, weighed at 1 PM, and pulled at 5 PM to take final weights for the day.

December 10, 2018 was the sixth day of the experiment. All product was inside the dryers by 10:30 AM, weighed at 1:30 and removed from the dryers at 5 PM for weighing. At this time, a DryCard test was done for all products, which revealed that none of the cauliflower was completely dried and neither was the tomato from the *supo*, but the tomatoes being dried in the chimney and cabinet dryers were finished. I skipped drying on December 11 due to a field visit to conduct the endline focus group discussions and interviews in Belapur.

The seventh and final day of the experiment was a half day from 9 AM-1 PM on December 12, 2018. I had to remove all of the products at 1 PM because it started to rain. At this time, the cauliflower in the cabinet dryer was the closest to being dried (based on DryCard color readings), but still around 65% RH. The chimney dryer cauliflower was close to cabinet cauliflower, but had slightly higher RH. The tomatoes on the *supo* were almost dry by the end but were still approximately 65% RH. One remaining question was how can the *supo* have the least amount of weight but still the highest RH? I hypothesized that a few big pieces on the *supo* may not have been fully dried that and was thus causing the entire batch to read as a higher RH. It is also a possibility that there were more pieces in the chimney batch, but were smaller overall, which could have accounted for increased weight, but lower RH. However, cut pieces of all produce was distributed randomly across drying methods.

It should be noted that on most days, whenever weights were taken, the trays of product were rotated. For example, if the tomatoes were located closest to the chimney end of the dryer in the morning, they were moved to the front-end of the chimney dryer after the next weigh in, which was typically done once mid-day. During this second experiment, when I weighed the products, I removed the product completely from the trays and only took product weight (rather than the entire tray and its contents and then subtracting the tray weight as I did in the first experiment). This second method was more accurate, but considerably more time consuming. I also took morning and evening weights inside rather than outside at the drying site because the drying site proved too windy and cold, which made taking accurate weights more difficult, as the scale would change its reading by a few grams when the wind blew.

During this second experiment, I logged temperature, relative humidity, and luminosity data on the HOBOs in 15-minute intervals instead of five-minute intervals as I did with the first experiment to reduce unneeded data points. I also brought all the product inside overnight starting from the beginning of the experiment, rather than leaving it in the dryers overnight on the first night as I did in the first experiment. During the second drying experiment, I observed that the *supo* had pieces of ash on the product because of a fire someone had lit nearby, attesting to the decreased sanitation and hygiene of the traditional drying method.

5.3 Results of the drying experiments

5.3.1 Results from experiment #1: weather, temperature, and relative humidity.

General weather conditions during this first experiment for radish and broadleaf mustard greens can be found in Table 4, which include a mix of sun and clouds from November 16-18, 2018.

Table 4. General weather observations from drying experiment #1 in Dadeldhura, Nepal in November 2018, which compared the chimney dryer, cabinet dryer, and traditional sun drying for radish and broadleaf mustard greens.

Date	Weather Description
Day 1 – November 16, 2018	Sunny and breezy in the afternoon, few wispy clouds towards the end of the day, cool
Day 2 – November 17, 2018	Sunny, breezy in afternoon, warm mid-day
Day 3 – November 18, 2018	Cloudy in the morning until around 10 AM

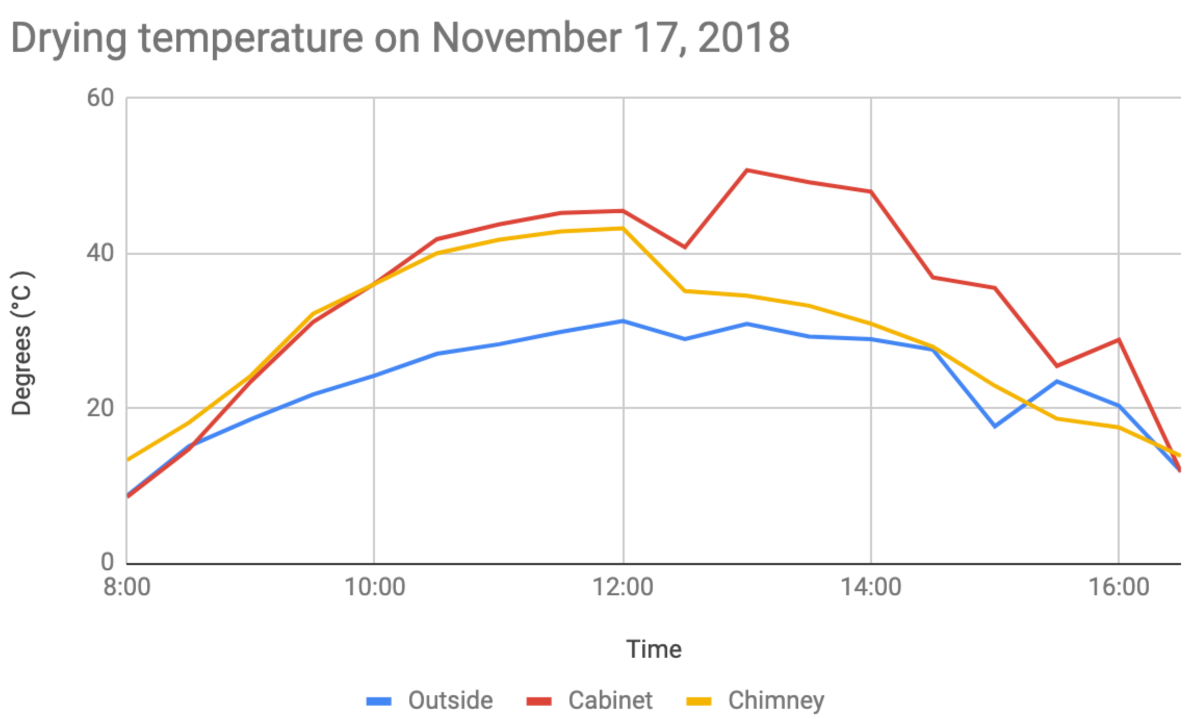

Figure 20. Temperature data on Day 2 (November 17, 2018) during a drying experiment in Dadeldhura, Nepal, which show that the cabinet dryer was consistently warmer than the chimney dryer and traditional sun drying method (outside).

Both the cabinet dryer and the chimney dryer were warmer than the outside temperature, until the end of the day (Figure 20). Averages were taken between the cabinet temperature readings (top and bottom trays) and the chimney dryer readings (temperature probe in the middle of the drying table and back of the drying table near the chimney-end). For the first two hours of the day, the chimney dryer was warmer than the cabinet dryer, whereas the cabinet dryer was the warmest method for the duration of the afternoon. On day 3 (November 18, 2018) under partial clouds, the chimney and cabinet dryers were still warmer than the outside ambient for most of the experiment (except around 1 PM when we opened the dryers to take product weights). In addition, the cabinet dryer was again consistently warmer than the chimney dryer for most of the day.

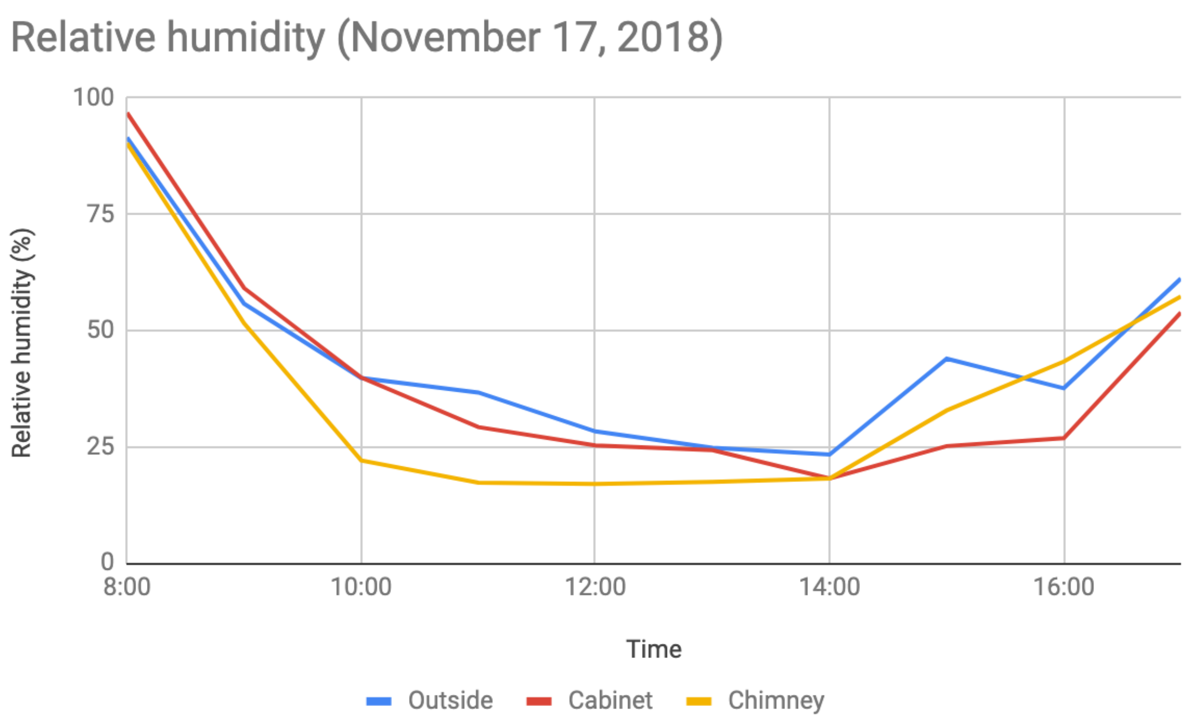

Figure 21. Relative humidity data on day 2 (November 17, 2018) of a drying experiment in Dadeldhura, Nepal, which show that the chimney dryer had lower RH throughout most of the day, until around 2 pm.

On the second day, which was the only full day of drying during the first experiment, the chimney dryer had the lowest relative humidity until 2 PM, after which the cabinet dryer became the lowest RH setting (Figure 21).

5.3.2 Results from experiment #1: radish.

At the end of day 1 (4 PM), all products lost weight, but products in the chimney dryer lost the most weight (42%). Products in the cabinet dryer and *nanglo* lost almost the same amount of weight by the end of the first day (26% and 25%, respectively). Overnight, the radish continued to lose weight, with the radish in the *nanglo* losing the most weight (4%) and the radish in the chimney and cabinet each losing an additional 2% overnight, inside the dryer. Based on touching the products in the morning, the chimney radish felt a little wetter, but still similar to the cabinet radish, whereas the *nanglo* radish had a bit of a crusty film on the outside.

By noon on day 2, the radish in the chimney dryer lost an additional 207 g, almost twice that of the radish in the cabinet dryer, which lost 104 g from 8 AM to noon. The *nanglo* radish lost 125 g, even more than the cabinet dryer radish. By noon, the radish had lost 85% of its starting weight in the chimney, 54% in the *nanglo* and 49% in the cabinet.

At the end of the second day (4:30 PM), the radish in the chimney had lost only an additional 15 g from noon to 4:30. The cabinet radish lost 131 g from noon to 4:30 PM and the *nanglo* radish lost 110 g, putting these two radish weights almost equal by the end of day 2. On day three, from 8:30 AM to 12:30 PM, the products continued to lose weight, with the cabinet dryer radish losing the most weight (62 g), followed by the *nanglo* radish, which lost 48 g, and lastly the chimney dryer radish, which only lost 13 g during the morning. Relatively minimal weight loss occurred during the last afternoon of the experiment, due to more rapid weight loss at the beginning. At the end of the experiment, the *nanglo* radish had lost 90% of total starting weight, 91% for the cabinet-dried radish, and 92% for the chimney-dried radish (Table 5). See Figure 22 for the weight data of the radish experiment. At this time, only the chimney dryer radish had dried completely.

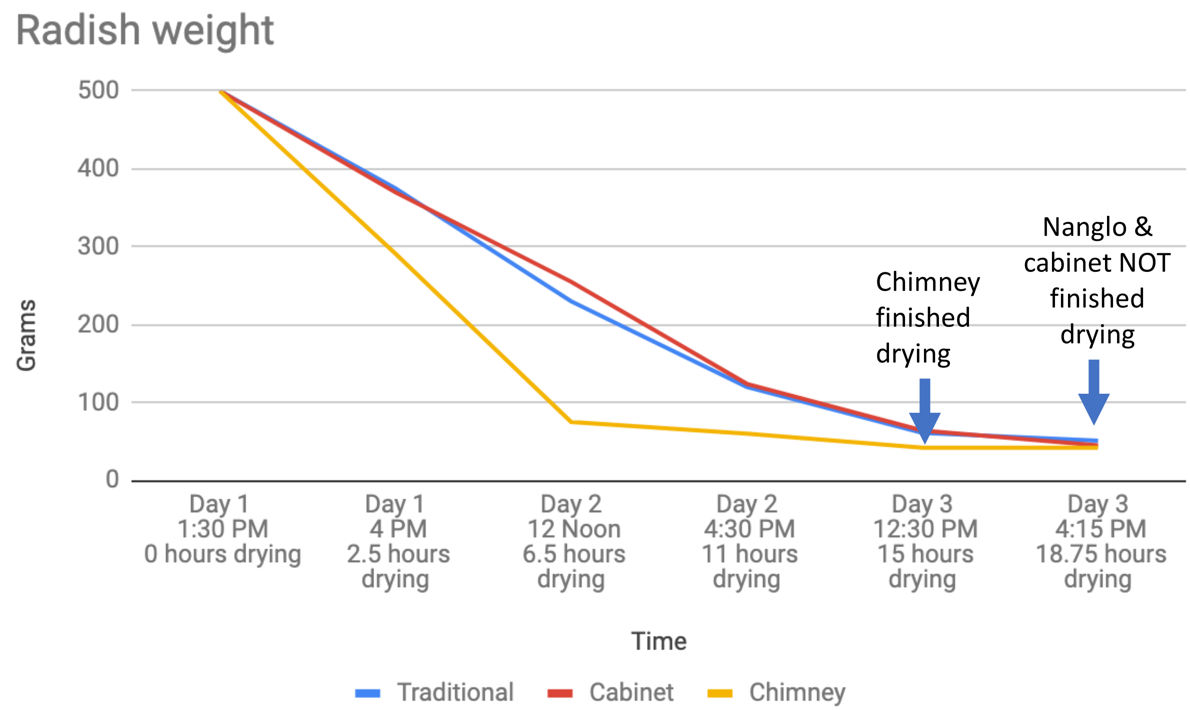

Figure 22. Radish weight in grams in the traditional sun drying method (nanglo), cabinet dryer, and chimney dryer over the course of three days of a drying experiment in Dadeldhura, Nepal in November 2018.

Table 5. Drying radish during an experiment in Dadeldhura, Nepal in December 2018.

Drying method	**Initial weight (g)**	**Final weight (g)**	**Percent weight loss (%)**	**Total time in the dryer (hours)**
Traditional (*nanglo*)	500	51	90	18.75
Cabinet dryer	500	45	91	18.75
Chimney dryer	500	42	92*	15 (3.75 at least partially shaded)

**Dried completely*

Drying method	**Average RH during drying (%)**	**Average air temperature during drying (degrees C)**	**Average solar radiation (Lux)**
Traditional (*nanglo*)	39.0	23.9	15,642
Cabinet dryer	34.5	35.0	15,642
Chimney dryer	30.7	28.8	15,642

Table 6. Drying time required to reach 90% weight loss in radish during a drying experiment in Dadeldhura, Nepal in November 2018.

Drying method	Drying time (hours)	Time difference	Percent difference
Traditional (n*anglo)*	18.75		
Cabinet dryer	17.80	0.95 hours faster than *nanglo*	5.0% faster than *nanglo*
Chimney dryer	13.00	5.75 hours faster than *nanglo*	30.7% faster than *nanglo*
		4.8 hours faster than cabinet dryer	27.0% faster than cabinet dryer

Ninety percent weight loss was selected as the "least common denominator" among the different drying methods for the radish, since the maximum amount of weight loss achieved by the *nanglo* was only 90% (Table 5). Then linear interpolation (Figure 23) was used to estimate the amount of time required for all drying methods to reach this same percent loss, which makes it easier to compare the drying methods. Thus, it is estimated that the chimney dryer is about 31% faster than the traditional drying method (*nanglo*) and approximately 27% faster than the cabinet dryer for radish under these drying conditions (Table 6).

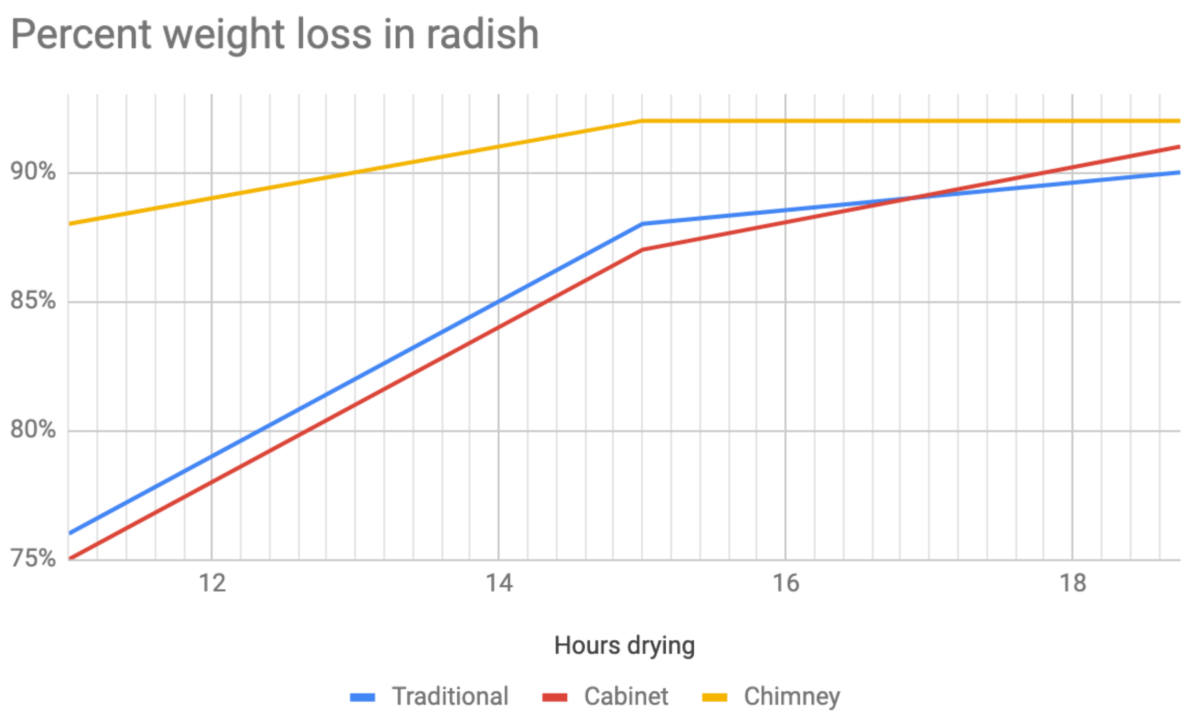

Figure 23. Linear interpolation for percent weight loss in radish to estimate how long it took each drying method to reach 90% weight loss during a drying experiment in Dadeldhura, Nepal in November 2018.

Figure 24. Debris and flies landing on the radish being dried in the nanglo during the first drying experiment in Dadeldhura, Nepal. Photos taken by Lauren Howe, 2018.

The compromised hygiene of the traditional sun drying method also became evident in this experiment, with flies and grass landing on the radish on the *nanglo* (Figure 24).

5.3.3 Results from experiment #1: broadleaf mustard greens.

At the end of day 1 (4 PM), all the leafy greens on each of the three different drying methods had lost weight, with the chimney greens losing the most (131 g), followed by the cabinet dryer greens (117 g) then *supo* greens (86 g). Overnight, the chimney tray of greens actually gained weight (16 g), whereas the cabinet leafy greens remained the same, and the *supo* greens lost an additional 5 g. There was no detectable difference between each tray of leafy greens at the start of the morning on the next day, from feeling by hand.

By noon on the second day, the leafy greens in the cabinet lost the most additional weight (107 g), followed by the greens in the *supo* (94 g), then the greens in the cabinet dryer (82 g). By 4:30 PM, the greens in the chimney dryer only lost an additional 1 g, meaning they were likely 100% dry, but I placed the leafy greens in a sealed container with the DryCard to confirm. From noon to 4:30 PM on day 2, the greens in the cabinet dryer lost 21 g and the *supo* greens lost 31 g. After a mid-day DryCard test, none of the leafy greens were completely dry. By the end of the second day, it was clear that the leafy greens were close to being sufficiently dried, but because the DryCard readings were not clearly below 65% RH, we put them back out the next morning. By 12:30 PM on day 3, all the leafy greens were sufficiently dried based on DryCard readings, however, final product weights were not accurately measured due to user error. Ultimately, my weight data are fairly accurate until 4:30 PM on day 2 when the *supo*-dried leafy greens lost 86% of the total starting weight, the cabinet-dried greens lost 88% and the chimney-dried greens lost 89% (Table 7). See Figure 25 for the weight data of the broadleaf mustard greens experiment.

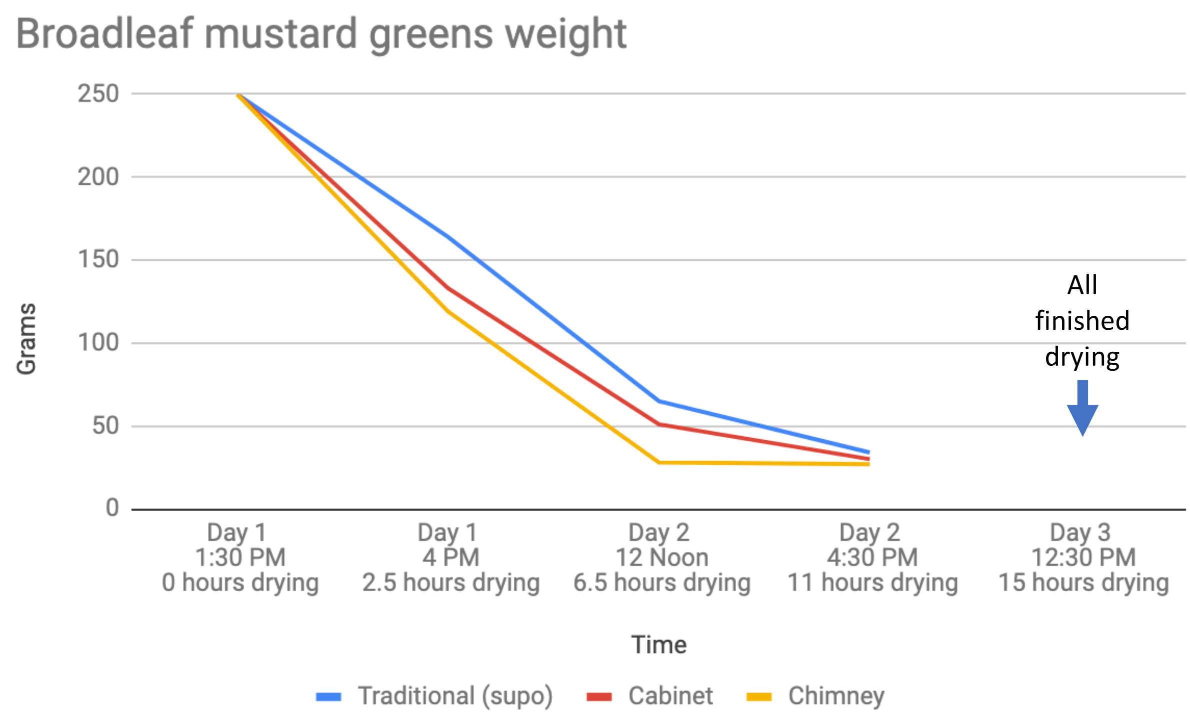

Figure 25. Broadleaf mustard greens weight in grams over a three-day drying experiment using three different drying methods in Dadeldhura, Nepal in November 2018.

Table 7. Drying broadleaf mustard greens during an experiment in Dadeldhura, Nepal in November 2018.

Drying method	**Initial weight (g)**	**Weight at 4:30 PM on day 2 (g)**	**Percent weight loss (%)**	**Total time in the dryer (hours)**
Traditional (*supo*)	250	34	86	11
Cabinet dryer	250	30	88	11
Chimney dryer	250	27	89	11 (1.5 at least partially shaded)

Drying method	**Average RH during drying (%)**	**Average air temperature during drying (degrees C)**	**Average solar radiation (Lux)**
Traditional (*supo*)	40.0	23.7	15,626
Cabinet dryer	37.5	34.7	15,626
Chimney dryer	31.2	29.0	15,626

Table 8. Drying time required to reach 86% weight loss in broadleaf mustard greens during a drying experiment in Dadeldhura, Nepal in November 2018.

Drying method	Drying time	Time difference	Percent difference
Traditional (*supo*)	11 hours		
Cabinet dryer	9.8 hours	1.2 hours faster than *supo*	10.9% faster than *supo*
Chimney dryer	6.2 hours	4.8 hours faster than *supo*	43.63% faster than *supo*
		3.6 hours faster than cabinet dryer	36.73% faster than cabinet dryer

Eighty-six percent weight loss was selected as the "least common denominator" among the different drying methods for the broadleaf mustard greens, since the amount of weight loss achieved by the *supo* was 86% by the end of day 2 (Table 7). Then linear interpolation (Figure 26) was used to estimate the amount of time required for all drying methods to reach this same percent loss, which makes it easier to compare the drying methods. Thus, it is estimated that the chimney dryer is approximately 37% faster than the cabinet dryer, and about 44% faster than the traditional drying method (*supo*) for broadleaf mustard greens under these drying conditions (Table 8).

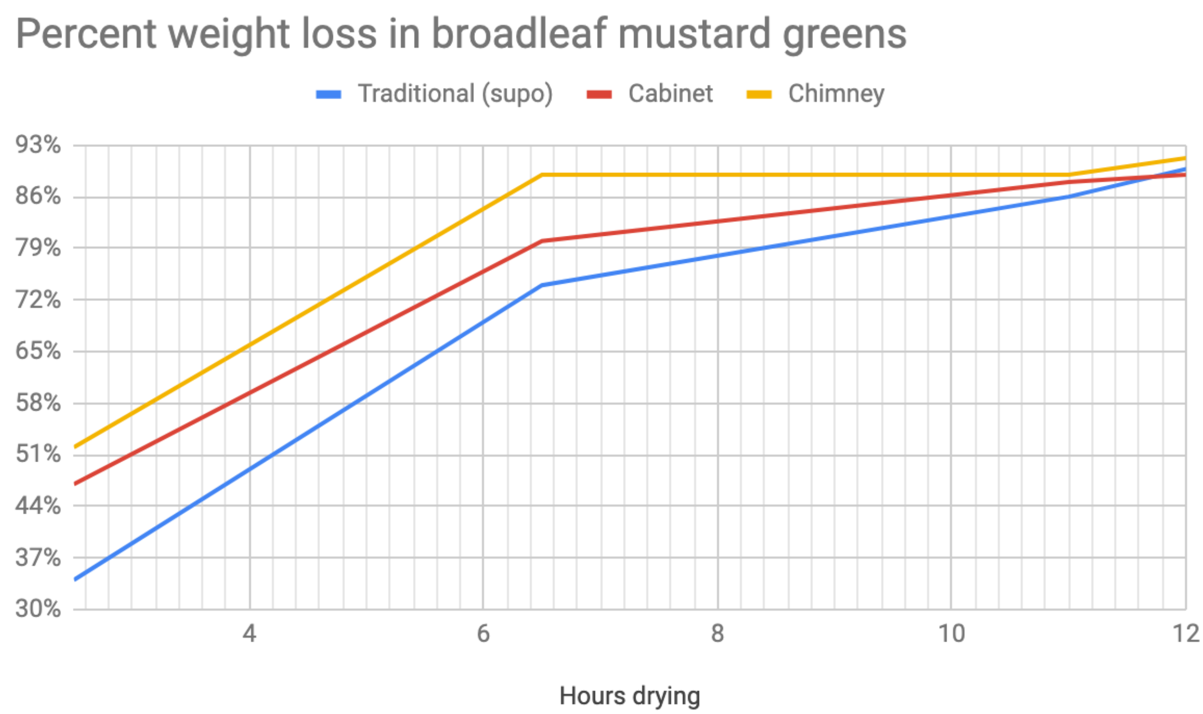

Figure 26. Linear interpolation for percent weight loss in broadleaf mustard greens during a drying experiment in Dadeldhura, Nepal in November 2018.

5.3.4 Results from experiment #2: weather, temperature, and relative humidity.

General weather conditions during the second drying experiment from December 4-12, 2018 for cauliflower, balsam apple and tomato can be found in Table 9, which include a mix of sun and clouds, as well as some rain.

Table 9. General weather observations from drying experiment #2 in Dadeldhura, Nepal (December 2018).

Date	Weather Description
Day 1 – December 4, 2018	Cool, cloudy with intermittent sun
Day 2 – December 5, 2018	Warmer than the previous day, mostly sunny, some intermittent clouds Cloudy from around 1-2 PM
Day 3 – December 6, 2018	Warm and sunny for most of day
Day 4 – December 8, 2018	Warm and sunny all day
Day 5 – December 9, 2018	Warm and sunny all day

Day 6 – December 10, 2018	Sunny morning, intermittent clouds in the afternoon
Day 7 – December 12, 2018	Cloudy all day with afternoon drizzle

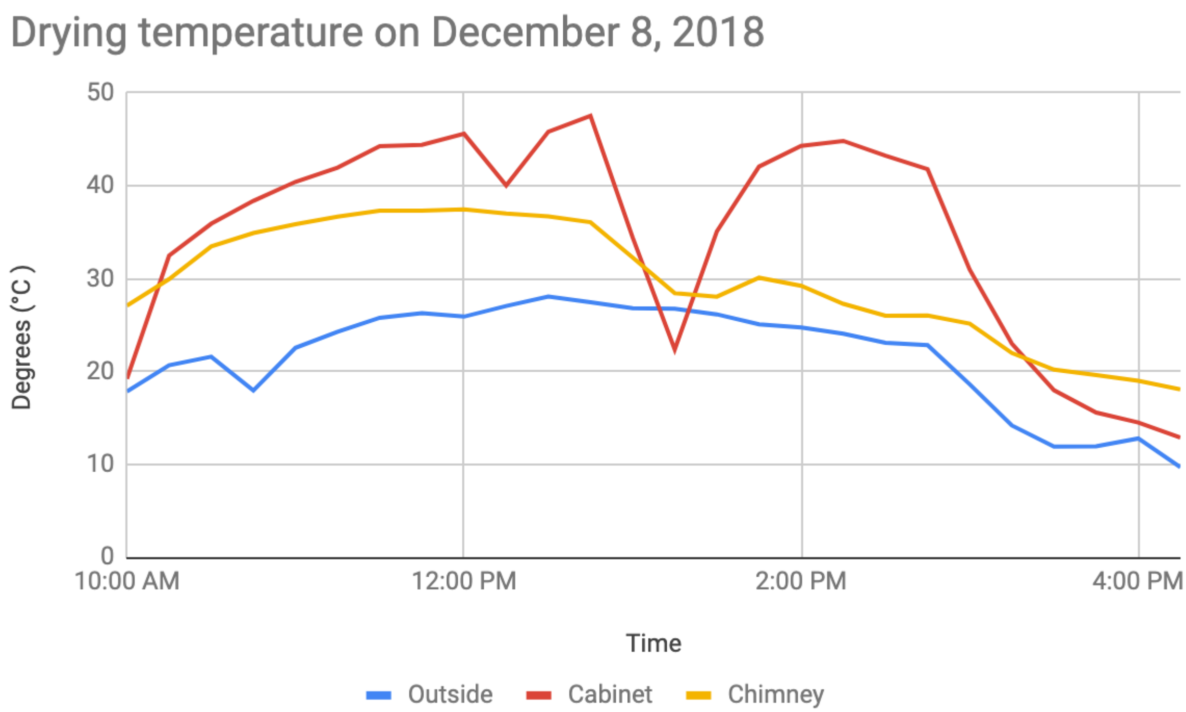

Figure 27. Temperatures in three different dryers during day 4 of a drying experiment in Nepal (December 8, 2018), when it was sunny all day.

Temperature data from December 8, 2018 were selected because it was sunny all day (Table 9, Figure 27). Averages were taken between the cabinet temperature readings (top and bottom trays, Figure 28) and the chimney dryer readings (temperature probe in the middle of the drying table and back of the drying table near the chimney-end). There was a sharp drop in cabinet dryer temperatures after 1 PM because this is when we opened the dryers to take product weights (Figure 27), which resulted in an increase in RH at this time (Figure 29).

Figure 28. Cabinet dryer with a temperature probe on the top tray and the HOBO data logger, also measuring temperature, on the bottom trays during a solar drying experiment in Dadeldhura, Nepal in December 2018. Photo taken by Lauren Howe.

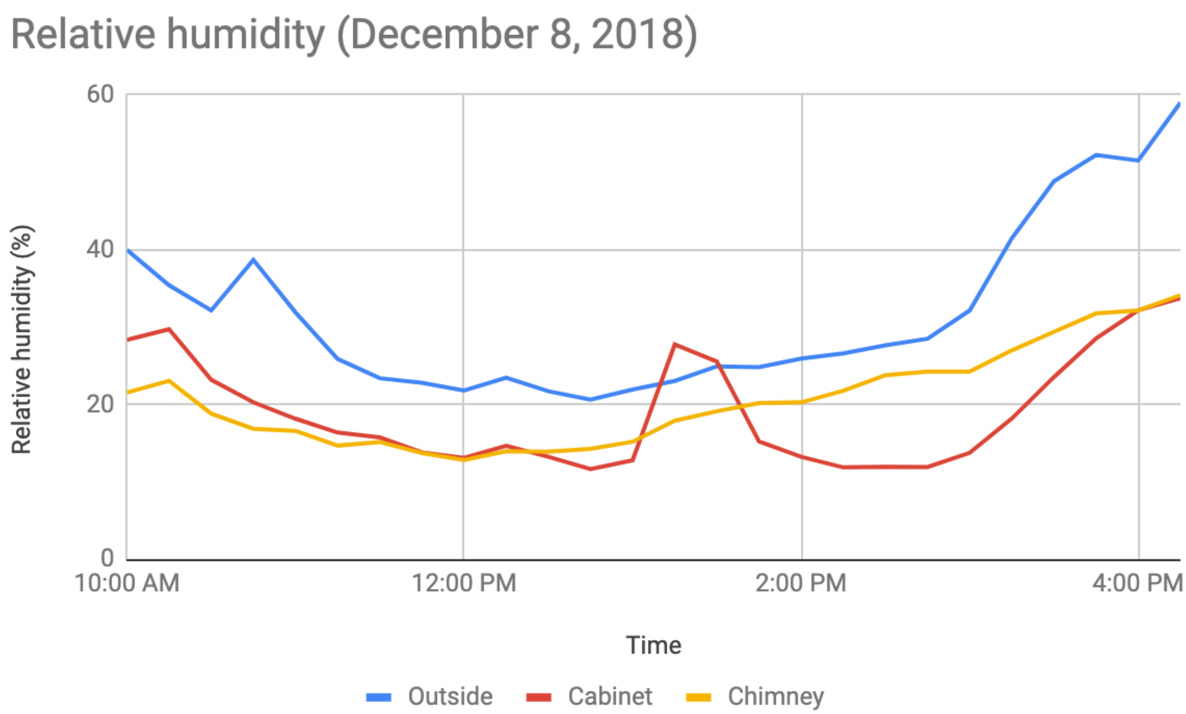

Figure 29. Relative humidity from three different drying methods on day 4 of a drying experiment in Nepal (December 8, 2018).

Relative humidity data were selected from December 8, 2018 (day 4) of the experiment for presentation because it was sunny all day with relatively warmer temperatures than other days (Table 9), when presumably the dryers would have more sun and therefore be removing moisture more quickly. Both the cabinet and chimney dryers had lower RH than the ambient conditions, except for the spike in the cabinet dryer after 1 PM, which is when we opened the dryers to take product weights (Figure 29).

5.3.5 Results from experiment #2: cauliflower.

Until the end of day 3 (December 6, 2018), the cauliflower being dried in the chimney dryer was losing moisture the fastest. However, by this time, both the cabinet and chimney dryer had lost the same amount of weight (213 g or 79% of their starting weight) (Figure 30). From day 3 to day 5, the cabinet and chimney cauliflower stayed within one gram of each other and both were consistently drying faster than the *supo*. After day 5, however, all three methods were performing about the same and none of the cauliflower was completely dried after six full days of drying (42.75 hours) according to DryCard readings, which hovered around 65% RH (Figure 31). Thus, I decided to omit the data for the last two days of this drying experiment (December 10 and 12) due to poor drying conditions, including high relative humidity inside the dryers (above 65% RH), cloud coverage, the low position of the sun due to the winter season, and the fact that I skipped a full day of drying (December 11, 2018) because of a field visit.

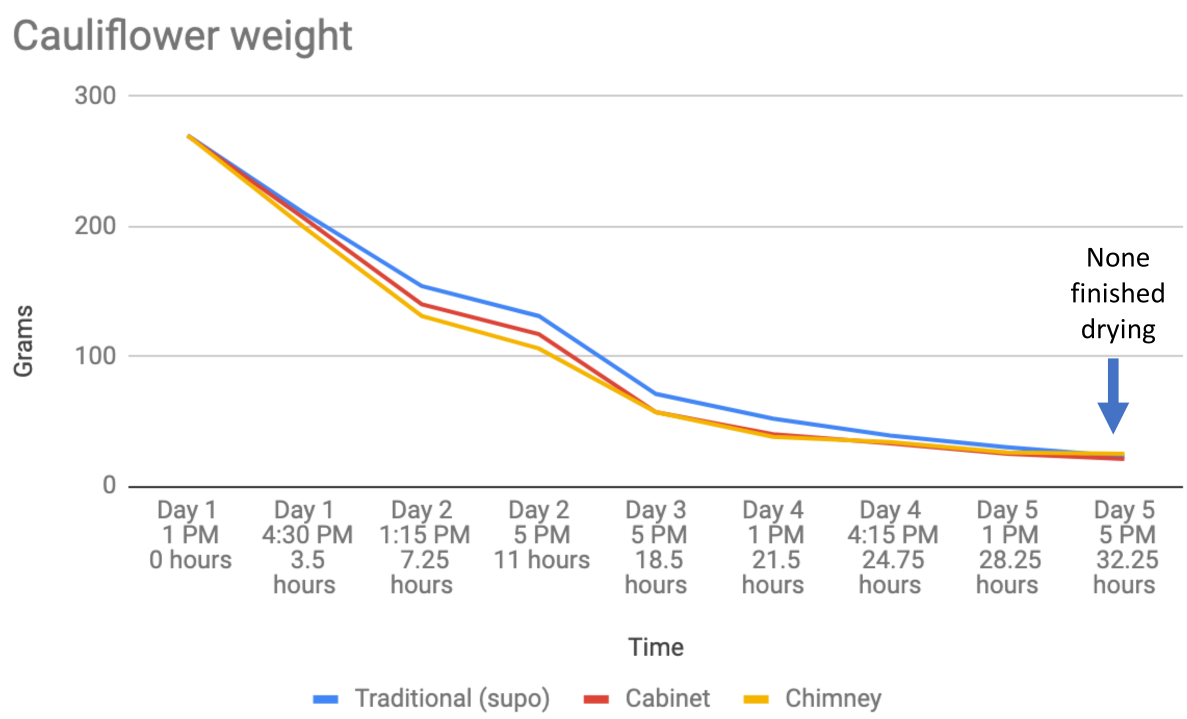

Figure 30. Cauliflower weight in grams from a drying experiment in Dadeldhura, Nepal, December 2018.

Figure 31. DryCard readings for cauliflower on day 7 (December 12, 2018) of a drying experiment in Dadeldhura. Photo taken by Lauren Howe, 2018.

It rained halfway through day 7 (December 12, 2018), so the experiment was terminated early.

By the end of the experiment, the chimney dryer cauliflower weighed the most (22 grams), followed by the cabinet dryer cauliflower (19 grams) and the *supo* cauliflower weighed the least (16 grams).

Table 10. Drying cauliflower during an experiment in Dadeldhura, Nepal, December 2018 (none finished drying).

Drying method	Initial weight (g)	Weight at 5 PM on Day 5 (g)	Percent weight loss (%)	Time in the dryer (hours)
Traditional (*supo*)	270	23	91	32.25
Cabinet dryer	270	21	92	32.25
Chimney dryer	270	25	91	32.25

Drying method	Average RH during drying (%)	Average air temperature during drying (degrees C)	Average solar radiation (Lux)
Traditional (*supo*)	40.7	20.3	12,353

Cabinet dryer	28.1	31.5	12,353
Chimney dryer	28.0	27.7	12,353

Table 11. Drying time required to reach 91% weight loss in cauliflower during a drying experiment in Dadeldhura, Nepal in December 2018.

Drying method	Drying time	Time difference	Percent difference
Traditional (*supo*)	32.25 hours		
Cabinet dryer	28.25 hours	4 hours faster than *supo* and chimney dryer	12.4% faster than *supo* and chimney dryer
Chimney dryer	32.25 hours		

Ninety-one percent weight loss was selected as the "least common denominator" among the different drying methods for the cauliflower, since the amount of weight loss achieved by the chimney dryer and *supo* (as the less effective drying methods for this crop during this drying period) was 91% by the end of day 5 (after 32.25 hours of drying) (Table 10). Then linear interpolation (Figure 32) was used to estimate the amount of time required for all drying methods to reach this same percent loss, which makes it easier to compare the drying methods. Thus, it is estimated that the cabinet dryer is approximately 12% faster than the chimney dryer and the traditional drying method (*supo*) for cauliflower under these drying conditions (Table 11).

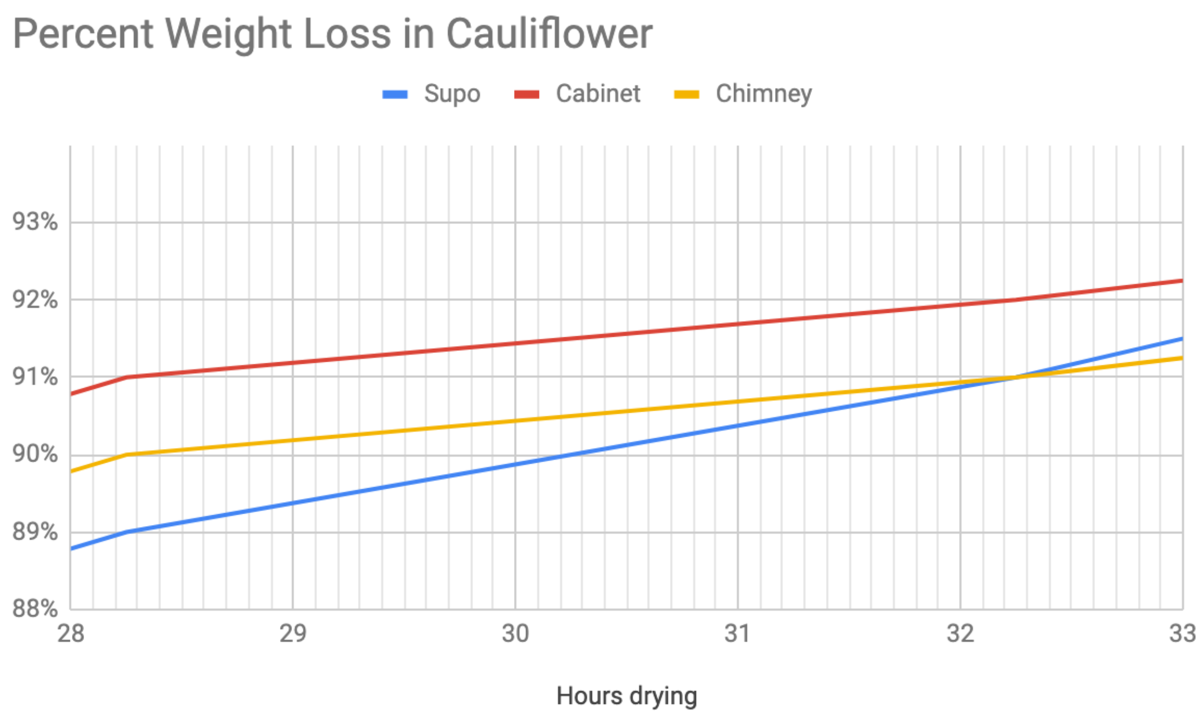

Figure 32. Linear interpolation for percent weight loss in cauliflower during a drying experiment in Dadeldhura, Nepal in December 2018.

5.3.6 Results from experiment #2: balsam apple.

Balsam apple was one of the quickest drying crops in this experiment. After only four hours of drying, the chimney dryer product had lost almost half of its weight (47% loss), the *supo* product lost 43% of the starting weight, and the cabinet dryer product lost 37%. Drying continued to occur at a high rate throughout the first half of the second day and began to slow considerably in the afternoon of day 2. By 2:30 PM on day 3, the chimney dryer balsam apple was sufficiently dried, as demonstrated by the DryCard test, whereas the cabinet dryer and *supo* product needed to be put back out the next day. By 1 PM on day 4, these products were dried completely as well. At the end of the experiment, all methods effectively dried the balsam apple, with final weight loss at 94% for the cabinet and chimney dryer and 93% for the traditional (*supo*) method (Figure 33, Table 12).

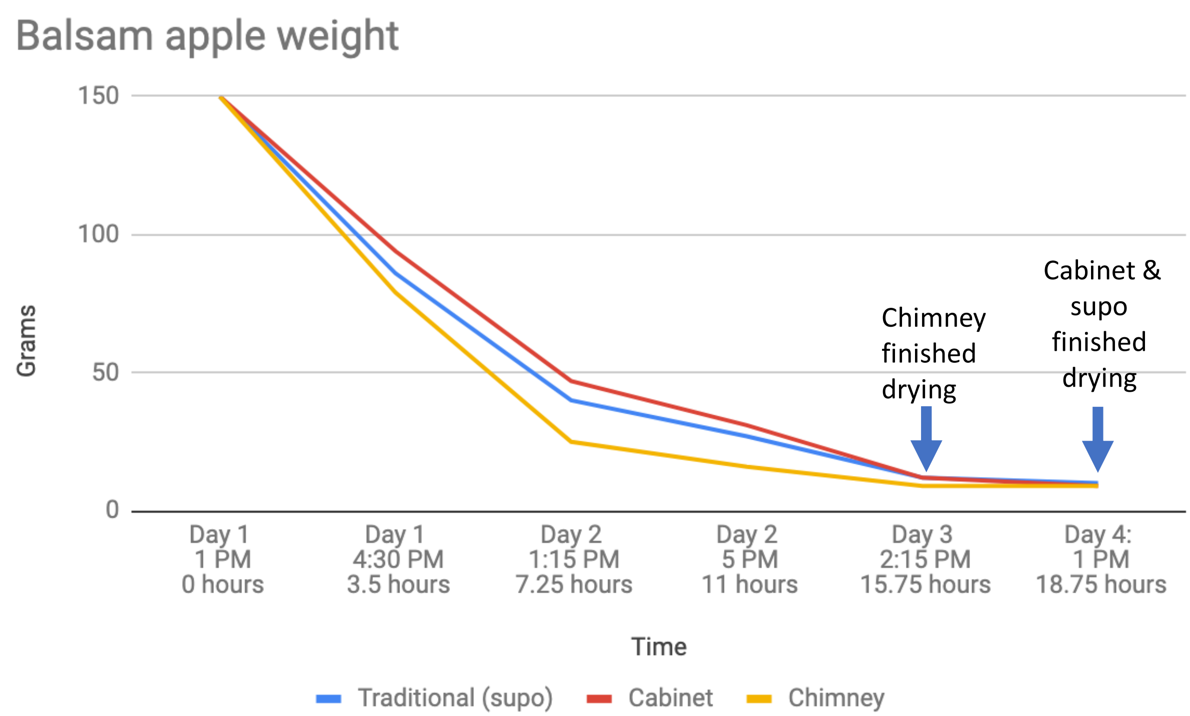

Figure 33. Balsam apple weight in grams from a drying experiment in Dadeldhura, Nepal, where all products dried completely by day 4 (December 8, 2018).

Table 12. Drying balsam apple in an experiment in Dadeldhura, Nepal, December 2018.

Drying method	**Initial weight (g)**	**Final weight (g)**	**Percent weight loss (%)**	**Total time in the dryer (hours)**
Traditional (*supo*)	150	10	93*	18.75
Cabinet dryer	150	9	94*	18.75
Chimney dryer	150	9	94*	15.75

**Dried completely*

Drying method	**Average RH during drying (%)**	**Average air temperature during drying (degrees C)**	**Average solar radiation (Lux)**
Traditional (*supo*)	42.5	20.4	12,932
Cabinet dryer	32.3	30.6	12,932
Chimney dryer	30.4	27.5	12,932

Table 13. Drying time required to reach 93% weight loss in balsam apple during a drying experiment in Dadeldhura, Nepal in December 2018.

Drying method	Drying time	Time difference	Percent difference
Traditional (*supo*)	18.8 hours		
Cabinet dryer	17.2 hours	1.6 hours faster than *supo*	8.51% faster than *supo*
Chimney dryer	14.8 hours	4 hours faster than *supo*	21.28% faster than *supo*
		2.4 hours faster than cabinet dryer	13.95% faster than cabinet dryer

Ninety-three percent weight loss was selected as the "least common denominator" among the different drying methods for the balsam apple since the *supo* achieved 93% weight loss, which was read as sufficiently dried by DryCard readings (Table 12). Then linear interpolation (Figure 34) was used to estimate the amount of time required for all drying methods to reach this same percent loss, which makes it easier to compare the drying methods. Thus, it is estimated that the chimney dryer is approximately 14% faster than the cabinet dryer, and about 21% faster than the traditional drying method (*supo*) for balsam apple under these drying conditions (Table 13).

Figure 34. Linear interpolation for percent weight loss in balsam apple during a drying experiment in Dadeldhura, Nepal in December 2018.

5.3.7 Results from experiment #2: tomato.

By 1 PM on the second day of the experiment, the tomatoes had lost a considerable amount of weight (in the first 6.5 hours of drying), with the chimney dryer tomatoes losing the most weight, the fastest, during this time period. This trend continued until day 4, when I incorrectly thought the tomatoes being dried in the chimney were finished, so I removed them early for a DryCard test, which explains a gap in the chimney dryer weight data between 1 PM on day 4 and 1 PM on day 5 (Figure 35). After 1 PM on day 5, the tomato weights for all three drying methods stayed fairly constant and equal, within 5 grams of each other, indicating that they were close to being completely dried. The tomatoes in the chimney dryer dried completely by 1 PM on day 5 (though, perhaps, they might have dried by the end of day 4 if I had not pulled them out prematurely), and by 1:30 PM on day 6, the cabinet tomatoes were also completely dried (per a DryCard test). On the last day of the experiment, I had to terminate early due to rainfall and the *supo* tomatoes were still hovering on the edge of 65% RH. At this point, all products had lost 95% of their initial weight (Figure 35, Table 14).

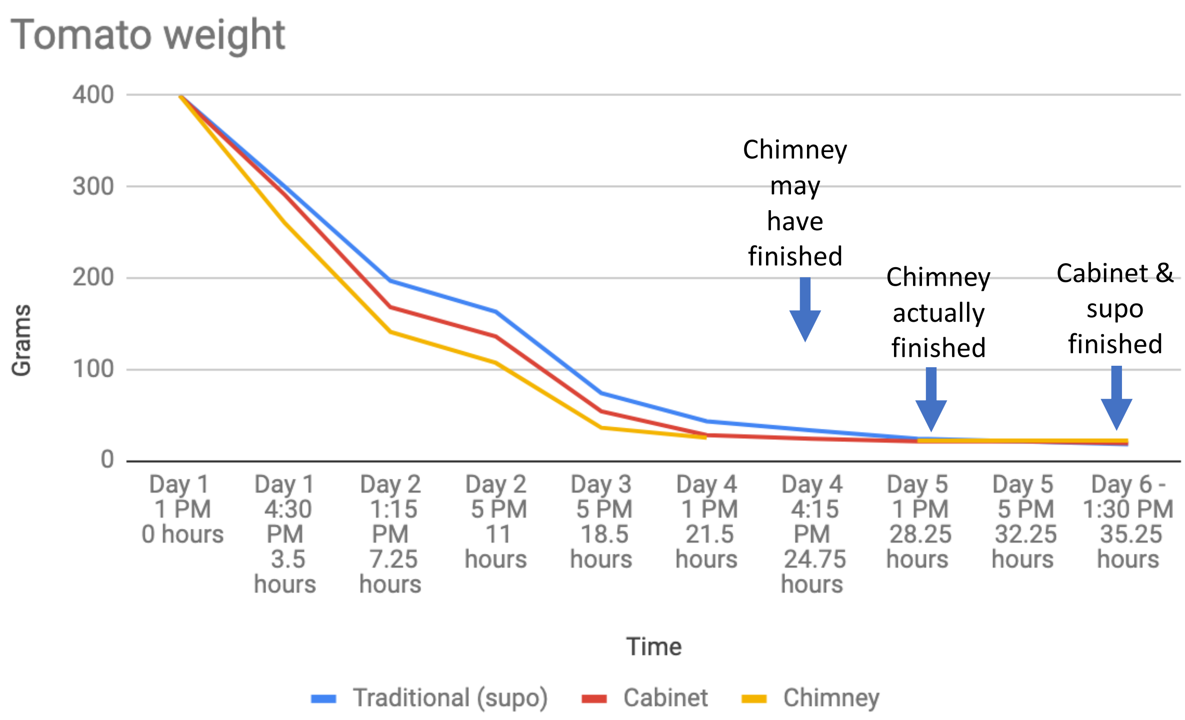

Figure 35. Tomato weight in grams during a drying experiment in Dadeldhura, Nepal, where all products dried completely by day 6 (December 10, 2018).

Table 14. Drying tomatoes during an experiment in Dadeldhura, Nepal in December 2018.

Drying method	**Initial weight (g)**	**Final weight (g)**	**Percent weight loss (%)**	**Total time in the dryer (hours)**
Traditional (*supo*)	400	20	95*	35.25
Cabinet dryer	400	20	95*	35.25
Chimney dryer	400	22	95*	25

**Dried completely*

Drying method	**Average RH during drying (%)**	**Average air temperature during drying (degrees C)**	**Average solar radiation (Lux)**
Traditional (*supo*)	39.3	20.8	13,355

Cabinet dryer	27.8	32.3	13,355
Chimney dryer	27.3	28.2	13,355

Table 15. Drying time required to reach 95% weight loss in tomatoes during a dry experiment in Dadeldhura, Nepal in December 2018.

Drying method	Drying time	Time difference	Percent difference
Traditional (*supo*)	35.25		
Cabinet dryer	35.25		
Chimney dryer	25	10.25 hours faster than the cabinet dryer and *supo*	29.08% faster than the cabinet dryer and *supo*

It did not make sense to use the linear interpolation approach for the tomato data because all three drying methods reached sufficient dryness at about 95% weight loss, and I had missing weight data for the chimney-dried tomatoes between day 4 and day 5 because I thought they were finished on day 4 and pulled them out to do a DryCard test (but they ended up needing more time). Ultimately based on actual hours in the dryer, it is estimated that the chimney dryer is approximately 29% faster than the cabinet dryer and the traditional drying method (*supo*) for tomatoes under these drying conditions (Table 15).

5.4 Overall discussion and reflection on the drying methods

For the radish, only the chimney dryer dried the product completely after 2.5 days of drying. In fact, the chimney-dried radish finished in two days (15 hours of drying), whereas after 2.5 days (18.75 hours), the cabinet- and *nanglo*-dried radish were not sufficiently dried, based on DryCard readings. I had to terminate the experiment early because of a field visit, so there is uncertainty as to how many additional hours the *nanglo* and cabinet dryer would have required to completely dry the radish. The questionable hygiene and food safety associated with the traditional method of drying was also revealed during this particular experiment, as flies, dirt and other debris were seen on the radish being dried on the *nanglo*. For the leafy greens, all three drying methods (*supo*, cabinet, and chimney) dried the product sufficiently after 1.5 days (15 hours). The outcome for the leafy greens was not surprising given that they are a very light weight crop that can generally dry quickly. For both products, the chimney dryer exhibited consistently faster drying rates and more rapid weight loss, compared to the cabinet dryer and traditional drying method, especially at the beginning of the experiment and more notably for the radish.

In the second experiment with cauliflower, balsam apple, and tomatoes, the product weight change results indicate that the chimney dryer is definitely drying product faster during the first 2-3 days. However, by the end of days 3-4, the cabinet dryer and even the traditional method begin to match in performance, as the drying rate decreases in the chimney dryer. This finding is consistent with general drying knowledge that moisture removal tends to be more rapid at the beginning of the drying and then decreases over time (Barrett, 2002). For the cauliflower, the cabinet and chimney dryers performed similarly, and none were dried after one week (approximately 42.75 hours of drying time), though they were both very close. For this commodity, neither improved method (chimney dryer or cabinet dryer) worked as well as I had hoped. This underperformance could be attributed to generally low-quality drying conditions, including relatively high RH inside the dryers (above 65%), intermittent cloud coverage, and the low position of the sun during the winter season. However, for the balsam apple and tomato, the chimney dryer was faster (especially the first few days) than both the cabinet dryer and the traditional method (*supo*), as expected in my initial hypothesis. In the second experiment for cauliflower, balsam apple and tomato, there was a large spike in relative humidity for the cabinet dryer around 1 PM on December 8, 2018 (Figure 29). This increase in RH is most likely due to a sharp decrease in temperature that occurred around the same time, from opening the dryer. Because cooler air holds less water, this temperature drop would result in an increase in RH.

Table 16. Summary of chimney dryer drying rates across experiments and crops for two drying experiments in Dadeldhura, Nepal in fall of 2018.

Drying Method	Radish	Broadleaf mustard greens	Cauliflower	Balsam Apple	Tomatoes	Average
Chimney dryer	**27% faster** than cabinet dryer and **31% faster** than *nanglo*	**37% faster** than cabinet dryer and **44% faster** than *supo*	**12% slower** than cabinet dryer	**14% faster** than cabinet dryer and **21% faster** than *supo*	**29% faster** than cabinet dryer and *supo*	**27% faster** than the cabinet dryer and **31% faster** than the traditional method across four crops (excluding cauliflower)

Across four commodities tested (radish, broadleaf mustard greens, balsam apple and tomato), it was estimated that the chimney dryer is, on average, 27% faster than the cabinet dryer and about 31% faster than the traditional drying method under these drying conditions (Table 16). While the cabinet dryer had consistently warmer temperatures across all treatments for all crops, the chimney dryer always had lower relative humidity, which explains why it tended to outperform the other drying methods, at least for the radish, balsam apple, and tomato. A reason why the chimney dryer is likely the most optimally performing method for these crops is because of the *combination* of increased temperature and airflow (the latter which is lacking from the cabinet dryer). These findings support my hypothesis that the chimney dryer would be the most effective drying method, presumably due to airflow around the product, even under cloudy conditions.

A remaining question is that if all products end up being sufficiently dried within the same amount of time, is there a reason that the chimney dryer should be considered superior to the other methods (i.e. is there any advantage to faster initial weight loss)? One thought is that faster initial weight loss might reduce risk of spoilage, especially under extended, cloudy conditions where the total drying time might be several days or weeks. Moreover, as bamboo baskets with many crevices, the *nanglo* and *supo* were dirty at the start of the experiment and moving the product around on it (especially the radish) made the product slightly soiled as well. In terms of general sanitation and food safety, there were flies landing on the product on the *nanglo* and *supo*, and pieces of grass and specks of ash from nearby fire pits were getting on the exposed product throughout the day.

It is important that NGOs, government extension agents, and other stakeholders introduce technologies that are clearly better than the traditional method. In this instance, the chimney dryer did outperform the cabinet dryer and the *supo* and *nanglo* in terms of time required to achieve sufficient dryness, while both the chimney dryer and cabinet dryer have the benefit of improved hygiene. Farmers, however, may require solid evidence that an improved solar dryer is remarkably better than their traditional method, given the associated costs and required behavior change. If the advantages are not properly demonstrated, then farmers may be less likely to adopt the technology, which is a matter of *observability* or "the degree to which the results of an innovation are visible to others" (Rogers, 1995).

Going into these experiments, I naturally wanted the chimney dryer to perform the best since this was the drying technology I was introducing in Dadeldhura. However, as the experiments progressed, I realized that ultimately, it does not matter if the cabinet or chimney dryer performs better. Rather, I just hoped that at least one of them is better than the traditional method. It is important to note that both the traditional method and the cabinet dryer are small, lightweight and portable, so they can be moved easily based on sun exposure. However, given that the chimney dryer and cabinet dryer are roughly the same cost (12,000 NPR or approximately $100), the chimney dryer would be better for larger quantities given its increased capacity. Ultimately, colleagues from the Horticulture Innovation Lab and I were surprised that the chimney dryer had lower internal temperatures than the cabinet dryer and thus did not perform as optimally as we would have liked, which could have been due to air leakage, afternoon shade, excessive wind from being located at Tufandada ("Windy Hill"), or generally poor-quality drying conditions (high relative humidity, cooler temperatures, and the low positioning of the sun in the winter season). Given the fact that I moved the cabinet dryer around to keep it exposed to the sun throughout the day, this adjustment likely gave it an advantage over the chimney dryer, which was not portable. Thus, any future experiments should ensure optimal location for all dryers (i.e. full sun for the entire day) and proper usage practices (e.g. ensuring that the dryers are fully sealed, product is thinly and uniformly sliced, and that weights are taken at the exact same time every day).

In general, I would recommend a more comprehensive evaluation of different drying methods (e.g. chimney dryer, cabinet dryer, and traditional sun drying) on different crops during different seasons. Conducting experiments on only a few crops during the fall/winter season may not be representative for the entire year and for all products, as some products will dry differently than others under varying climatic conditions. Moreover, several women expressed interest in wanting to dry during the rainy season, and I am unsure if the dryers will operate well under those humid conditions.

5.5 Limitations and suggested modifications for future experiments

A lesson learned from this experience was that we can do our best to control factors in a research setting, but when activities have a social component, humans are difficult to control. In future experiments, it would be ideal to place all the product inside the dryers at the same time every morning, weigh and rotate them at the same time mid-day, and remove them from the dryers for final weights at the same time every evening. In the case of the experiments I ran, exact timing was unfeasible due to field conditions. Moreover, because products lose weight throughout the day, it is important to take midday weights to pinpoint if the weight change is happening more rapidly in the morning or afternoon.

Because wind speed is a crucial component of the chimney dryer design, future experiments should include precise wind speed measurements using an anemometer under all drying methods, rather than just using tissue paper to observe airflow as I did with the chimney dryer. In the case of these experiments, the anemometer proved time consuming and difficult to use, which is why I did not employ it diligently. Hanging tissue paper from the center pole of the chimney dryer before covering it with plastic, however, is still an easy and low-tech method for visually confirming airflow and can be used in conjunction with an anemometer. Moreover, testing airflow can be done using incense sticks, which are widely available in Nepal, as a bee smoker did not prove very effective. Because an ongoing challenge with the chimney dryer is ensuring that the clear plastic is fully sealed around the sides and back of the dryer, using a combination of a bike tire tube, scrap wood, and bricks can be more effective than any one of these methods alone. In the event that the plastic cover over the table is still sagging down onto the top trays and coming into contact with the product, the plastic should be kept as taut as possible and perhaps one should consider adding more center support poles to the dryer design if this does not significantly increase the headspace above the product.

In terms of obtaining accurate weights, product should be weighed by itself every time, rather than weighing the tray and product and subtracting the tray weight, which was done in the first experiment to save time, but at the expense of accuracy. Taking weights on a flat surface at an indoor location proximal to the experiment site would have been ideal, as the scale sometimes changed by up to 10 grams when we took the weights outside on the chimney dryer shelf near the inlet because it was the only nearby flat surface. Alternatively, a box with one end open could be placed over the scale to protect it from the wind. Moreover, all product should be brought inside overnight to prevent the chances of re-wetting and should be weighed each morning before loading it into the dryers to see if weight has changed overnight.

In terms of best practices for using and setting up the instruments (i.e. HOBO data loggers), all the trays should be removed from the chimney dryer and each HOBO should be placed and secured in its desired location, then the trays should be reloaded. Rather than using the start button on the HOBOs, which can be unreliable, they can be configured by plugging them into a computer and launching them with delayed start at the desired time interval (e.g. 5-

or 15-minute logging) and set to launch at a specific even time (e.g. 1:30 PM or 2 PM) that will allow the researcher enough time to place the product onto the trays, load the trays into the dryer, and seal the dryer with plastic. In fact, logging every 5 minutes seemed excessive, which is why I adjusted it to log every 15 minutes in the second experiment. It is important to remember to put the solar shields on the HOBOs and tape them down to prevent wind from displacing them. Lastly, instruments should be carefully calibrated, ideally in the field, to ensure the highest accuracy.

In the future, it is recommended that the exact drying area of each surface (e.g. the *nanglo*, *supo*, cabinet dryer tray, and chimney dryer tray) is calculated, which would provide a more accurate understanding of which method has larger drying capacity, especially for cost comparisons. From simple observation, it appeared that the cabinet and chimney trays can hold more product than both the *nanglo* and *supo*. The *supo*, however, was much easier to handle due to the bamboo material, which does not have sharp edges and can be carried with one hand. The chimney and cabinet trays both have sharp edges from where we cut the metal mesh and are more cumbersome to handle. These trays, however, are easier to arrange product to lie flat, whereas on the *supo*, individual pieces tend to overlap due to the curved interior surface.

Lastly, it should be noted that Nepali farmers may not have time to constantly monitor and move the portable drying devices (e.g. *nanglo, supo*, or cabinet dryer) into the sun during the day, as well as rotating trays frequently, both of which contribute to more optimized drying conditions. If this study was conducted under more realistic conditions by not incorporating these adjustments, then the results may have been different. For instance, the chimney dryer might perform even better if the traditional bamboo baskets and cabinet dryer were kept in the same location throughout the duration of the experiments.

6 Discussion

6.1 Time savings and pathways from food safety and quality to food availability

The chimney solar dryer is an example of a technology that facilitates both *process* and *product upgrading*. Process upgrading has been defined as "an increase in the efficiency of production processes, resulting in reduced unit costs" and "can involve improved organization of the production process or improved technology" (Manfre et al., 2017). In this case, the chimney dryer is an improved technology that has been shown to make the drying process more efficient, as demonstrated by the aforementioned drying experiments in Dadeldhura. However, it should be noted that during the solar drying experiments I conducted in Dadeldhura, I tended to the product inside the dryers very carefully by checking it frequently, rotating the trays, and moving the cabinet dryer into the sun throughout the day. Based on my interviews, farmers' usual practices do involve some labor in the form of periodic inspection of the drying product, but the performance of the improved solar dryers, both the cabinet and chimney, might not be as optimal in real-life conditions as during the experiment. However, I still believe that the improved dryers will function better than the traditional sun drying method based on the experimental results. Besides an improvement in the process, the chimney dryer also resulted in product upgrading, or "an improvement in the quality of a product or variety that increases its value to consumers" (Manfre et al., 2017), as evidenced by gains in food safety and color retention. The chimney dryer would also be considered a labor-saving technology in the domain of food processing and preparation as "preserving more of the harvest translates indirectly to saving labour [sic]" (Bishop-Sambrook, 2016).

While the chimney dryer can be faster than sun drying depending on the crop and season, and saving time is arguably critical for farmers who may already be overburdened, time and labor savings seemed to actually be less important to women farmers than expected (though they were still valued). This surprising finding can be attributed to the fact that drying is a relatively passive activity that does not require a significant amount of active time or arduous labor. Women may leave their product out for 7-10 days and only check on it once or twice, not even bringing it inside overnight. As a result, any time saved does not significantly impact their current traditional drying practices. However, faster drying does reduce the risk of product developing mold or otherwise spoiling, especially under cloudy conditions. As a result, time saved is directly related to improved product quality and thus quantity through reduction in spoilage. At endline, farmers felt there would be increased food available during the lean season due to decreased spoilage as a result of utilizing the chimney dryer, making vegetables available year-round, in some form. This increase in food availability is crucial for these communities in Dadeldhura district, where dried foods are consumed weekly or even daily, especially in the dry or lean season when fresh produce is limited. The potential for dried foods to contribute positively to household diets during times of seasonal shortages has been shown in other countries including Niger and Zambia (FAO, 1997). In Dadeldhura, the relative importance of dried foods means that improving the method, quality, and quantity of dried foods available may have a significant impact on the nutrition and diversity of the household diet, and the importance of dried food products should not be underemphasized.

In addition to time saved and losses prevented, it is critical to emphasize the other benefits of the chimney solar dryer, including improved hygiene, sanitation and food safety, plus color, taste and quality retention. Food safety and quality are intrinsically linked to food availability because if food is not safe or nutritious, it will ultimately be less available for bodily absorption; hence, the INGENAES Gender Technology Assessment captures this relationship as a single area of inquiry. The perceived hygiene, health, and food safety benefits of improved solar drying using the chimney dryer ended up being a key finding among farmers. It should be noted, however, that this realization came early on in the research during the baseline FGD, even before the women saw the chimney dryer in person. Clearly, health, sanitation, and food safety appear to be important driving factors that motivate farmers' desire to utilize the dryer, but this motivation could have reflected social desirability bias early on, as participants may have wanted to please or gain approval from the NGO program staff.

Another important finding from this research was that after the introduction of the chimney dryer through community-level construction and trainings, some farmers felt that the vegetables dried in the chimney dryer tasted better and were more nutritious than those dried in the open sun, so consumption will naturally increase. I could not validate these claims by actually measuring nutrients or palatability, but regardless, if farmers believe it to be true, then this is an unexpected benefit of this technology. In fact, this quantification may actually be less important compared to farmers' perceptions in the context of technology adoption. Although seemingly incongruous, this phenomenon is known as *relative advantage*, one of Rogers' five characteristics of innovations for which "[i]t does not matter so much if an innovation has a great deal of objective advantage. What does matter is whether an individual *perceives* the innovation as advantageous" (Rogers, 1995, emphasis added). Relative advantage can also be expressed in terms of low initial investment, profitability, reduction in effort, time and discomfort, how immediate the benefits will be felt, and social prestige (Rogers, 1995). In this case, the aforementioned perceptions of improved taste and nutrition within the target population can contribute positively to the chimney dryer's rate of adoption in Dadeldhura. Nevertheless, it would be beneficial to conduct a future study to quantify nutrient retention in chimney-dried products compared to sun-dried, as well as validate taste and consumer acceptability claims.

6.2 Adapting technology for local context

In addition to improving the drying process and final product for farmers in Dadeldhura, one of the goals of this research was to test the Chimney Dryer Manual. While conducting this research, I came to realize that building a chimney solar dryer is somewhat like cooking, and the manual that the Horticulture Innovation Lab published in 2018 is like a recipe for building a chimney dryer that can be adjusted based on personal taste. The construction materials in their exact proportions (e.g. 56 meters of 3 cm x 3 cm wood for the frames of the table and chimney) are like the specified amounts of ingredients in a recipe. In certain cultural and economic contexts, like Nepal, trying to follow this figurative recipe perfectly is neither practical nor affordable. When the wood for building the dryers arrived several hours late to our Training of Trainers in a tangled mess, it became clear that presenting and implementing the dryer design exactly how it is laid out in the manual does not always make sense.

To that point, if I were to conduct our training activities again, I would have presented the basic concept of the chimney dryer and let imagination abound by asking participants: how could you adapt this design to the local context? Which local materials are readily available and affordable? After going through the process of building the dryer with the wood cut in the exact manual-prescribed dimensions during the TOT, we reflected as a group on how this design could be modified to fit the local context. One person suggested using a prefabricated table made from iron for stability and durability, which might even be more affordable due to fewer pieces, or even produce crates that only cost 500 NPR each (approximately $4 USD), which was done successfully in Tanzania. Moreover, if stainless steel mesh is not available, someone recommended painting the mesh to prevent rusting, though caution should be used to ensure that the paint does not contain lead or any contaminants that could transfer to the food.

One of the most ubiquitous and unexpected points of feedback, however, was that several people in Nepal expressed desire for a smaller solar dryer than the standard size described in the manual (with a 12-foot-long table). Related to a smaller size is portability, enabling users to easily move the dryer in the event of hazardous weather conditions. From the chimney dryer that was built by CGEDN outside Kathmandu to the reactions during the TOT in Dadeldhura, both farmers and NGO partners shared this sentiment. They emphasized that farmers in Nepal have very small plots of land, and they feel the chimney dryer in its standard dimensions is both too large for individual household drying needs and would occupy too much space on farmers' property. This finding was unexpected as many of the farmers in East and West Africa where the Horticulture Innovation Lab has previously introduced this technology have requested a larger dryer to meet their commercial drying needs. This discrepancy could be explained by the fact that drying is not currently highly commercialized in Dadeldhura.

After learning early on that one size does not fit all in this situation, I tried to emphasize that the chimney dryer construction manual does not have to be followed exactly and size can be adjusted based on preference. For the subsequent community-level dryers, we shortened the table to 8 feet instead of 12 feet after the Training of Trainers. While there is some flexibility allowed in the dryer design that will likely not compromise dryer performance, there are some key dimensions that should not be modified. For example, according to the chimney dryer designers at UC Davis, the chimney should always rise about two meters above the table, and the height between the trays and the clear plastic/support shelf should be small (approximately 5 cm). With a new sense of acceptance and willingness to be flexible with the design, we conveyed these critical aspects to the carpenters and then pivoted to promoting the manual as a series of guidelines that can be tweaked as preferred. According to one of the chimney dryer designers:

> "Presenting the dryer in this perspective empowers the farmers to be the ones who manage the process…We are teaching them concepts they can use and adapt to their needs. We are using the chimney dryer as an example to teach the Nepalese how to harness technology for their benefit."

Hopefully, disseminating the chimney dryer with a flexible approach towards its dimensions and size will promote technology *reinvention* at the farmer level. Reinvention has been defined as "the degree to which an innovation is changed by the adopter in the process of adoption and implementation after its original development" (Rice & Rogers, 1980). In fact, we saw two instances of reinvention in Nepal, one being the CGEDN beneficiary farmer in Mulkarka Village outside Kathmandu who shortened the height of the chimney, reduced the length of the table, fixed the clear plastic permanently on the sides of the dryer and created a mesh screen door at the dryer opening to keep out pests, as well as the carpenter in Bagarkot who created a similar mesh screen at the front of the dryer. In the case of the CGEDN-beneficiary farmer who shortened the chimney, this reinvention likely resulted from the "user's lack of detailed knowledge about the innovation" (Rogers, 1978 as cited in Rice & Rogers, 1980;), i.e. not knowing exactly how the chimney dryer operates and the need for a certain chimney height to facilitate proper airflow, perhaps because he did not have direct access to the Chimney Dryer Manual translated into Nepali. Regardless, reinvention of innovations can be beneficial towards making a technology more appropriate for and responsive to the local context (Rice & Rogers, 1980).

Despite some initial NGO concerns for the chimney dryer taking up too much space on small landholdings, farmers reacted positively to the 8-foot-long chimney dryer. Smallholders were generally willing to devote space for the dryer, especially if it becomes a profitable endeavor. Furthermore, farmers in Belapur noted that they currently cannot grow crops on all of their land because of limited rainfall and irrigation infrastructure. Thus, they are more than willing to build the dryer on fallow land that is currently unused. This inconsistency between NGO and farmer viewpoints indicates the need for close communication between project partners and beneficiaries to ensure that farmers' needs are truly being met.

6.3 Promoting adoption: compatibility, complexity, observability and trialability

Many of the farmers' and NGO partners' comments could easily apply to both traditional sun drying and improved solar drying, which begs the question of how to convince stakeholders of the benefits unique to the chimney dryer. For example, the village model farmer from Bagarkot summed it up well during the endline FGD:

> "In this season, we have a lot of production, but during the season when there is less vegetable production, the fresh vegetables will be so expensive to buy. At that time, if we have our own dried products in our house, we won't need to buy. It will be tastier to eat

> as well as it will save our money. It will save the time to go to shop and buy the products also. So, [the chimney solar dryer] will make our life easier in every aspect."

This comment could have been referencing traditional sun drying, a cabinet solar dryer, the chimney dryer, or any other improved drying technology. Similarly, the Executive Director from one of the partner NGOs noted that the chimney dryer is beneficial

> "not only for farmers growing in a large-scale, but it would be better for farmers who produce in smaller quantities, as their production is too small to sell in the market, and the market needs higher scale production, so they can dry surplus and resell it."

Here, she appears to be pointing out that the chimney dryer will allow farmers who produce more than they can consume, but still may not harvest enough fresh product to sell in the market, to then dry the remaining small quantities. Then farmers can aggregate the small quantities of dried product to sell in the market. However, this practice could also be done with traditional sun drying, and the current lack of a market for dried foods is a limiting factor in both scenarios. Thus, perhaps, the underlying value the community places on dried foods as a part of their diet and rural lifestyle is more important than the attribution of the benefits to a specific technology. The interchangeability of their comments also points to the *compatibility* of the chimney solar dryer as an innovation. As one of Rogers' five characteristics that can influence an innovation's rate of adoption, compatibility is "the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters" (Rogers, 1995). Farmers in Dadeldhura are already highly accustomed to drying their products in the sun, which makes the chimney dryer a particularly relevant or compatible technology for this community. Furthermore, it would be much more challenging and potentially culturally inappropriate to introduce a solar dryer to a community that does not have a pre-existing tradition of consuming dried foods, as it would be inconsistent with the local social system's values and norms.

In addition to relative advantage and compatibility, other favorable aspects exist for promoting the adoption of the chimney dryer. These characteristics include its low level of *complexity*, i.e. the degree to which individuals can understand and use the dryer, and its *observability* (Rogers, 1995). Beyond the pictorial training aids we developed (Appendix 5), which show the multiple benefits of the chimney dryer compared the traditional method of sun drying with text captions in Nepali, I passed around bags of previously dried product using different drying methods to demonstrate differences in color and quality. This visual activity showed that the chimney-dried product appears higher quality than traditionally sun-dried vegetables, a particularly poignant and effective method for convincing people about this technology. Another aspect of observability is that the actual chimney dryer structure is a tangible technology that is easily spotted from a distance, which can "stimulate peer discussion…as friends and neighbors of an adopter often request innovation-evaluation information" (Rogers, 1995). This phenomenon occurred in Bagarkot where a male teacher who did not attend the training simply saw the technology, asked about it, and proceeded to become the village's first user, an early-adopting innovator of higher social status (Rogers, 1995).

Through the pilot project design, constructing a few chimney dryers on the land of village model farmers in Bagarkot and Belapur was intended to promote the *trialability* of the technology, "the degree to which an innovation may be experimented with on a limited basis," which "represents less uncertainty to the individual who is considering it for adoption, as it is possible to learn by doing" (Rogers, 1995). It was our hope that by constructing one chimney dryer in each village, farmers would take advantage of the opportunity to try the technology, and if they are satisfied with the results, they would ideally invest in their own. Trialability can be especially important for farmers who do not have the resources (e.g. financial, land, time, social capital, etc.) or desire to take risks without ample support. Furthermore, piloting the chimney dryer on the land of village model farmers was a key strategy because VMFs are opinion leaders in the community, who are well-regarded and can "influence other individuals' attitudes or overt behavior informally in a desired way with relative frequency" (Rogers, 1995).

6.4 Cost and affordability

"In case we can't spend money on [a chimney solar dryer], we will dry in the traditional way."
-Village model farmer from Pokhara

As is the case with virtually every new technology or management practice, cost and affordability are key components to long-term adoption. The Horticulture Innovation Lab considers the chimney dryer a low-cost technology as it can typically be built for less than $200 in different countries (Horticulture Innovation Lab, 2018c). Affordability, however, is relative and highly contextual. The reality of the situation in Dadeldhura is that farmers' current drying method is essentially free and unlimited, not requiring a significant investment of capital or materials, with the exception of bamboo baskets or plastic tarps, which they might already have around their homestead. However, after building multiple dryers, the cost for each dryer became progressively lower as we figured out how to incorporate more bamboo and use carpenter labor more efficiently. Ultimately, we calculated that the total material costs for a smaller dryer (8-foot-long table) were about 10,000 NPR or around $90 USD. Once carpenter labor is factored in (about four days for cutting the wood and assembling the dryer), the cost increases to about 14,000 NPR (approximately $125 USD). Skilled labor may only be required for one day to cut the wood, otherwise, anyone can construct the dryer, which will keep costs down, though employing a carpenter is likely more efficient and less frustrating for the novice builder.

The issue then becomes if farmers are willing to invest this amount of money into a chimney dryer. Based on our FGDs and KIIs, the general consensus was that farmers would be willing to spend about 7,500 NPR ($67) on average, up to about 10,000 NPR ($90 USD) for a chimney dryer. Thus, the current price before labor seems to fall within this willingness-to-pay range, and staying within this threshold is certainly possible with local materials and minimal carpenter labor. In fact, for farmers who already have some materials on their farm and can do their own labor, it was estimated that the cost could be as low 2,500-5,000 NPR (approximately $21-$42 USD), based on the chimney dryers constructed by CGEDN in Shivapuri Nagarjun National Park, outside Kathmandu. Moreover, I discovered that some people want to build the dryer themselves, which will keep costs down. However, others prefer to buy it ready-made, which will drive up the cost, but is now possible given that we trained local carpenters and distributed the Chimney Dryer Manual widely.

Knowing the estimated costs of constructing a chimney dryer and farmers' willingness to pay, other aspects of financing should be considered. In this case, two distinct dynamics of affordability may be at play: the chimney dryer may not be currently deemed affordable by farmers because the potential for commercial drying is limited, coupled with *liquidity constraints* or lack of available cash to purchase the dryer despite potential profitability (Ragasa, 2012). One option to overcome capital constraints would be for communities to construct chimney dryers as a shared resource among multiple households. As this was a pilot project, we chose to build one dryer per community on the land of the local village model farmer because they are already modeling progressive practices such as chicken breeding and polyhouses for protected cultivation of horticultural crops. However, this limited construction means that at least 4-6 families need to share a dryer. Although some people preferred the idea of having their own individual dryer for their household, several individuals did express interest in sharing a dryer at the beginning, recognizing the benefit of distributing the financial burden among multiple households.

Subsidies are another intervention that could be implemented either separately or in tandem with multiple households sharing a dryer. Both government officials and NGO partners mentioned the need for subsidies for the dryers because farmers might be unlikely to adopt the technology on their own without financial support. However, this belief begs the question of the sustainability of the innovation and the potential for long-term adoption if it requires government monetary support. Upon deciding whether to institute subsidies, the potential for *anchoring* and *crowding-out* should be considered whereby farmers may fixate on the lower, subsidized prices and later, refuse to pay for agricultural technologies at the true market value after the subsidies end, which can impede adoption (Omotilewa, Ricker-Gilbert, & Ainembabazi, 2019). Alternatively, developing the private market sector to make chimney dryers and the associated technologies (e.g. DryCards, hermetic storage, etc.) commercially available could be a more viable solution for long-term change.

6.5 Potential chimney dryer challenges

Although the chimney dryer has many benefits, there are also challenges associated with this technology that should not be overlooked. I have already discussed cost and affordability as a barrier to adoption, as well as both decreased drying capacity and an increased space requirement compared to traditional sun drying. In addition to these issues, the chimney dryer is also susceptible to weather damage from high winds that can tear the clear plastic, and local farmers in Bagarkot feared that heavy rain or hailstones may also damage the plastic. Although the chimney dryer cannot be as easily re-located as a cabinet solar dryer, separating the chimney from the drying table and rolling up the clear plastic does allow the dryer to be easily moved to a protected area. If re-locating the dryer is not possible, it is important to ensure that the chimney is somehow staked or secured to the ground. The Horticulture Innovation Lab recommends using either guy-wires or rope to reinforce the chimney, which farmers in Belapur did on their own after we left the study site (Figure 36, left). Another option is to turn the dryer on its side while not in use to prevent it from potentially blowing over in heavy wind, or putting the clear plastic on the table under shelter between uses to reduce wear and tear and extend duration of use. Besides wind and other weather-related damage, farmers were concerned about pests like mice contaminating their dried products. As a result, the carpenter in Bagarkot installed a metal screen in front of the dryer opening to deter pests (Figure 36, right).


Figure 36. Securing the chimney dryer with rope and a wooden post in Belapur (left, photo taken by Debendra Shah, 2019) and pest protection through a wire screen in Bagarkot (right, photo taken by Lauren Howe, 2018).

In terms of ease of use, it became clear that farmers are determined to leave their product in the dryers overnight because of the extra work of bringing it inside each evening and putting it back out each morning, which adds additional time and labor to their already heavy workloads. However, moist conditions may develop inside the dryers overnight due to cold temperatures and condensation. Leaving the product inside the dryer overnight is not a highly recommended practice, as there is the potential for mold growth or spoilage to occur if the relative humidity inside the dryer increases significantly and if moisture develops inside the dryer under the clear plastic from temperature decreases and subsequent condensation. Because fungal growth exists when relative humidity is higher than around 62% (Semenuik, 1954 as cited in Roberts, 1972), the risk of mold developing overnight is potentially heightened. For example, I observed RH values inside and outside the dryers exceeding 95% during some evenings while running the drying experiments in Nepal. Furthermore, Horticulture Innovation Lab staff in Bangladesh cited that fungus has developed on products when left in the dryer overnight (M.R. Islam, personal communication, August 6, 2018). Thus, the Horticulture Innovation Lab recommends future research carefully assess the effects of leaving product inside the dryers overnight, and to err on the side of caution, the Lab recommends that people bring the product inside overnight where the relative humidity and chances of the product re-wetting might be lower. However, I recognize this recommendation may not be enough to incentivize farmers to add to their workload given that their current drying practices are already relatively unsanitary, and this practice is likely not worse than their current method. Still, I hope that farmers would be willing to bring the product inside overnight if they knew condensation and re-wetting of the food is associated with increased risk of mold or fungus, which can have adverse effects on their health.

Farmers also asked about using the dryer during the rainy season, which is not recommended by the Horticulture Innovation Lab. The chimney dryer can be utilized during cloudy conditions, but during periods of extended rainfall and high humidity, it does not work effectively. The same Horticulture Innovation Lab staff member in Bangladesh also observed fungus on products during the rainy season. However, because the product is covered by the clear plastic, it will “tolerate some degree of drizzling” (M.R. Islam, personal communication, August 6, 2018). Unfortunately, the monsoon season in Nepal coincides with harvesting time for some crops, so this is a seasonal challenge that is not easily overcome by the chimney dryer. In addition to a desire to utilize the dryer during the rainy season, some farmers were interested in trying it for drying pulses and other food products. In general, the chimney dryer has been used for higher value soft items like fruits and vegetables, and in some cases, fish, which makes the initial capital investment more economical. Seeds, pulses, grains, and other small products could possibly be dried in the chimney dryer, but because of a limited capacity, dryer cost and relatively low prices for these commodities, farmers might not be able to efficiently dry these foods in large quantities, in terms of cost and time. Furthermore, the trays would need to be covered with a finer mesh screen to accommodate these foods, which would otherwise fall through the larger holes. The Horticulture Innovation Lab is currently developing a dryer made from used wood pallets for grains and other granular items.

A couple of other challenges related to the chimney dryer include farmers' uncertainty about how to use the trays. As previously mentioned, the user in Bagarkot was unsure about how much to fill the trays and how often to rotate them. In addition, some farmers struggled to slice the produce as thinly as we recommend for more efficient drying, which will extend the drying time, and they would sometimes overlap the pieces too much on the trays. The distance between pieces and amount of overlap will impact the performance of the dryer in that too much overlap can inhibit effective and fast drying, whereas too much space between pieces is also inefficient. In our endline focus group discussions, it also became clear that some farmers mistakenly thought they needed two people to use the dryer. More specifically, they believed that a pair of individuals is required to lift the clear plastic that covers the drying table. We corrected this in our follow up, and explained that we only demonstrated using the dryer with two people during the training activities to involve more farmers with hands-on practice as part of the learning process, while in fact, they chimney dryer can easily be used by one person.

It is important that farmers understand that final product quality depends on the quality of the product that goes into the dryer initially (Wakjira, 2010). For instance, drying fully ripe (or even overripe) product is recommended because it will have optimum sugar content and the most flavor, whereas drying unripe (or moldy) product will not yield a quality (or in some cases, safe) final product. In one instance during a training, farmers cut up under-ripe tomatoes that were still slightly green for drying, which likely resulted in a subpar dried tomato (though we did not taste them to assess).

As with sharing most common resources, challenges exist, like agreeing upon a schedule or rotation and planning for maintenance. In anticipation, we built community-level planning into the three-day training workshop on using the chimney solar dryer to help farmers strategize how to overcome these challenges. More specifically, long-term maintenance and repair should be planned for, which Chua & Chou (2003) identify as critical factors for identifying improved drying technologies for lower-income countries and smallholder settings. The clear plastic covering the drying table is the component most likely to break down and require repair. With this knowledge, we included a learning module titled, *Community planning for future chimney dryer usage and maintenance* during our training sessions. During this activity, farmers in Belapur agreed to raise funds (2,000 NPR or about $18 USD) for maintenance through forming a chimney dryer user group through which farmers would pool resources to cover any repair costs, which could include purchasing clear tape to patch any holes in the plastic. They also discussed that people who live nearby the dryer will take care of it, and "we will do all the repairing activities like changing the plastic, mesh and wood on our own…we won't need any technical assistance because we know how to do all these things from the training." Similarly, in Bagarkot, they wrote that they will pay for chimney dryer repairs with the interest generated by their savings group. Lastly, the chimney dryer is a new technology and new practice, which requires shifts in attitudes and behavior change, the latter of which can be a slow and challenging process (Straub, 2009), especially when related to a habitual or engrained practice like a traditional agricultural method (Johnson, 1972).

6.6 The dry chain

This research clearly revealed that farmers already know how to dry product, even if it is not the most sanitary or efficient method, but that measuring sufficient dryness and proper storage are also a part of the issue. Researchers at UC Davis coined the term "dry chain," which is analogous to the “cold chain” for refrigerated storage and transport of perishables. The dry chain is a concept that involves adequately drying food products soon after harvest, measuring dryness for safe storage, and storing them using moisture-proof containers throughout the postharvest process, from transporting and marketing until the final point of consumption (Bradford et al., 2018). Thus, besides just introducing the chimney solar dryer, this project truly became about the entire “dry chain” to prevent mold growth and thus mycotoxin (e.g. aflatoxin) development, which are harmful carcinogenic compounds that have been associated with stunting (Smith et al., 2015). This pilot project is thus representative of a “technology cluster” where the chimney dryer, DryCard, and moisture-proof storage are “distinguishable elements of technology that are perceived as being closely interrelated” (Rogers, 1995). While some technology clusters are promoted collectively to foster a faster adoption of the innovations, we promoted the chimney dryer, DryCard, and improved storage jointly in Nepal out of necessity because the quality of the final dried product depends on the integrity of each of these respective processes. For instance, if a farmer uses the chimney dryer for their radish, but removes it from the dryer before it is adequately dried and is unable to measure the dryness with more precision than simply bending it, then the final dried radish will be compromised. Similarly, if a farmer uses the chimney dryer and the DryCard, but stores the product in a porous container, the food item may re-wet during storage and develop mold. Hence, each process represents a crucial link in the dry chain.

As a result, I identified three process changes that should ultimately be implemented to improve the dry chain in far western Nepal: first, the drying process (i.e. using the chimney dryer instead of traditional sun drying). Farmers could also pair an improved solar dryer with technology like drying beads, which are mineral-based desiccants used to further remove moisture, especially from products like seeds (Horticulture Innovation Lab, 2018b). Second, measuring dryness (i.e. bending product by hand plus using the DryCard to measure RH), and third, proper storage using moisture-proof containers (e.g. plastic jars or a system similar to the

Purdue Improved Crop Storage (PICS) bags, which combines layers of plastic bags to create an airtight seal). In our endline focus group discussions, we advised that farmers start with "low hanging fruit," by asking them which improved practices they are most interested in adopting and which they thought would be the easiest to implement. There were a variety of responses to these questions across each of the three aforementioned processes. We ultimately emphasized that eventually all three processes should be improved for optimal drying, home consumption and sales of dried food products.

6.7 Recommendations for equitably scaling the chimney dryer and dry chain

One goal of this research was to understand if the chimney dryer will impact distinct groups of people differently. The data revealed that both large and small farms, as well as collection centers in "vegetable pocket areas" (locales of high production) have the potential to benefit from this technology. In addition to high vegetable-producing areas that have reliable access to markets, one interviewee said the chimney dryer can also facilitate drying "in rural areas [where] there are seasonal roads, which are damaged during the [6 month long] rainy season. In such conditions, the rural people can dry the products when there is production, but no transportation." This finding was encouraging because it points to the chimney dryer being a relevant and applicable technology for a variety of individuals operating at different scales and locations. Furthermore, in selecting the two communities for this pilot research, staff members at HKI targeted Bagarkot and Belapur for specific reasons. There is the belief that the chimney dryer can be effective for communities that can grow produce all year round, have marketable surplus after home consumption and are located relatively nearby population centers, such as the farmers in Bagarkot. The dryer can also benefit farmers of different scales who are located in more isolated regions with a true lean season during which additional dried foods contribute significantly to household food security, as is the case with the community of Belapur.

While interest in dry chain technologies should arguably originate at the farmer-level rather than NGOs or government for long-term sustainability, farmers can be partially motivated by consumer demand for dried products. For example, one NGO partner said, "Farmers may not invest in the dry chain on their own unless the market pulls these products. For household consumption, farmers aren't going to change their practices." A somewhat paradoxical situation exists, however, in which farmers may only invest in a chimney dryer (especially to sell dried foods) if there is a market, while customer demand is not yet widespread, perhaps because of low exposure to dried foods at the outset.

To scale up the entire dry chain concept, including the chimney dryer, DryCard, and dry-storage, and develop a market for dried foods, large-scale buy-in among stakeholders is required. Coordination should involve community members, government, NGOs, and private sector. Multiple stakeholders including local NGOs and government expressed that demand for technologies should come from the farmers before any kind of technical support or budgetary provision is provided. Thus, it is necessary to first make community members aware of proper postharvest management. Farmers we interviewed already realize that a significant portion of their fresh produce is lost due to the inability to store it after harvest, but improved postharvest handling, including solar drying should be explicitly promoted. One option is a public-private-partnership approach where NGOs as a private entity can provide training and technical support on improved drying and the local government (e.g. ward office) could provide funds or material provision to farmers (as well as training). This is an example of a pluralistic extension system in which multiple entities, in this case governments, NGOs, and universities collaborate to facilitate access to information and services for farmers (Ragasa, 2012).

A related finding was the critical importance of incorporating local government officials in our pilot project plans, including inviting them to community-level trainings to get their buy-in. For example, the Agriculture Knowledge Center, a district-level government office based in Amargadhi is now also keen to promote the chimney solar dryer in vegetable pocket areas across Dadeldhura. As a result of these coordination efforts, the local government may be more likely to invest in disseminating improved solar drying practices and even share costs with the farmers, if subsidies are deemed an appropriate financial intervention.

After improved drying, finding adequate packaging materials to store dried foods is crucial for scaling. At the community level, finding this packaging was a challenge, as truly air tight containers were hard to come by and glass containers are extremely rare. I brought 400 sealable bags from the U.S., which proved effective for demonstration and training purposes, as well as to serve as sample bags for the experiments. However, bringing a solution from abroad that cannot be procured locally is certainly not a sustainable solution. Thus, I recommend that strong efforts be made to explore local moisture-proof packaging options that are effective and affordable for community members.

Other needs for scaling up the dry chain and marketing dried products include raising awareness among consumers, which can be assisted by NGOs, government, and the private sector. This market development requires implementing proper packaging with aesthetically-pleasing labeling and branding. Farmers will need to be linked with traders and/or directly to consumer markets to sell their products, which might involve transportation and knowledge of prices for dried products, especially specialty food products. Some of these needs could be self-generated through farmer cooperatives that could engage in collective drying, branding and marketing. Cooperatives are an important platform for collective action that “offer a potential in [sic] increasing the poor’s bargaining power and in enabling them to pool extremely scarce resources together” (Ragasa, 2012). The government can also play a role in market development by assisting with quality control, setting minimum standards, grading and regulating expiration dates for dried products.

In terms of the chimney dryer’s gender-related impact, stakeholders including men and women farmers, NGO partners, and government officials all agreed that women would tend to benefit more from this technology as the primary individuals practicing drying in the community, but that men would benefit from the commercialization of drying. This sentiment is not an uncommon trend as "[t]he risk of men taking over a productive venture from women has been reported in numerous cases" (Ashby et al. 2008 as cited in Ragasa, 2012). This pilot study revealed that the chimney dryer certainly has the potential to benefit women in terms of time and workload. However, for the advantages to extend into the area of income and asset generation, women need to be better integrated into value chain development for dried foods. Thus a gender-sensitive approach to value chain development is necessary, one that identifies and analyzes the root causes of gender-based systemic constraints to participation in economic activities and links these to structural change (FAO, 2016). For example, efforts could be made to facilitate women's participation in the dried foods value chain by targeting and customizing training and providing them with better access to "infrastructure services, information, credit, and other business development services" (Ragasa, 2012). These strategic efforts would help enable women to purchase, rent, or otherwise finance a chimney dryer and associated dry chain technologies, as well as provide them with gender-specific training and information about transporting and pricing their products. In addition to access to information, resources, and services, additional measures, such as policies and regulations (e.g. around rural finance), may be required to guarantee that women maintain control over income-generating assets when men attempt to take charge following profitable commercialization (Ashby et al., 2008).

6.8 Reflections on gender in this project

This research project was filled with complex gender dynamics and critical self-reflection about my positionality as a researcher. In an article titled the "Emissaries of Empowerment," the authors write about how many development projects are centered around gender empowerment, in an effort that often takes an "apolitical" and "technocratic" approach with a sole focus on economic livelihoods that are pedaled by "white saviors" (Cronin-Furman, Gowrinathan, & Zakaria, 2017). Rather than recognizing and engaging different women as complex, multi-faceted members of society with unique stories, agency, and potential for challenging social norms in a political manner, "empowerment programming is explicitly depoliticizing, obscuring women's relationships to power and the state" (Cronin-Furman et al., 2017). On the one hand, I am concerned that as an American woman and "[culturally]-white intervenor," I potentially contributed to this pattern by bringing the chimney dryer as an oversimplified technical solution for future income generation and targeting women as the main users, thereby substituting "marginal improvements to the material conditions of women's lives for the capacity to mobilize to shift the conditions of their repression" and offering "'empowerment' instead of power" (Cronin-Furman et al., 2017). In this way, I was perpetuating the "victim myth" by assuming what women in Dadeldhura needed (an improved solar dryer), rather than directly understanding their preferences and priorities (Doss et al., 2018). Instead, I deferred to my project partners to convey community needs and let this initial guidance inform the structure and topic areas of our FGDs, building on preconceived notions.

At the same time, I tended to over-generalize women's experiences. Time and capacity constraints led me to treat the women farmers in the project as a "monolithic group" and disregard the "heterogeneity among women" (Doss et al., 2018). Following advice from HKI, I was able to separate participants by gender for focus group discussions, but beyond that, I did not have the capability to meaningfully engage women by subgroup (e.g. age, ethnic group, social status, marital status, or income). Rather, I grouped all women into their gender category and drew conclusions based on the experiences of a few women who tended to dominate the conversations. Despite efforts to encourage all participants to share their opinions, in most cases, the dominant voices were those of the village model farmer or the community health volunteer. In contrast, younger women who had recently become mothers or just moved to the community to live with their in-laws talked far less, potentially revealing local politics and power dynamics. My approach and limited capacity did not acknowledge that "there are wealthy women as well as poor women" and that "characteristics other than gender may be more important for program design and targeting" (Doss et al., 2018).

During my international travels, some people I have met have been confused when I tell them that I am American, assuming that all Americans must be white. Yet in this context, as a Chinese-American, I appeared more like my Nepali colleagues than fellow citizens from the U.S. who are Caucasian. However, despite being a self-proclaimed feminist, these racial dynamics and good intentions do not erase the power dynamics inherent in this project and may not be enough to exempt me from representing a (culturally) "white" woman from the West attempting to "rescue" women in the developing world (Cronin-Furman et al., 2017). Because I did not want to contribute to further marginalization and political disempowerment of women, I actively considered how to engage women in a more meaningful and participatory way, while not intentionally excluding men. For example, during our TOT workshop, I had originally planned to build two dryers and asked people to count off into two groups (1, 2, 1, 2...) for the build. People laughed, perhaps because my idea was culturally misplaced, to think that women would or should participate in construction and carpentry work. Instead, the women trainees mainly stood around as the men took the lead on cutting the wood and nailing together the pieces.

Furthermore, our TOT activity may have illustrated other aspects of traditional Nepali gender dynamics. For instance, men tended to dominate discussion and reflection time, whereas women appeared to be shyer and more reserved, though these were my observations as a Western outsider. I had hoped to rectify this situation through individual interviews with TOT attendees, with the goal of adequately hearing the perspectives of women participants. However, these interviews were more difficult to carry out because they required the assistance of my co-PI and translator, as the women I interfaced with in Nepal, even government staffers, tended to be less proficient in English than their male counterparts. In the case of one post-TOT interview, the women staffers who actually attended the training were accompanied by their male director, who dominated the conversation, despite being absent from the workshop. This challenge may be reflective of larger patriarchal norms in Nepal (Pradhan, 2005), as some researchers (albeit with a Western lens) have posited women in East Africa as more "empowered" compared to the traditionally patriarchal societies of South Asia (Miedema, Haardörfer, Girard, & Yount, 2018), making it important to both question and respect these deeply rooted social norms.

In fact, I believe this project both fit within and challenged traditional gender norms in Nepal. The creators of the INGENAES Gender Technology Assessment present the idea that a technology may be considered "gender neutral" in its design, but as soon as it is introduced into a social context, it becomes gendered (Manfre et al., 2017). The chimney dryer could be characterized in this fashion, as anyone can use it, making it appear gender neutral, however, if male carpenters construct the dryers and women farmers are the primary users, then it becomes a gendered technology. My colleagues and I contemplated the extent to which women should participate in the chimney dryer building process at the community level, rather than engage solely as users. We questioned if women should simply learn the construction through observing male carpenters, or if it would be a more respectful use for women's time to omit them from the building portion all together, as they have myriad home responsibilities. On the one hand, I believe it can be productive and beneficial to challenge traditional gender norms (if done in a culturally-sensitive and respectful way) and encourage people to get outside their comfort zone and learn new skills. In contrast, my *Suaahara* colleagues conveyed that it is not very culturally appropriate for women to do this kind of manual labor in Nepal.

Hence, my attempt at equitable engagement was met with some resistance, as it seemed like women were often bored or disengaged during the building process. This incongruity could be attributed to my positionality as a researcher from the U.S. wanting to "fully engage" women, despite potential cultural impropriety. Clearly, engaging all stakeholders, especially women, in a meaningful way requires intentionality and cultural competency. Of course, I wanted to hear the opinions of the male carpenters who participated in the actual building to understand construction challenges, but if it is women who will be the principal users of the dryer, it is critical to get their perspective in the design process so we can build it to suit their needs. Ultimately, I was surprised that the recommendations about changing the design of the dryer were not necessarily gender-specific (e.g. smaller drying trays that are less cumbersome for women to carry), but more related to farm size (i.e. some people want a smaller dryer due to limited land).

Furthermore, it is vital to balance a "woman-focused" project with involving husbands and in-laws, as these individuals are often the heads of household and primary decision makers. In fact, targeting women alone while excluding men has not been considered a gender-responsive action, as "[i]t is more effective to design programs so they reach both men and women, taking their gender-differentiated roles and opportunities into account," while "[e]vidence suggests that getting men's support is critical to, and often necessary for the success of gender-responsive projects" (Ashby et al., 2008). Similarly, a woman may be very excited about building and using a chimney dryer, but if she does not have the support of her family, the investment will be impossible. I found this during our FGDs, when women were unable to definitively say if this was a technology they could build or adopt because they had not yet consulted with their families and they themselves do not have control over the household income or decision-making processes. It became clear that working in Nepal is never just engaging an individual woman, but an entire household and community. Thus, future efforts should intentionally secure the buy-in and/or participation of husbands, in-laws, and other key decision makers. Through comprehensive gender-sensitization that does not limit the reach to 1,000 days mother-farmers, greater inclusion may also prevent gender-based discrimination and violence that have been associated with agricultural interventions in other instances (Ragasa, 2012), as altering power dynamics between men and women may cause conflict and backlash against women (Doss, Meinzen-Dick, Quisumbing, & Theis, 2018).

If I could redo this project, I would focus on community strengths and be more conscious of social dynamics, nuanced identities among participants, and attempt to ensure that the voices of less-privileged community members are heard in a politically-relevant way. The social subtleties revealed during the community discussions and training workshops also speak to the complexities of facilitating meaningful and equitable participation in international development, emphasizing the need for approaches like participatory rural analysis that offer "a potential for gender inclusion, enabling unheard voices to be heard and creating a space for new rules for engagement" (Ragasa, 2012). I would, however, maintain the male participation in the project, especially through trainings that included men and women, as mixed groups can draw on everyone's strengths, promote "the possibility of cooperation and complementarity between genders," and working with both genders is crucial to understanding their constraints, roles, and dynamics (Doss et al., 2018).

7 Conclusion and next steps

7.1 Summary of research and findings

The original research question for this study was "Is the chimney dryer an appropriate and beneficial technology to disseminate to Dadeldhura's farmers, especially women, for drying fruits and vegetables?" Here, appropriate was defined as relevant, affordable, locally-available, and user-friendly; and benefits were assessed in terms of food availability, quality and safety; time and labor; and income (as defined by the INGENAES Gender Technology Assessment). I utilized several different mechanisms to simultaneously answer this question including qualitative methods (focus group discussions, key informant interviews, observation, and a seasonal calendar activity) and quantitative methods (solar drying experiments with different drying techniques and crops, and cost comparisons). Utilizing triangulation, I compared the results of the mixed methods to establish validity of the findings.

First and foremost, drying surplus vegetables, is an important food preservation method in Dadeldhura district of Nepal where cold storage is limited. Drying reduces food loss and contributes to increased availability of valuable micronutrients and dietary diversity throughout the year. This practice is especially useful during the lean season when fresh produce is not readily available and is particularly important for women and children, as nutritionallyvulnerable subgroups. Traditional sun drying is widely practiced by farmers, primarily women, who tend to use bamboo mats such as *supo*, plastic tarps, or even put their food products directly on rooftops. This open-air sun drying is fairly unhygienic, as it leaves product exposed to the elements, which can result in contamination from debris, animals, and weather. Relatively inefficient drying is another drawback of this method, which can lead to incomplete moisture removal and/or product spoilage.

To improve the drying process, this research piloted an appropriate technology designed by the Horticulture Innovation Lab called the chimney solar dryer, which has been promoted as a more efficient and hygienic drying method in different countries. Quantitative experiments were conducted in Dadeldhura to compare the performance of the chimney dryer with a cabinet-style solar dryer and traditional open-air sun drying using bamboo containers. Crops dried included radish, broadleaf mustard greens, cauliflower, balsam apple and tomato. The chimney dryer was the fastest method for radish, leafy greens, balsam apple and tomatoes, whereas the rate of drying for the cauliflower was similar under all methods. One noticeable difference was that the enclosed dryers prevented the products from being contaminated by rain, ash, and flies. The chimney dryer also resulted in noticeably improved color retention.

After introducing the chimney dryer in Dadeldhura through training of trainers and community-level extension activities, the technology was generally well-received and engendered apparent interest among stakeholders, including local farmers, produce collectors and traders, NGO partners, and government officials. People were excited about the dryer's potential to reduce drying time and product loss, improve food safety, and preserve food quality and nutrients. Besides the apparent relevance and curiosity around this technology, community members identified other aspects of technology compatibility including user-friendliness and the availability and relative affordability of the construction materials. However, despite the seemingly reasonable costs, farmers may still be unwilling to invest their own monetary resources into acquiring a chimney dryer, without a subsidy or financial support. This hesitance could be due to a culture of dependence on NGOs and government programs that has been engendered within rural communities and plagued international development efforts globally. Besides subsidies, farmers can utilize existing HFP and village savings groups, or form new cooperative associations to pool financial resources for purchasing a dryer to share collectively.

A major finding of this research was the importance of adapting the technology to fit local needs. The Chimney Dryer Manual developed by the Horticulture Innovation Lab can serve as a guide that is amenable to interpretation and modification, especially by carpenters and farmer-users whose lived realities can better inform the dryer design, materials, and usage. Examples of technology innovation that occurred in Nepal as part of this research include decreasing the dryer length and utilizing locally-available bamboo instead of wood from a furniture shop. During multiple chimney dryer building sessions in the field, it became clear that utilizing the skilled labor of carpenters, supported by NGO staff, is preferred for construction. The Horticulture Innovation Lab has seen laypeople construct the chimney dryer in the past, but it can be more laborious and challenging for those who are unskilled in tool use and carpentry.

In terms of the three domains of the INGENAES Gender Technology Assessment: food availability, quality and safety; time and labor; and income and assets, it was expected that time savings would have been the most important benefit of the dryer. While farmers did recognize this advantage, community members actually seemed more persuaded by the chimney dryer's potential to improve hygiene and food quality, including the possibility of nutrient retention. Reduced time and labor may have been less significant than expected due to the fact that drying is a relatively passive activity that does not require a tremendous amount of active input. Faster drying, however, is key for minimizing food spoilage and thus increasing food availability. It was agreed by all stakeholders interviewed that women would benefit more from the chimney dryer than men in terms of improvements in time and workload because they are the individuals who are largely responsible for drying to feed their families. Beyond household consumption, the chimney dryer also has the potential to contribute to income generation through the sales of dried foods. While this may take more time for smallholder farmers to benefit from, as the local market for dried product has not been well developed, the potential for produce collection centers and commercial-scale sellers to immediately implement chimney dryers and sell dried product may be greater. Similarly, there is the possibility that men could dominate the practice of drying if it becomes profitable, which calls for intentional efforts to develop the dried foods value chain in a gender-equitable manner that prioritizes the needs of women and other marginalized producers.

In terms of scaling the chimney dryer, it is important to recognize that this technology is only one aspect of the larger, interconnected “dry chain.” Analogous to the cold chain, the dry chain is all about adequately drying products and keeping them dry until the point of consumption. In addition to improved solar dryers like the chimney dryer, the dry chain concept could include the DryCard™ for measuring sufficient dryness and hermetic storage containers that keep product sealed from air and moisture, which can cause mold growth and spoilage, including harmful mycotoxins.

Overall, the chimney solar dryer is a promising technology for improving the drying process for fresh fruits and vegetables in Dadeldhura, Nepal. Community members and project partners deemed the chimney dryer a relevant and user-friendly technology and confirmed that it can be constructed with locally-available materials. This technology has the potential to especially benefit women farmers, though it can be utilized by a number of stakeholders in the horticulture value chain, including men farmers, producer cooperatives, collectors or traders, and even carpenters. It can increase the amount of food available, especially during the dry or lean season, improve the quality and safety of the food, reduce time, and has the potential to generate income if the value chain for dried produce is developed. Barriers to adoption include the cost, which can be addressed through households pooling resources to construct and share a dryer and through government subsidies, both of which can make the dryers more affordable.

Furthermore, the skilled labor of carpenters and creative approaches to modifying the chimney dryer design and materials to better fit local context can both improve chimney dryer adoption.

7.2 Research limitations of qualitative data collection

A number of research limitations related to the qualitative aspects of the project exist and should be explicated. As a pilot project, this research was only carried out over the course of about three months during the peak of the Nepali festival season, which caused some delays in the work. For examples, for the first dryer we built as part of a Training of Trainers activity, the carpenters ended up arriving almost two hours late with the wood for only one dryer instead of two (as we had originally requested), and not all of the wood was pre-cut or labeled. "They are used to Nepali time," someone said, and another colleague commented that the chimney dryers are such a small project for them, they probably did not make our order a priority. Still others said that people were in "festival-mode," which creates a challenging environment for project efficiency. In fact, I requested the wood three weeks earlier while I was still in Kathmandu, and once the project team arrived in Dadeldhura, we visited the furniture shop several times before the training, always met with reassurance that "everything was fine." As a result of the wood arriving late and not pre-cut, the initial dryer build took twice as long: about eight hours instead of four, over the course of two days instead of one. Thus, I am concerned that this first building process was such a disorganized, stressful, and time-consuming experience that trainees may have been discouraged from building this technology in the future and disseminating it to their respective communities.

In a lower-income country with poor road conditions and infrastructure, transportation in the field was an ongoing challenge. We had planned to spend about two weeks in each village carrying out the trainings and FGDs. However, due to a lack of reliable transport and the fact that the *Suaahara* field office in Dadeldhura does not have a private vehicle, we struggled to get to and from the community level to carry out the project activities. Public mini busses only run once a day in the afternoon, the facilities for staying overnight in the villages often do not exist, and staying with local families can burden them and is hence discouraged by the NGO. As a result, we found ourselves in a predicament of wanting to support the communities that are more marginalized and remote, where unfortunately, the infrastructure does not exist to easily reach them. Ultimately, by the time we were able to actually facilitate the community-level dryer trainings and conduct the endline focus groups, there were only two weeks between these activities. Behavior change and technology adoption can be slow processes, especially for an activity like drying, which can take several days. In considering the diffusion of innovation process, technology adoption will also not occur at the same time for everyone, with innovators (i.e. the earliest adopters), laggards, and all the individuals in between (Rogers, 1995). Thus, two weeks between baseline/training and endline was obviously not enough time to assess technology adoption across a community. Instead, we had to focus more on perceptions of benefits, attitudes towards the technology, and potential for future behavior change.

In international work, language barriers are often a challenge. Originally, I expected to be working with strong English speakers, but some members of the original field team had been recently transferred to other offices. We were able to accomplish most of the project activities, but the pace was certainly slower given the communication difficulties. I had to rely heavily on my co-PI and research assistant, who translated all project materials (e.g. chimney dryer construction manual, training facilitator manual, focus group discussion guides, training surveys, etc.) into Nepali, which took a significant amount of time, especially because they were iterative documents that were being modified as needed, as well as translating and transcribing all focus group discussions. While her persistence and ongoing dedication to the project made this research possible, in an ideal scenario, I would have been fluent in Nepali and able to communicate directly with community members to reduce the risk of miscommunications and increase transparency. Furthermore, the chimney dryer was well-received by local community members, but it is unclear if this interest would have been as ostensible if the pilot project had not been implemented by a foreigner (myself) who was visiting Nepal from an agricultural university and donor in the United States. Lastly, due to the limited geographic area, short time period, and small sample size of project participants, this research serves as more of a formative case study that is not intended to be generalized across time and space.

7.3 Next steps and further research

Several developments have occurred related to this project after the in-country research was conducted. For instance, the Horticulture Innovation Lab has since worked with R&D Innovative Solution, an agricultural entrepreneurial venture based in Bhaktapur outside Kathmandu to develop a robust business plan for manufacturing and distributing the DryCard throughout Nepal. The Horticulture Innovation Lab has sent them materials to make the first 10,000 cards, and after their initial capital investment in the card making equipment, we hope they will become a self-sustaining manufacturer that can supply DryCards locally. The *Suaahara* field team has been following up with the pilot communities over the last few months and have sent photos and written reports showing that farmers are continuing to utilize the chimney dryers. Long term sustainability and technology adoption, however, will only become apparent over the subsequent months and years.

Besides scaling up dry chain technologies in Nepal in the future, I recommend any follow up projects make a concerted and culturally-informed effort to facilitate equal participation from all stakeholders, especially those voices that are more marginalized within an already oppressed social group (e.g. new mothers and lower income, caste and ethnic groups, etc.). It has been shown that successful participatory projects "include an explicit gender strategy at the start of the project, rather than as an afterthought" and enables "joint identification of problems and implementation of solutions involving both women and men; and emphasis on linking small women and men [sic] to markets" (Ragasa, 2012). Thus, future next steps should include a thorough market or value chain analysis with a gender lens, as well as additional testing of the dryer under various field conditions, seasons and crops.

It was also identified by a *Suaahara* staff member that as a hub for surrounding hilly districts, Dadeldhura is a relatively accessible area in the context of the remote western part of Nepal. In contrast to Dadeldhura, a majority of rural communities in Nepal are difficult to access by road, which would require creative provision and transportation of supplies for building the chimney solar dryer. However, it is these communities that might benefit even more from a food preservation and value addition technology like the chimney dryer, as these villages are more remote and have constrained access to transport and markets. The reduction in weight and volume, as well as the value addition to food products can enable these communities to more easily transport and sell their products, even to distant markets. Thus, while Dadeldhura served as a suitable field site to pilot the chimney dryer, testing the technology in more remote mountainous districts might be more important and beneficial.

This pilot project collected preliminary data in Nepal around the challenges and opportunities of building, utilizing, and training farmers to use the chimney solar dryer, and to measure dryness and adequately store dried foods for consumption. Findings will inform the planning of a future, randomized controlled trial to assess whether an intervention with the chimney dryer, which includes a nutrition education and behavioral change component, can 1) increase access to fruits and vegetables year-round, 2) increase dietary diversity and micronutrient intake among women and young children, and 3) improve nutrition and health outcomes. Feedback from the chimney dryer trainings and focus group discussions have been compiled, analyzed, and shared with the *Suaahara* team, as well as UC Davis researchers who are interested in implementing the aforementioned future study. More immediately, this initial pilot study is contributing to additional formative research that is currently being planned by researchers at UC Davis around recipe development, taste testing, and acceptability trials for dried foods (e.g. snack foods), especially for women and young children; shelf life studies to see how long chimney-dried product can retain its quality if properly stored, as well as potentially quantifying nutrient retention in chimney-dried products and examining use of the DryCard for mycotoxin prevention among dried commodities like chili peppers and peanuts.

The application of the INGENAES Gender Technology Assessment will inform strategies for increasing the uptake and adoption of the dryers across different population subgroups, including women, and the potential for income-generation among smallholder farmers. Data gathered from the focus groups as part of the gender technology assessment have been analyzed and shared with the Horticulture Innovation Lab team, including the designers of the chimney solar dryer. The goal of sharing these findings is to potentially modify the chimney dryer design, construction manual, and dissemination process. As a result, the construction manual is currently being revised, partially based on feedback from users in Nepal. I also shared my experience adapting and utilizing the INGENAES Gender Technology Assessment with Cultural Practice LLC, the company that co-designed the toolkit. Sharing research findings, including success stories and lessons learned from piloting the chimney dryer in Nepal, will hopefully inspire other organizations, government entities, farmers groups, entrepreneurs, and agricultural extensionists to utilize this new suite of technologies across Nepal and in other parts of the world.

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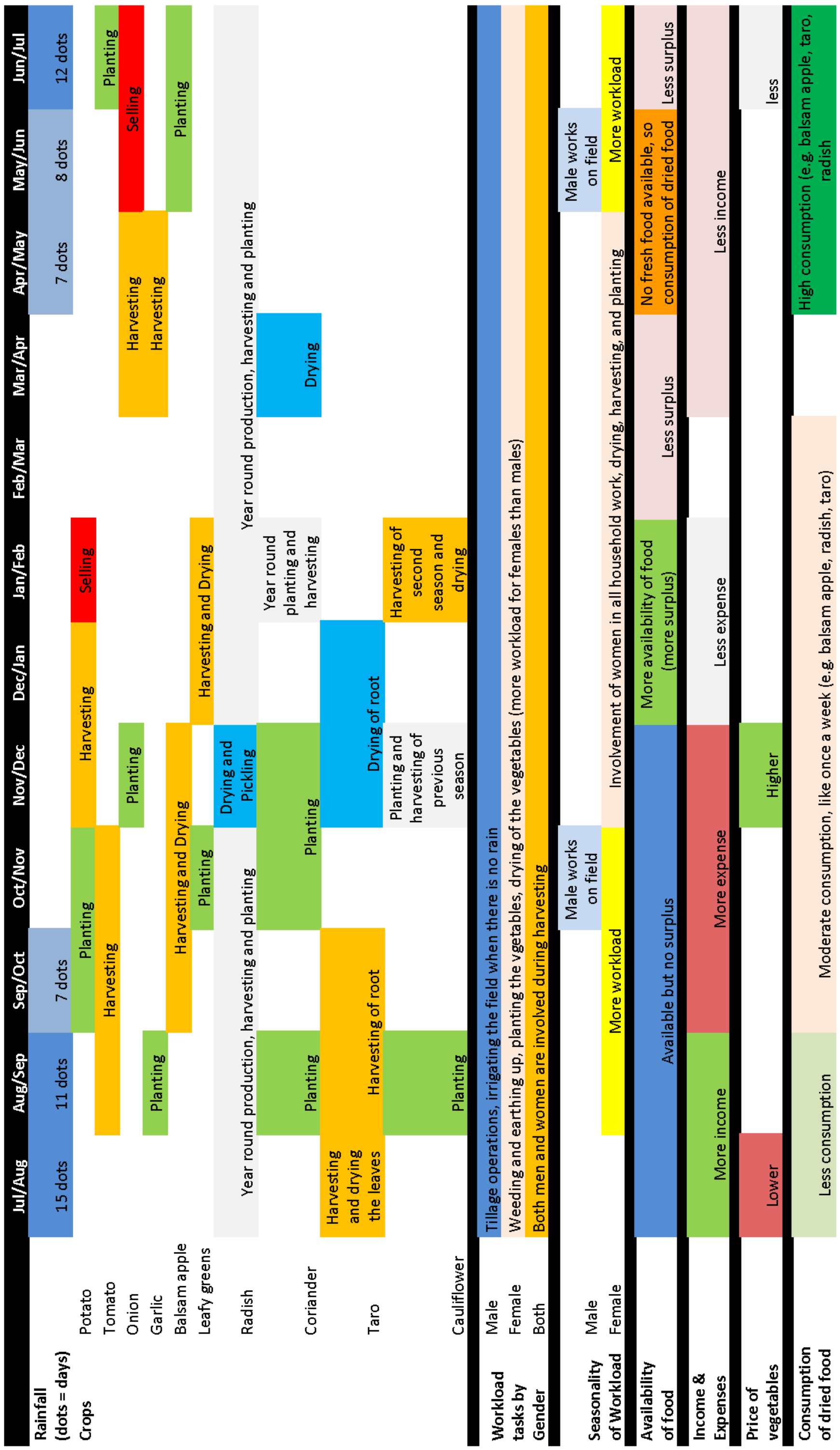
9 Appendices

9.1 Appendix 1: Seasonal calendar from Belapur



9.2 Appendix 2: Link to more information about the chimney solar dryer

For more information about the chimney solar dryer, including the construction manual and the training facilitator manual: https://horticulture.ucdavis.edu/chimney-solar-dryer

9.3 Appendix 3: Focus group Discussion (FGD) Interview Questions

Focus Group #1 (Baseline)
Topic: Drying Practices & Dried Foods Knowledge, Attitudes and Practices (KAP)
Targeted participants: Village model farmers and 1,000 days mothers
Timing: Before dryer build, approximately 2 hours

Starting by doing a show of hands and asking:

- Has anyone received any prior training in proper postharvest handling of fruits and vegetables?
- Has anyone received any prior training drying fruits and vegetables?

Q No.	Theme of Questions	Main Question	Probe Questions
1	Introductory - current practices	Tell me about your experiences drying fruits and vegetables.	• Do you dry fruits and vegetables (F&V)? • Which F&V are best for drying? • Which season (specific months) are they dried in? • What about drying meat or fish? How is it done, and in which season?
2	People	Who usually does the drying in your household?	• Do men or women do the drying? • Adults, children, or elderly? • Why are these the people who do the drying?
3	Methods	Describe the method you use to dry (e.g. *nanglo*, *supo*, plastic tarp, cloth, etc.)	• What do you like about this method? (e.g. it's fast, easy, cheap, hygienic, has good final product quality, etc.) • How much product in kilograms (or number of *nanglo*) do you typically dry in one drying session? • Do you dry multiple products at a time or do you wait until one product is completely finished drying before starting the next one? • How much time does drying require? Describe the time required for different crops (e.g. number of hours or days). • Are you satisfied with the time requirement? If you didn't have to spend

			this time drying, how would you prefer to spend your time – what activities would you do more of instead of drying? • During drying, do you turn the product over one piece at a time? Do you stir it, shake/mix it, or move it around? Why do you do this? • Do you bring the product inside the house over night? Why? • What do you wish was better or improved about this drying method? • Have you tried to improve it? If yes, how? • Are you satisfied with the final product quality (e.g. color, texture, taste, smell, nutrients, etc.) of traditional sun drying? Please describe. • Are you satisfied with the cleanliness and hygiene of traditional sun drying? Do you feel that the product dried from sun drying is completely sanitary and safe to eat? Why or why not
4	Consumption	Tell me about how your community or family consumes dried fruits and vegetables.	• Does your household currently consume dried F&V? • If yes, which dried F&V do you eat? • If no, what are the main reasons? • At what times of year (specific months) are different dried foods eaten? • Why are dried F&V consumed during these months and not in other months? • During this season, how often does your household eat dried F&V (e.g. twice a day, once a week, twice a month, etc.)? • If you did not dry foods, would your family have enough food to eat throughout the year? Please describe.
5	Preparation	Describe how the dried fruits and vegetables are prepared and then consumed	• Which food dishes do you use dried F&V in (e.g. achar/pickle, tarkari/curry, other)? • Who usually prepares them? • Does preparing the dried F&V take more, less or the same amount of time compared to preparing fresh ingredients? • Does someone need special knowledge to prepare or cook dried fruits or vegetables? What is that special knowledge? Why do they need it? Who teaches them?
6	Attitudes and personal preference	How do you feel about eating dried F&V?	• Which dried F&V do you like to eat, and why (e.g. taste, texture, etc.)? • Which dried F&V do you dislike, and why?

			• What do you dislike about eating dried F&V? • Do you think there is a way to improve the flavor or texture of dried F&V (e.g. through a different cooking method or ingredient)? • How do you feel about eating dried F&V as a snack (plain, not rehydrated and cooked in a dish)? • Do you want to eat more dried F&V in the future? Why or why not? • Is there anything else you would like to say about eating dried F&V?
7	Nutrition	What do you think about the nutrition or healthiness of eating dried F&V?	• Do you think dried F&V are as good as, better or worse than fresh F&V for human nutrition and health? • Do you think this means that you should or shouldn't eat dried F&V?
8	Measuring dryness	How do you know if a dried product is dry enough to store long term? Describe your practices for measuring dryness.	• Do you bend, rip, or crush the produce to test its dryness? • Do you look for moisture development inside a storage container? How often do you check the product to see if it is dry enough? • How effective are these methods for measuring dryness? • Are you ever uncertain if a product is dry enough to store? What do you do if you are unsure? • Do you wish there was a better or more accurate way to know if a product is dry enough to store? How would this benefit you?
9	Storage	Describe your practices for storing dried F&V.	• How do you store dried F&V (e.g. glass jar, plastic container, plastic bag, etc.)? • Where do you get these containers? Are they easy to find? Are they expensive? • Why do you use this type of storage container (especially if it is not working effectively)? • Are plastic bags or glass jars easily available? Are they affordable? • Once you place dried product into the container, where do you place the container (e.g. inside or outside the home; in the sun or in the darkness; in warm or cool conditions; in dry or wet conditions, etc.)? • How long do you store them for before eating?

			• Do you store different F&V differently? (For example: Do you store different products in different containers? Do you store different products for shorter or longer amounts of time?) • Do you have any issues with pests, insects, or mold growth during storage? Which products are affected by these issues? • Do you have any other issues with storing dried products? Which products are affected by these issues? • Do you know what is causing these storage problems? • What ideas do you have for solving these storage problems?
10	Market sales	What do you think about the idea of selling dried F&V?	• If you are not selling dried F&V currently, why not? For example, if quantity of dried product is too small to sell, how can you increase your drying capacity? • Do you think people would be interested in buying dried F&V? Why would they be interested? For example, why is dried chili sold in the market but no other dried foods? • Who would be interested in buying dried F&V? • Where would the best market be? Describe how would you transport your product to that market and if it would be easy or difficult. • Do you think selling dried F&V would be profitable? Are you personally interested in selling dried F&V? Why or why not? • What support do you need to sell dried F&V? • Why do you think people would NOT be interested in buying dried F&V? How would you convince others to buy dried F&V – what you would say? • For selling fresh F&V, who makes marketing decisions in your household (e.g. what products to sell, how much of each product to sell)? • For selling fresh F&V, who does the actual selling and negotiating of sales (e.g. you, your husband, someone else in the family)? • When selling fresh F&V, who receives and controls the income (e.g. you, your husband, someone else in the family)?

			• When your household generates income from selling fresh F&V, how do you decide what to spend the money on? Is it a decision made together as a couple or just made by you, or just made by your husband? • How do you typically use any extra income (e.g. children's schooling, more fresh F&V, more animal source foods, motorbike, television, etc.)?
11	Improved solar drying	How do you feel about improved solar drying (compared to traditional sun drying)?	• Are you familiar with improved solar drying? • How did you hear about it? • Have you seen it being done? Who does it? • What have you heard about the benefits or challenges? • Have you or anyone in your household tried using an improved solar dryer? Who? Why? • If not, are you interested in trying an improved solar dryer? • Who in your household makes decisions about the technology that is purchased or used?
12	Chimney dryer	Show an image of the chimney dryer and **give a limited explanation [without explaining all the benefits]:** *it is an improved solar dryer that can be constructed with local materials like wood and plastic.* Then ask: what do you think about the chimney dryer?	• How do you think it will change or improve your drying activities? • What types of F&V do you think would work best in the chimney dryer? • *Then explain: Compared to traditional sun drying, the chimney dryer dries product faster, is more hygienic and sanitary by protecting product from weather, dust, insects and pests, and helps preserve the nutrients, color, taste, texture, and quality of food items,* then ask: • Would you be willing to spend money on a chimney solar dryer? • How much money would be you willing to spend? • If it cost 10,000-15,000 NPR, would you spend this much money on a chimney dryer? • Would you prefer to pay someone to build you a chimney dryer or would you prefer to buy the materials and build it yourself? If you prefer to build it yourself, who will actually construct it – you or your husband?

			• Will you need to discuss with and convince your husband to either build a dryer or pay for one? Will it be possible to convince him? Please describe.

Focus Group #3 ("Endline")
Topic: Using the Chimney Dryer
Targeted participants: The same group of Village model farmers and 1,000 days mothers as the baseline FGD
Timing: 2 weeks after the dryer is built, approximately 2 hours

Q No.	Theme of Questions	Main Question	Probe Questions
1	Current use	Describe the current use (or disuse) of the chimney dryer.	• How many times has the chimney dryer been used since the training? Who used it? • What do you think is easy about using the dryer? • What do you think is difficult about using the dryer? • How much time do you think it takes to dry products in the chimney dryer compared to sun drying? • How does the capacity of the chimney dryer compare to your traditional, sun drying practice? • Is the dryer too small, big, or just right for your drying needs? Would you prefer a bigger or smaller dryer? • How do you feel about the amount of space/land the dryer occupies? • Do you have to ask permission from someone to use the dryer? From whom do you need permission (e.g. VMF, husbands, in-laws, etc.) • If you have not personally tried the chimney dryer yourself, why? (e.g. too expensive; not convinced it will improve the drying process; haven't learned to use it; not available in the area; too big or small; inappropriate for men/women, too difficult to use)
2	Changing practices	Describe how the chimney dryer will affect your drying practices.	• Do you think your drying practices will change as a result of using the chimney dryer compared to traditional sun drying? • Will using the chimney dryer make the task of drying easier or harder to perform? Please explain. • Can you dry products in the chimney dryer by yourself only or do you need the assistance of someone else? • How do you think the amount of time you spend drying will change as a result of using the chimney dryer?

3	Use of dried F&V	How will the dryer change the food available for your household to consume?	• Do you think the amount of food available for home consumption will change as a result of the dryer? How will it change? • Will the amount of food you have during the lean season change? How will it change? • Do you think your household will be able to consume more nutritious foods as a result of the chimney dryer? Please explain. • Will the sanitation and safety of the food available change as a result of the solar dryer? How? • How do you plan to use any additional F&V you have dried?
4	Problems with the chimney dryer	Describe any issues you are experiencing with the chimney dryer.	• Are you experiencing any problems drying produce with the chimney dryer? • Do you think the chimney dryer will operate well on both sunny and cloudy days? • Do you plan to leave the products inside the chimney dryer overnight? Do you think there will be any problems with this practice? • What will you do if the dryer gets damaged or breaks (e.g. plastic rips) - will you or someone else in your community repair it if needed? • How much would a repair cost? Are you willing to pay for the repair?
5	Future use	Will you use the chimney dryer in the future?	• Why or why not? • Are you interested in drying other products with the chimney dryer? Which products (e.g. meat/fish, pulses, etc.)?
6	Dryer design and materials	How do you feel about the dryer design or materials?	• Do you have any recommendations about the dryer design or materials? • Are the construction materials (e.g. wood, plastic, and metal mesh) readily available in your local community? Are they affordable? Are they easy to transport? • What do you like about the design? How could the design be better to meet your needs?
7	Affordability	If your family agrees, are you interested in spending money for your own chimney dryer?	• If yes, would you prefer to build your own individually or continue to share it as a group?
8	Telling others	How would you describe using the chimney dryer to other people?	• What would you tell someone about the advantages of using a chimney dryer? • What would you warn someone in terms of disadvantages before they tried using the chimney dryer? • Would you recommend the chimney dryer to others? Why or why not?

9	Measuring dryness	Have you tried using the DryCard?	• What do you think of the DryCard? Describe your experience using the DryCard. How many times have you used it? Have you had any issues with it? • Will the DryCard benefit or help your family? If so, how? • Are you interested in obtaining more DryCards? • How much money would you be willing to spend on one DryCard? • Would 100-200 NPR for one DryCard be affordable for your family? • Will you tell other people about the DryCard? If so, who will you tell and what will you say to them? • If you have not tried using the DryCard, why not? • Do you have anything else you would like to add about the DryCard?
10	Storage	Have you tried any new or different storage containers?	• If you are using different storage containers (e.g. glass jars, plastic containers, plastic bags lined with a paper bag, etc.), which ones? How are they performing compared to the previous container? • If yes, why did you choose to use this different container? • These airtight containers can be bought from the shop in Belapur for 15 NPR - do you consider these containers affordable? • Have you had any new issues with pests, insects, or mold growth during storage? Which products are affected by these issues?
11	Market sales	Do you think using the chimney dryer will change how much income your household generates?	• If your household were to start selling dried F&V in the future, who would do the selling (e.g. you, your husband, in-laws, someone else)? • If your household were to start selling dried F&V in the future, who would receive and control the income (e.g. you, your husband, in-laws, someone else)? Would this control be different than before you started using the chimney dryer? • If your household were to generate extra income from selling dried F&V in the future, how would YOU personally prefer to use the extra income (e.g. children’s schooling, more fresh F&V, more anima source foods, motorbike, television, etc.)? • How do you think your husband would prefer to use any extra income? What about your in-laws? • How do you think you will experience the benefits of the dryer compared to other people

			in your household (e.g. your husband, in-laws, etc.)? What are these benefits (e.g. food available, money, less labor/time, etc.)
12	Closing	Is there anything else you would like to say about the chimney dryer?	

9.4 Appendix 4: Key Informant Interview (KII) Questions

KII: TOT training participants follow up

1. How does your organization decide which technologies to promote? (e.g. Directions from the Ministry/NGO/project; Consultation with farmers; Recommendations from input supplier, etc.)
2. How does your organization decide to whom to target specific technologies? For example, if you have a new seed variety, how do you decide which farmers to inform?
3. How do you feel about the chimney solar dryer compared to traditional sun drying? Do you predict any problems or challenges with the chimney dryer in local communities?
4. In your opinion, why is Dadeldhura a good district to implement this pilot project for improved solar drying?
5. Would you recommend the chimney dryer to other districts or municipalities? Why or why not?
6. What were your main takeaway messages or lessons learned from the TOT?
7. What information did you share and/or actions did you take shortly after TOT with your colleagues?
8. What are you plans related to disseminating the chimney dryer in the future (e.g. sharing, trainings, funding, partnerships, etc.)?

KII: Ward representative or local government official

1. How does the local government ward office decide which technologies to promote? (e.g. Directions from the Ministry/NGO/project; Consultation with farmers; Recommendations from input supplier, etc.)
2. How does the local government ward office decide to whom to target specific technologies? For example, if you have a new seed variety, how do you decide which farmers to inform?
3. In your opinion, do you think traditional sun drying of F&V is effective?
4. In your opinion, why is Bagarkot/Belapur a good community to implement this pilot project for improved solar drying?
5. How do you feel about the chimney solar dryer compared to traditional sun drying?
6. Have you seen or heard of the chimney dryer being used? Who uses it the most and why?
7. What have you heard about the advantages or benefits of the chimney dryer?
    a. Are there specific advantages for women farmers?
    b. Are there specific advantages for men farmers?
8. What have you heard about the disadvantages or challenges of the chimney dryer?

    a. Are there specific disadvantages for women farmers?
    b. Are there specific disadvantages for men farmers?
9. How do you feel about the dryer design or materials?
    a. Are the construction materials (e.g. wood, plastic, and metal mesh) readily available in your local community? Are they affordable? Are they easy to transport?
    b. Do you have any recommendations about the dryer design or materials?
10. Would you recommend the chimney dryer to other municipalities? Why or why not?
11. Describe the likelihood that people in the community will adopt the chimney dryer for continued, long term use.
    a. What requirements would be necessary for the people to accept and adopt the chimney dryer? (e.g. meeting an actual need, affordability, user-friendly, durable, easy to maintain, less labor and time, increased capacity, faster drying time, etc.)
    b. Who is more likely to adopt or use the chimney dryer (e.g. age, gender, entrepreneurial history, number of children, social status, open/willing attitude, etc.)? Why?
    c. Who is less likely to adopt or use the chimney dryer? Why?
    d. Why would people hesitate to adopt it? What aspects would these communities find challenging about this technology?
12. What role do you think the local government ward office could play in supporting the dissemination of chimney solar dryers?
13. Farmers seem interested in selling dried F&V if they can make money, but this depends on market opportunities. Do you think selling dried F&V could be profitable?
    a. Do you think people would be interested in buying dried F&V? Is there existing demand or would demand need to be created?
    b. Where would the best market be? What is the location (i.e. how far would the product need to be transported)? Is it realistic that farmers could transport their product to these markets easily?
    c. Which customers would be interested in buying dried F&V (e.g. nearby hotels, restaurants, middle class urban consumers in KTM, etc.)?
    d. What challenges do you anticipate in producers selling dried F&V?
    e. What support do you think producers would need to overcome these challenges to sell dried F&V? For example: infrastructure, inputs, packaging, awareness raising or marketing, support services, etc.
    f. Are you aware of any other laws, regulations, licenses etc. that might affect the commercial production and/or sales of dried F&V?
    g. What role do you think the government could play in supporting the marketing and sales of dried F&V?
14. If this pilot project goes well, what is the local government's plan for continuing to support the chimney dryer dissemination in Nepal in the future?

KII: Local collectors/sellers for marketing opportunities

1. Tell me about your collection/selling process for fresh F&V:
    a. Who do you collect your products from? Do you aggregate products from multiple producers?

    b. What kind of fruits and vegetables do you collect/sell – fresh, dried, other value-added products?
    c. Do you do any additional processing, packaging, or value addition of the F&V?
    d. Do you have to do any marketing of the products you collect/sell?
    e. Who do you sell your products to? Where is the market located?
    f. How do you transport your products to market?
2. What challenges do you experience in collecting and selling fresh F&V?
3. How could the collection and selling process be improved? Who could improve it?
4. Do you think selling dried F&V instead of or in addition to fresh F&V could address some of your challenges – which challenges?
5. Do you think selling dried F&V could be profitable?
6. Do you think people would be interested in buying dried F&V? Is there existing demand or would demand need to be created?
    a. Who would be interested in buying dried F&V?
    b. Where would the best market be? What is the location (i.e. how far would the product need to be transported)?
    c. How can the dried food products be transported to market? Are there already transportation mechanisms and proper infrastructure in place?
    d. How big is the potential market for dried F&V?
    e. How would collecting and selling dried F&V compare to fresh? More or less expensive? More difficult or easier? More or less labor? More or less time? More or less profitable?
    f. Do you think local consumers would accept dried F&V (e.g. food preferences for taste, appearance, texture, culture, cooking, and processing standards)?
7. What kind of packaging is needed for dried food products? Is this packaging currently available?
8. What kind of marketing is needed for dried food products? How can this be achieved?
    a. E.g. different mediums like radio, newsletters, billboards, TV, etc.
    b. What kind of content would you include in the marketing ads? (e.g. nutrition, storability, extended shelf-life, recovery of lost income, etc.)
    c. If there is a market for dried F&V, what makes some of the products successful (part of recipes? Effective packaging? Taste? Marketing?)
9. Are you aware of any other laws, regulations, licenses etc. that might affect the production and/or sales of dried F&V?
10. Would you personally be interested in selling dried F&V?
    a. What would be easy for you in selling dried F&V?
    b. What challenges do you anticipate in selling dried F&V?
    c. What support do you need to overcome these challenges to sell dried F&V? For example: infrastructure, inputs, packaging, awareness raising or marketing, support services, etc.
11. What role do you think the government, NGOs, or other stakeholders could play in supporting the marketing and sales of dried F&V?

KII: NGOs or partner initiatives
Background information

1. What is the relationship between your organization and the Suaahara project?
2. How does your organization decide which technologies to promote? (e.g. Directions from the Ministry/NGO/project; Consultation with farmers; Recommendations from input supplier, etc.)
3. How does your organization decide to whom to target specific technologies? For example, if you have a new seed variety, how do you decide which farmers to inform?
4. How do you feel about the chimney solar dryer compared to traditional sun drying? Do you predict any problems or challenges with the chimney dryer in local communities?
5. In your opinion, why is Dadeldhura district (and Bagarkot and Belapur more specifically) a good district to implement this pilot project for improved solar drying?
6. Would you recommend the chimney dryer to other districts or municipalities? Why or why not?
7. What were your main takeaway messages or lessons learned from the TOT?
8. What information did you share and/or actions did you take shortly after TOT with your colleagues?
9. What are you plans related to disseminating the chimney dryer in the future (e.g. sharing, trainings, funding, partnerships, etc.)?

Chimney dryer concept

10. What are the advantages of the solar dryer?
11. Are there specific advantages for women farmers?
12. Are there specific advantages for men farmers?
13. What are the disadvantages of the solar dryer?
14. Are there specific disadvantages for women farmers?
15. Are there specific disadvantages for men farmers?
16. Are you using/will you use different training methods to reach women farmers than you use to reach men farmers on the solar dryer? If so, why? If not, why not?
17. What farm or farmer characteristics do you prioritize when selecting participants for group activities (e.g., training, FFS) for training on the [targeted technology]?
    a. Age
    b. Sex
    c. Size of plot
    d. Choice of crop
    e. Location
    f. Degree of market-orientation/engagement

Chimney dryer price

18. What would be considered an affordable price that community members would be willing to pay for a chimney dryer (either at the individual household or group level)?
    a. Do you think people would spend money (e.g. 10,000-15,000 NPR) for a chimney dryer?
19. How will users pay for the dryer (both build and repair)?
    a. Personal savings? Are credit or microfinancing mechanisms available?
    b. Will women be able to convince their husbands or in-laws to invest in this technology?

Chimney dryer adoption

20. Describe the likelihood that people in the community will adopt the chimney dryer for continued, long term use.

   a. What requirements would be necessary for the people to accept and adopt the chimney dryer? (e.g. relevant in terms of meeting an actual need, affordability, user-friendly, durable, easy to maintain, less labor and time, increased capacity, faster drying time, etc.)
   b. Who is more likely to adopt or use the chimney dryer (e.g. age, gender, entrepreneurial history, number of children, social status, open/willing attitude, etc.)? Why?
   c. Who is less likely to adopt or use the chimney dryer? Why?
21. Why would people hesitate to adopt it? What aspects would these communities find challenging about this technology?

Gender-specific interview questions:
I am attempting to assess the gender implications and other social impacts of the chimney solar dryer in terms of food availability, quality, safety and nutrition, as well as men and women's labor, time, income, assets by using the USAID Integrating Gender and Nutrition within Agricultural Extension Services (INGENEAS) gender tech assessment to guide my focus group discussion questions with female village model farmers and 1,000 days mother-farmers.

22. What tasks are women and men responsible for along the agricultural value chain in Nepal? (e.g. women in weeding or postharvest handling; men in land preparation)
23. What do you think this project assumes about the agricultural and household roles of men and women? For example:
    a. Women do the drying and food preparation so the dryer will save women's time and labor
    b. Dryer involves basic carpentry work, so men will build it
    c. Dryer is affordable and easy to use so women can use it
    d. Men do the marketing and sales of agricultural products, so any sales of dried products will accrue income to men
    e. The dryer will increase food quality and safety, positively impacting men, women, and children

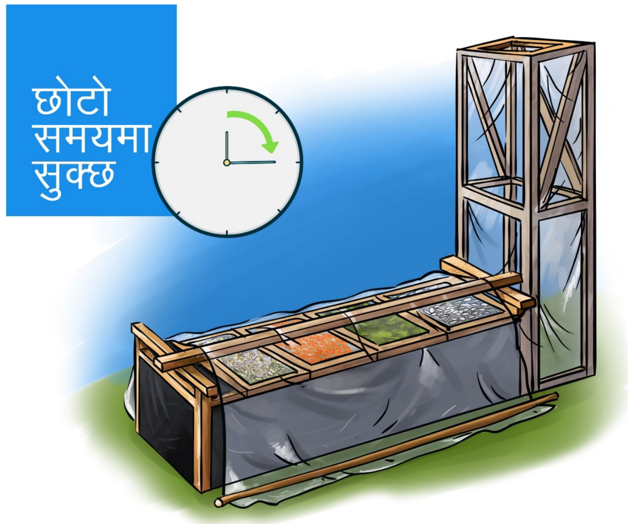
However, I recently saw an article in the Guardian about how many gender empowerment programs tend to take a narrow "apolitical and technocratic" approach and end up just reproducing gender norms and keeping women in boxes. I am concerned that my project is falling into this trap (especially because male carpenters are constructing the dryers and women will mainly be the users). I think women should have a say in the construction and design of the dryer (especially because they will be the main users), but it does not seem culturally appropriate to have women participate in the building process.

24. How do you think we can overcome this challenge?
25. How can we ensure that both women's and men's voices are heard in this project?
26. What are challenges that women may face in acquiring and adopting technologies? What about men? How can we overcome these?
27. How can we actually empower women instead of just reproducing traditional gender norms that may be oppressive and marginalizing towards women?

Marketing and sales of dried F&V
28. Farmers seem interested in selling dried F&V if they can make money, but this depends on market opportunities. Do you think selling dried F&V could be profitable?

    a. How would collecting and selling dried F&V compare to fresh? More or less expensive? More difficult or easier? More or less labor? More or less time? More or less profitable?
    b. What would be easy about selling dried F&V?
    c. What would be challenging about selling dried F&V?
29. Do you think people would be interested in buying dried F&V? Is there existing demand or would demand need to be created?
    a. Which customers would be interested in buying dried F&V? (e.g. nearby hotels, restaurants, middle class urban consumers in KTM, etc.)
    b. Where would the best market be? What is the location (i.e. how far would the product need to be transported)? Is it realistic that farmers could transport their product to these markets?
    c. In considering the opportunities to sell dried product, it seems like selling in Bhatbhateni would be the gold standard, but probably not possible for everyone, especially not immediately. Thus, are there intermediary dried food markets? For instance, we can see dried chilis, roasted peanuts, etc. being sold on the side of the road and in informal markets that seem less regulated in terms of quality control and food safety – would this be possible for other dried products? Or direct sales to local hotels that don't require regulation, branded packaging, etc. Maybe these could be marketing starting points for small-scale producers.
    d. How big is the potential market for dried F&V?
    e. Do you think local consumers would accept dried F&V (e.g. food preferences for taste, appearance, texture, culture, cooking, and processing standards)?
30. Packaging, branding, and marketing:
    a. What kind of packaging is needed for dried food products? Is this packaging currently available?
    b. What kind of branding and marketing is needed for dried food products? How can this be achieved?
        i. E.g. different mediums like radio, newsletters, billboards, TV, etc.
        ii. What kind of content would you include in the marketing ads? (e.g. nutrition, storability, extended shelf-life, recovery of lost income, etc.)
        iii. If there is a market for dried F&V, what makes some of the products successful (part of recipes? Effective packaging? Taste? Marketing?)
31. What kind of quality control measures are required for developing a market for dried foods? How can these be achieved, and what role do different stakeholders play?
32. Are you aware of any other laws, regulations, licenses etc. that might affect the commercial production and/or sales of dried F&V?
33. What support do you think producers would need to overcome these challenges to sell dried F&V? For example: infrastructure, inputs, packaging, awareness raising or marketing, support services, etc.
34. What role do you think the government, NGOs, or other stakeholders could play in supporting the marketing and sales of dried F&V?
35. If this pilot project goes well, what is your organization's plan for sustaining or continuing to implement the chimney dryer in Nepal?

9.5 Appendix 5: Training aids

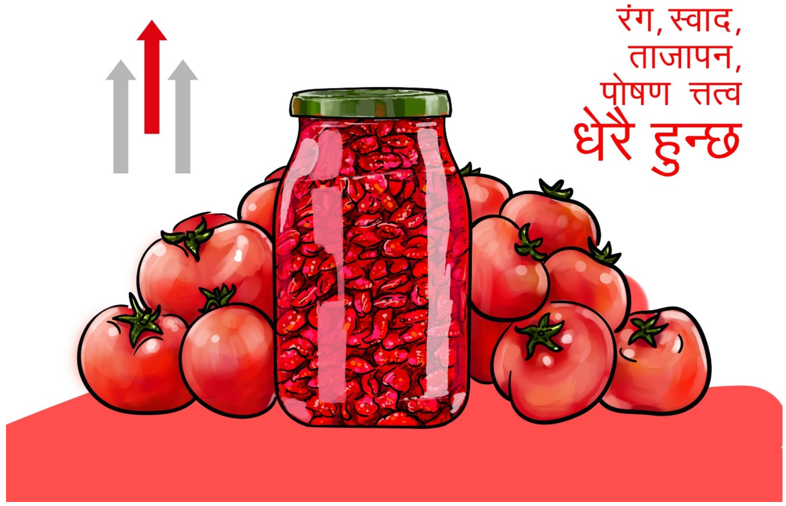


Translation of Nepali caption: “It takes less time to dry”

Translation of Nepali caption: “It takes more time to dry”

Translation of Nepali caption: "It is protected from rain, dust and animals"

Translation of Nepali caption: "It is not protected from rain, dust and animals"



Translation of Nepali caption: “Color, taste, freshness and nutrition are more conserved”

Translation of Nepali caption: “Color, taste, freshness and nutrition are less conserved”