SOLAR FOOD DRYING FOR AFGHAN COMMUNITIES

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Abstract

Solar food drying is a thousands years old technique used for food preservation. Bacteria, yeast, and mold are prevented from spoiling the food due to a low moisture content. Dried food takes up less room and is light and easier to transport. Afghanistan is a leading exporter of dried foods, but often still using inefficient traditional outdoor direct drying methods with longer drying times. Traditional outdoor drying is also less hygienic and subject to contamination from dust, insects, birds, and animals.

New Mexico State University (NMSU) introduced more efficient active and enclosed passive solar food drying techniques to Afghanistan in 2009 with faster drying times, better hygiene, and improved quality of dried foods. Food is normally dried between 50 to 80°C, which is a desirable range for drying and pasteurization. Solar drying reduces moisture content typically from about 10 to 20 percent. There are now over a dozen Afghan vendors supplying solar dryers. Many farmers also rent out their food dryers to after they have dried their own crops. This paper discusses solar dryer theory, operation, drying results, vitamin and color retention, business development, and applications in Afghanistan.

Keywords: solar energy, food drying, Afghanistan

1. Solar Food Drying

Solar food drying was the only method for long term food preservation for thousands of years until canning was developed at the end of the 18th Century. Bacteria, yeast, and mold are prevented from spoiling the food due to a low moisture content. Dried food takes up less room and is light and easy to transport. Food is normally dried between 50 to 80°C, which is a desirable range for drying and pasteurization. Solar drying reduces moisture content to 10-20%.

Figure 1. Traditional outdoor direct solar food drying in Afghanistan has been used for thousands of years like drying apricots on a rock, but this slower drying method often leads to mold and allows access for insects, birds, and vermin.

Traditional outdoor food drying techniques commonly use rocks, rooftops, and tarps which generate relatively low drying temperatures highly dependent on the ambient temperature and available sunlight. Traditional methods rely on longer drying times that often take five or more days. These slower drying times make food more susceptible to spoilage from mold, bacteria, and yeast if the weather does not cooperate and the sky clouds up for a day or more in

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the middle of the drying process. Traditional outdoor food drying is also less hygienic and subject to contamination from dust, insects, and animals.

Afghanistan has a centuries old tradition of using indirect solar food dryers in the form of adobe type barns (keshmesh khanas – literally raisin houses), but only for drying grapes into raisins. Fifty years ago before the wars, Afghanistan provided over ten percent of the global raisin supply (AFP, 2017).

Figure 15.Traditional raisin drying adobe barns (keshmesh khana) have been used for centuries in Afghanistan. (AFP, 2017)

The input energy to a solar dryer and the energy output of solar dryer is given below. For *I* is the amount of solar energy falling on a solar dryer, *A* is the aperture area of the solar cooker and Δt is the period of time; the amount of energy received by the solar dryer (E_{in}) is calculated by the following expression:

$$E_{in}=IA\Delta t.$$

The energy output of a solar dryer is the increase in energy that the food has due to the temperature increase and moisture driven out. From this point of view, energy output of the solar dryer (E_{out}) is given as follows:

$$E_{out} = m_f c_{pw}(T_{ff}-T_{fi})$$

where m_f is the mass of food, c_{pw} is the specific heat capacity of water (which is driven out of the food), T_{ff} is the final food temperature and T_{fi} is the initial food temperature (for any solar day). The basic concept is shown below where solar energy is used to dry food either passively or actively in a vented solar dryer that removes the moisture to a desirable moisture content level.

2. Solar Dryer Types

2.1 Rack Dryers

This is the simplest dryer to build and is a completely passive natural air dryer, a simple rack or even cardboard box can be used with cheese cloth or netting on top to keep the flies out. It's preferable to use some kind of screen underneath the food to allow for greater airflow and faster moisture removal.

Figure 2. Outdoor rack type dryer drying apricots in Afghanistan which allows for better air circulation underneath the product.

2.2 Direct Dryer (Greenhouse or Tunnel)

Direct dryers come in several configurations such as greenhouse or tunnel dryers and moisture is removed either passively or actively. Glazing is used and important as it allows the visible short wavelength sunlight to pass through, but and helps trap heat inside the box from the reflected long wavelength radiation through the greenhouse effect. The glazing should seal the top of the dryer in order to minimize heat from leaking out. Glazing facing the sun (perpendicular) achiees a higher solar heat gain.

Figure 3. Direct greenhouse dryer used by the French NGO GERES in Afghanistan for apricots.

2.3 Indirect Solar Dryer

Indirect solar dryers are the best type since the food is not dried in direct sunlight, which has strong UV rays that break down vitamins and color in food. Thus, indirect solar dried food has better vitamin quality and improved food color retention. There is no need for sulfur or blanching techniques sometimes used with some commercial food dryers designed to prevent spoilage and rot. Indirect dryers provide better control of the food drying process, which can more easily regulate the interior dryer temperature through passive or active (e.g. electric fans) venting.

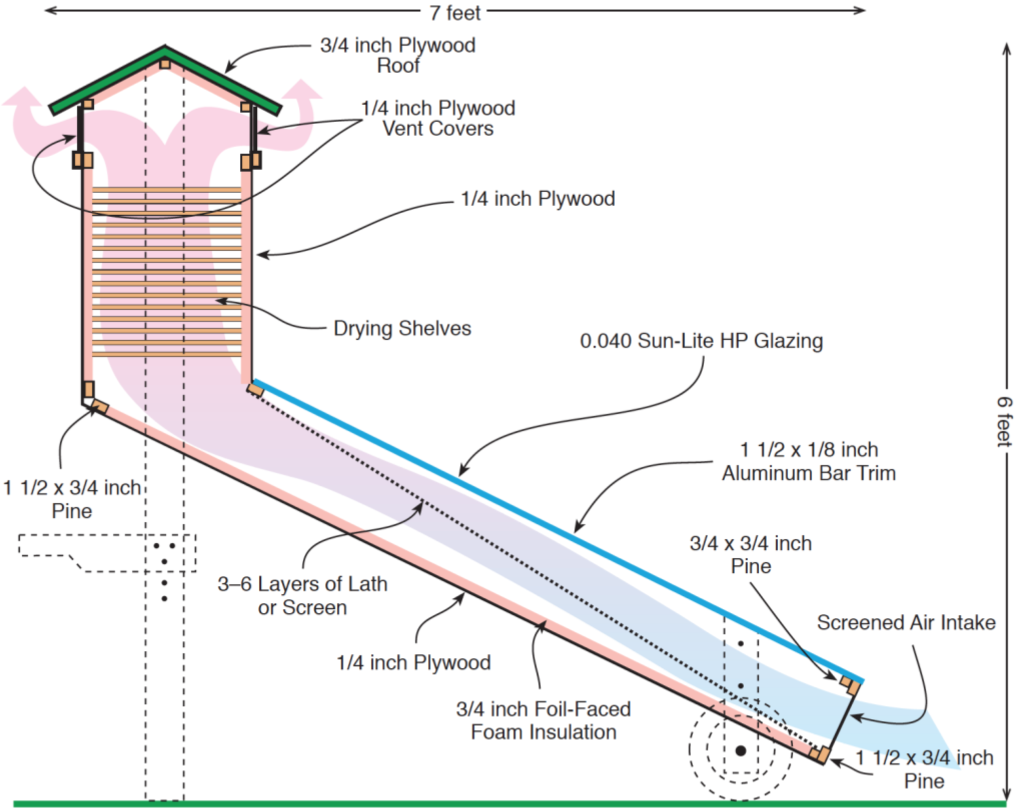

Figure 4. Indirect solar food dryer design originally developed by Appalachian State University, which dries food about 3 times faster than outdoor drying, reducing spoilage. NMSU introduced this design to Afghanistan in 2009. Black metallic windown screen was folded over about 5 times over to serve as an excellent absorber plate with great air mixing abilities (Scanlin, 1997)

3.0 Solar Dryer Operation

Successfully drying foods depends on two primary parameters: temperature and airflow. The goal is to keep air temperatures low enough to avoid cooking the food or causing it to crust, while maintaining enough warm air to discourage the activation of enzymes that would begin the spoiling process. The high sugar and acid content of fruits make them safe to dry in the sun. Vegetables are low in sugar and acid and at greater risk of spoilage. Meats are high in protein making them ideal for microbial growth when heat and humidity cannot be controlled. The target temperature is typically between about 40 and 75°C depending on the type of food. Airflow is also important, as it helps to create balance in the drying process and removes moisture.

Proper food preparation requires cutting it into thin slices, no more than about one centimeter thick, and spread them out over the drying trays, allowing plenty of room for air to move around the individual pieces of fruit or vegetable. Add the food to the drying trays and place inside the solar food dryer. You can rotate the dryer to track the sun each day for faster drying until the food is completely dried. This helps to create a uniform drying process.

A solar dryer is turned towards the sun and left until the food is properly dried. The solar dryer may be checked every few hours, to rotate the dryer to track the sun more precisely and to ensure that shadows from nearby obstacles like buildings or trees are not blocking the direct sunlight. The long absorber is made of black wire screen, which collects heat under a glass cover. Small wooden vents in the front and at the top assure that air is drawn through. Moisture is eliminated through the vent at the top as air flows naturally.

The drying time depends primarily on the solar dryer type of equipment used, the amount of sunlight at the time, and the quantity of food that needs to be dried and its moisture content. Air temperature and airflow affect performance and drying time. Some foods with lower moisture content (e.g., onions) dry faster in maybe 1.5 days, while other foods with a higher moisture content (e.g. tomatoes) take longer as long as 3 days to dry. Larger quantities of food, and food cut in larger pieces, take longer to dry.

3.1 Ideal Food Drying Temperatures

- Fruits and Vegetables: 40-55°C
  - Temperatures over 65°C can result in sugar caramelization of many fruit products
- Meats: 60-65°C
- Fish: 55-65°C
- Herbs: 35-40°C
- Rice, Grains, Seeds: 45°C
- Livestock Feed: 75°C

3.2 Solar Dryer Usage

1. Place the solar dryer outside in a location that will have FULL sun exposure all day.
2. Cut the food into thin strips placed on the drying trays/racks to be placed in the solar dryer.
3. If using a vented dryer, adjust the vents leaving them wide open for the start of the drying process to remove more moisture and gradually closing them down to bring up the interior temperatures as the food dries over the next 2 to 3 days.
4. For faster drying, have the dryer aimed directly towards the sun, moving it every couple of hours to track the sun which moves about 15° per hour across the sky. By pointing the solar dryer ~20° ahead of the sun's path through the sky, you will have less need to move the dryer throughout the day.
5. Occasionally want to reorder racks or move food around on trays for more even drying; the food will not burn.
7. Avoid opening the dryer too often as this lets the heat out. Be careful when opening the solar dryer as the temperatures are hot enough to burn you. Drying racks are hot and should be handled with oven mitts. Always exercise caution with solar dryers. Sunglasses, long sleeves, and hats are useful when working outside with a solar dryer.

4.0 Afghanistan Solar Food Drying

NMSU introduced indirect solar food dryers into the country initially through the USAID Afghanistan Water, Agriculture, and Technology Transfer (AWATT) in 2009 working with NGOs like MEDA and Global Partnership for Afghanistan. as a faster and more hygienic method for drying food. Later this effort was further expanded by NMSU in collaboration with Winrock International under the USAID Afghanistan Clean Energy Program (ACEP) working with MAIL and FAO to disseminate to all provinces in the country.

Food can be dried about three times faster than traditional outdoor drying. With indirect solar dryers, the food is also no longer exposed to direct UV rays as in traditional outdoor drying; the UV causes vitamins and natural food colors to break down. Indirect solar dried food improves vitamin quality and improves food color retention which is aesthetically more appealing. There is no need for sulphur, blanching, etc. Indirect drying also provides better control of the drying process - can more easily regulate the temperature through passive (or active) venting.

NMSU chose a solar food dryer designed in the early 1990's by Appalachian State University as an economical and efficient food preserver, which was created by Professor Dennis Scanlin. Solar dryers are easy to build with locally available tools and materials and operate simply by natural convection. The solar food dryers designed at ASU are basically wooden boxes with vents at the top and bottom. Food is placed on screened frames that slide into the boxes. A properly sized solar air heater with south-facing plastic glazing and a black metal absorber is connected to the bottom of the boxes. Air enters the bottom of the solar air heater and is heated by the black metal absorber. The warm air rises up past the food and out through the vents at the top.

The dryers produce temperatures of 130° to 180° F, which is a desirable range for most food drying and for pasteurization. With these dryers, it's possible to dry food quicker, even when it is partly cloudy, hazy and very humid. Inside, there are 13 shelves that will hold 35 to 40 medium-sized apples or peaches cut into thin slices (Hartley, 2009).

Figure 5. NMSU trained Afghan carpenters such as Mr. Hakim on how to build indirect solar food dryers using all local materials.

Afghans have long been known for their excellent quality raisins and other dried fruits which they have exported for centuries to Pakistan, India Iran and more recently to UAE. With these newer indirect food dryers, not only can farmers triple production, the quality of the dried fruit and vegetables is much higher than the traditional outdoor drying. The enclosed indirect dryers eliminate dust, flies, and mold, as well as ultraviolet rays from direct sunlight which discolor fruit and damage the vitamins they contain. Birds and other animals also are blocked from attacking the drying food in the newer solar dryers.

In two or three days, five kg of fruit or vegetables can be dried and ready for use or sale. During the four month summer season, this would mean 600 kg can be dried, producing 120 kg of dried fruit which sells for up to $5 per kg – a profit of $600 per summer. The indirect solar food dryer, which can last for manyyears, can be built for $120 and Afghan carpenters sell them for about $200 – a sum that can be made back in less than half a summer of dried food production. Larger dryers can go for $350 or more. Units are distributed across the country.

Figure 6. Indirect solar food dryer developed by NMSU disseminated with local NGO partner MEDA. Afghan women are very entrepreneurial, and when they were finished drying products, they rent out the solar food dryers to their neighbors.

4.1 Solar Dryer Value Added

AWATT designed and conducted trainings on the construction and use of solar fruit and vegetable dryers initially in Parwan and later Nangarhar. Drying helps preserve and extend the market window for many fruit and vegetable products. This work produced direct benefits for women in the region. Initially five Afghan carpenters were taught to build indirect dryers. Commercialization of the solar dryers was rapid with the receipt of nearly three dozen orders during the first growing season. Through the NGOs the dryer technology diffused throughout the country. Within two years of introduction over 1,000 solar food dryers were sold throughout Afghanistan, generating over US$250,000 in local manufacturing sales in a couple of years.

The drying units create value added for Afghan farmers by offering an improved alternative to the way fruits and vegetables are traditionally dried outdoors. Initially when first introduced, women's groups cost shared half for each dryer (US$250 each) with NGO support. The owner's learned to also rent out the dryers to their neighbors typically for about 20% of dried food production (NMSU, 2011). NGOs like MEDA and Global Partnership also worked with the women's groups on how to package and market solar dried food.

Figure 7. Business development and market development for dried products for export are essential components for successful selling solar dried foods. Organically grown solar dried products from Afghan women's groups have strong market appeal.

4.2 Capacity Building

Capacity building and business development are important to solar drying promotion. AWATT and later ACEP conducted a series of solar food drying workshops for female participants from Afghan women's groups, universities, government development promoters in Jalalabad, Parwan, and Kabul provinces. The goal with MAIL was to Train the Trainers for women agricultural extensionists across the country. The participants learned solar drying fundamentals including food preparation, sanitation, solar energy fundamentals, drying processes, dryer components, performance, and dynamic evaluation of the food drying process and product quality. The training deployed solar food dryers designed by NMSU who taught local carpenters to build units. Indirect solar food dryers have proven popular, with over 250 units sold in the past year. The units are passively vented and no electricity is used. Solar dryers are used to prepare dried apples, raisins, apricots, eggplants, onions, tomatoes and other high value fruit and vegetables. Farmers have tripled drying production, while the color, quality, and vitamin content of the dried fruit and vegetables is better since the food is not exposed to the sun's UV rays. Likewise, dust, flies, and birds cannot get into the enclosed drying chamber. In two or three days, 12 kg of food can be dried. The faster drying times reduces spoilage from mold and fungus as compared to outdoor drying.

Besides training NGOs, NMSU also assisted PRTs (Provincial Reconstruction Teams) with solar food dryer education and dissemination. The Kentucky Agribusiness Development Team in Kapisa taught men how to build solar food dryers, and the women on how to hygienically prepare food, as well as operate the dryers. The women were typically proud their male relatives had built the indirect food dryers. Both men and women learned how to price their produts for sale. One woman relayed the story of how her mother-in-law had praised her dried eggplant. Now that is a success story in any culture (Getchell, 2011).

Figure 8. NMSU AWATT indirect solar food drying workshop held in Dari language with Afghan women's groups in Jalalabad in 2009 with the Afghanistan Ministry of Women's Affairs.

Figure 9. Engineering students undergoing solar food drying class at the Kabul University Renewable Energy (KURE) Lab.

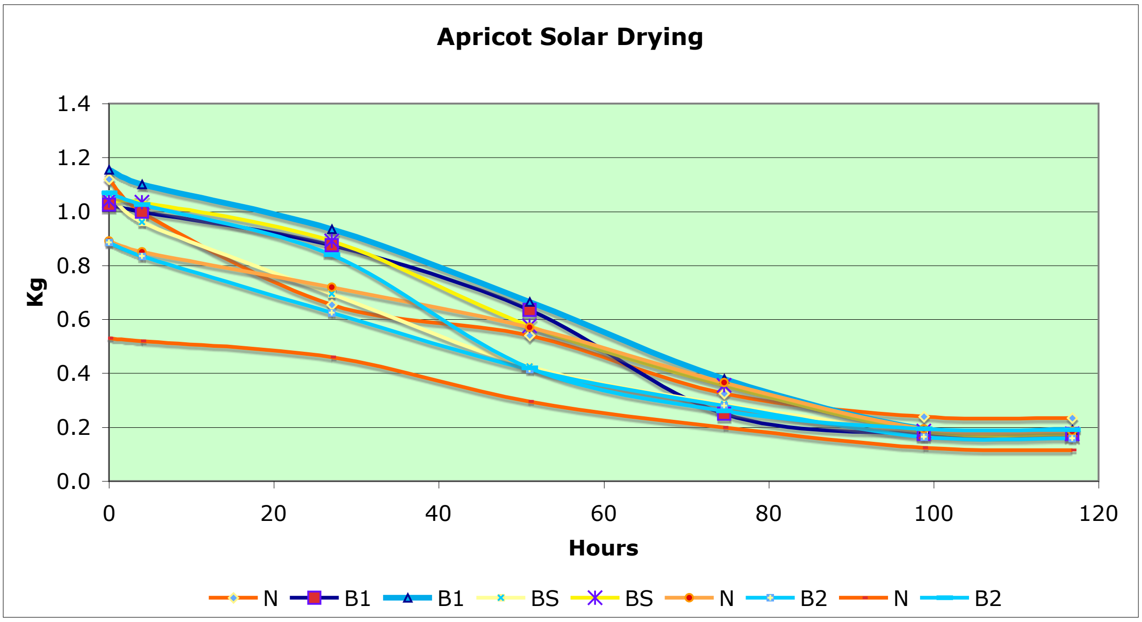

Figure 10. Apricot drying results from KURE Lab by weight (kg). Roughly takes 3 days to dry the product.

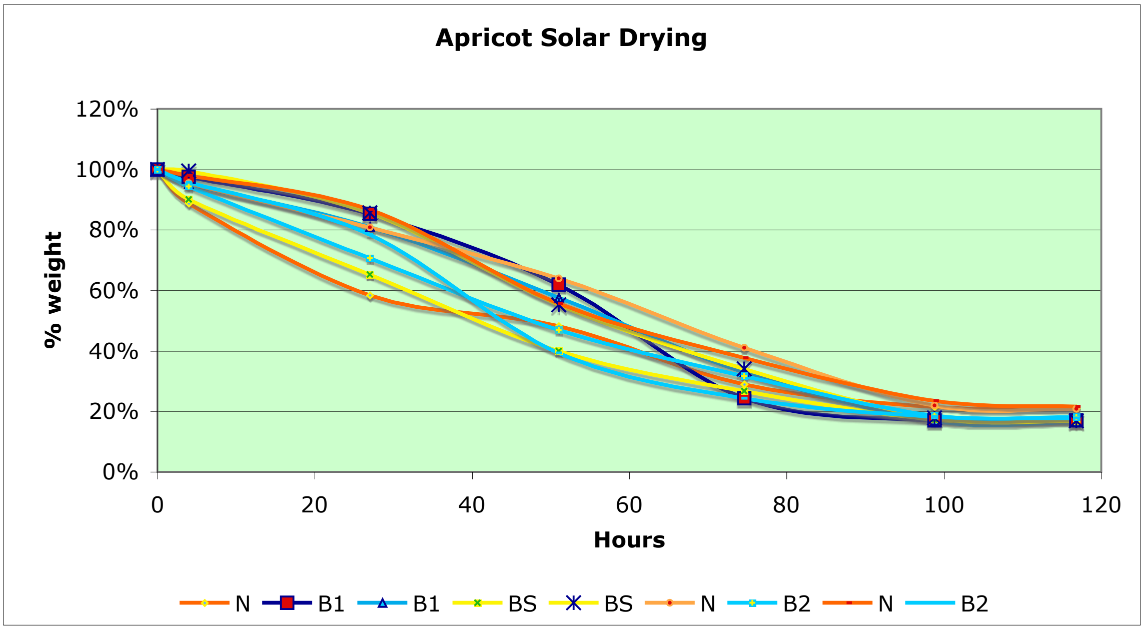

Figure 11. Apricot drying results by moisture content from the KURE Lab.

Figure 12. ACEP Train the trainers solar food drying workshop in Kabul with MAIL/FAO women extensionists who work nationally to teach farmers on how to utilize driers. They helped spread the concept across the country to even the most remote provinces.

4.3 Antioxidant Comparison: Direct vs. Indirect Solar Food Dryers

AWATT partner Southern Illinois University (SIE) condcted an antioxidant analysis comparing direct and indirect solar dried food. Antioxidants are compounds that prolong the shelf life of foods by protecting them against deterioration caused by oxidation, such as color changes. Direct photooxidation is caused by free radicals generated by radiation from UV light and then proceeds by normal free radical chain reactions. Phenolics are a group of phytochemicals that are biosynthesized from all kinds of plants. Common phenolics such as quercetin, chlorogenic acid, gallic acid, or syringic acid are widely found in a variety of fruits and vegetables like apricots and peppers. Antioxidants play an important role in promoting human health and combating chronic diseases. Total phenolic content and DPPH assays are useful assays for evaluating the antioxidant activity of food products.

The conventional phenolic content, scavenging DPPH free radical assays are used for antioxidant evaluation. SIU studied the correlation between DPPH free radical activity, total phenolic content, and ABTS (Vitamin C) compared between the direct dried and indirect dried food products. Determination of total phenolics was made using the Folin-Ciocalteu Method. A determination of antioxidant activity was made using an ABTS radical assay. Finally a determination of antioxidant activity was also made using a DPPH assay (Huang, 2005). From Table 1, you can see that the DPPH average was higher with the indirect dried food product than direct dried products, generally indicating a higher percentage antioxidant content as would be expected for the indirect dried product not exposed to UV light, especially for red peppers and prunes.

Table 1. Antioxidant Comparison between Direct and Indirect Solar Dried Fruits

Sample Name	Total Phenolics (umole/g)	Total Phenolics Average	ABTS Assay (umole/g)	ABTS Average	DPPH Assay (umole/g)	DPPH Average
Prune - Direct Drying - 1	88.331		138.253		82.277	
Prune - Direct Drying - 2	76.395	82.363	129.771	134.012	82.475	82.376
Prune - Indirect Drying - 1	87.76		123.715		86.003	
Prune - Indirect Drying - 2	98.794	93.277	128.731	126.223	95.587	90.795
Berry - Direct Drying - 1	51.395		114.724		58.721	
Berry - Direct Drying - 2	48.417	49.906	117.544	116.134	50.924	54.8225
Berry - Indirect Drying - 1	45.84		106.886		53.947	
Berry - Indirect Drying - 2	44.684	45.262	103.782	105.334	59.05	56.4985
Tomato - Direct Drying - 1	51.781		107.848		43.938	
Tomato - Direct Drying - 2	42.966	47.3735	100.66	104.254	43.52	43.729
Tomato - Indirect Drying - 1	49.672		107.668		44.78	
Tomato - Indirect Drying - 2	47.97	48.821	112.27	109.969	38.03	41.405
Red Pepper Direct Drying - 1	62.066		132.63		51.332	
Red Pepper Direct Drying - 2	53.717	57.8915	133.345	132.9875	47.733	49.5325
Red Pepper Indirect Drying - 1	63.787		122.101		65.548	
Red Pepper Indirect Drying - 2	59.628	61.7075	134.42	128.2605	58.249	61.8985
Peaches/Apricot Indirect Drying -1	53.654		105.71		83.799	
Peaches/Apricot Indirect Drying -2	47.565	50.6095	98.404	102.057	77.39	80.5945

Source: Southern Illinois University 2009

4.4 Afghan Industry Solar Food Dryers

Historically, Afghanistan has produced high-quality and organic dried fruits and vegetables for centuries, renown for their superior taste and quality. These traditional Afghan dried fruits includes raisins, apricots, figs, cherries, prunes, dates, and mulberries. In the country, the process of drying fruits is a family business that has been passed down from one generation to another for many years. People typically dry their fruit in an entirely natural way either in direct sunshine or in the case of raisins in well aerated drying barns. From 2005 to 2015, when the security situation was better, there was solar food dryers development and using solar fruit dryer in the country by the international committees, with some local private companies trained and encouraged to start manufacturing of solar fruit dryers for both small and large scale drying.

One of the key challenges is educating farmers about the benefits of solar technologies to increase production of solar-dried fruits. If farmers use improved solar dryer technologies, they can increase production, reduce spoilage, improve hygiene, and sell an overall higher products will quality product. Most companies shown in Table 2 typically sell from two to five units per week during the summer and fall season. The great thing about the indirect solar food dryers is that they are made in country with local materials by local shopworkers, regardless of who is in power nationally.

Table 2. Afghanistan Renewable Energy Union Members solar dryer vendors (2021)

Company Name	Location
Qaderdan Rural Technology and Development Workshop	Kabul
Zaib Pamir Elect Engineering Company	Jalalabad
Silicon Solar Company	Kart-e-Parwan
Behroz Rayan Technical Engineering Company	Herat
Royal Group Co Ltd	Kabul
Afghan Lucky Door Logistics Services Company	Kabul
Takwin Electrical and Electronics Engineering	Kabul-Logar Road
Yosouf Mosawer Solar Manufacturing Company	Kabul

Figure 13. Indirect solar dryer innovation in 2021 by Zaib Pamir Co. with the addition of an active fan powered by a PV module to increase drying rates and productivity.

Fig. 14. Modern commercial scale indirect solar food dryer in central Afghanistan with active fans for large scale food drying increases production and reduces spoilage.

5.0 References

(AFP, 2017) Afghan raisin houses get a facelift to boost productivity," *Arab News*, https://www.arabnews.com/node/1211891/food-health

(Getchell, 2011) KY ADT's Solar Food Drying Project is a Family Affair, *Afghanistan Gazette*, USDA, Kentucky Agribusiness Development Team, Vol. 2, Issue 25, November 10

(Hartley, 2009) J., "Solar Food Dryers Designed at ASU Preserve Food Worldwide," High Country Press, Boone, North Carolina. http://www.highcountrypress.com/weekly/2009/07-16-09/solar_food_dryers.htm

(Huang, 2005) D., Ou, B., & Prior, R. L. The chemistry behind antioxidant capacity assays. Journal of Agricultural and Food Chemistry, 53(6), 1841-1856.

(NMSU, 2011) Final Project Report: USAID Afghanistan Water, Agriculture, and Technology Program (AWATT), submitted to USAID Afghanistan, Kabul Afghanistan, 2011

(Scanlin, 1997) D., M. Renner, D. Domermuth, H. Moody, "Improving Solar Food Dryers," *Homepower #57*, February/March.