Dehytray™: An Innovative Portable Solar Food Dehydrator for Low-Cost Food Preservation

Yara Benavides Paz, Ph.D. & Carlos Aguilar, Ph.D.

Photo: J. Ambuko (Research Group, University of Nairobi)

Food Science in Action:

- ✓ Food Processing
- ✓ Post-Harvest Processing
- ✓ Food Engineering
- ✓ Food Safety
- ✓ Food Quality

Students learning to use the Dehytray for drying produce at the Food Processing Hub, Department of Plant Science and Crop Protection, University of Nairobi, Kenya (2021)

The Dehytray is a multipurpose solar-powered dehydrator that can dry food faster under less favorable conditions and more hygienically than open-sun drying. This device was designed mainly for smallholder farmers and families in developing countries, where a large amount of their harvest is lost each year due to lack of access to affordable drying methods. The lack of food preservation methods in these communities has resulted in critical food insecurity and health issues. Having access to affordable technology like the Dehytray solar dryer could not only help reduce food losses but also increase profitability in small grower agriculture through the delivery of value-added foods.

Introduction

From the moment fruits, vegetables, seeds, or animals are harvested, deterioration begins. However, for many people in developing countries, reliable food preservation technologies to slow deterioration are not within reach.

Currently, it is estimated that around 690 million people worldwide are hungry and undernourished and that approximately 3 billion people cannot afford a healthy diet.[1] It is unfortunate that the number of people impacted by severe food insecurity is increasing and by 2030, it is estimated that hunger will affect more than 840 million people worldwide.[1]

Of the 11 billion tonnes of food currently produced globally,[1] estimates indicate that about one-third is lost through the different food supply chain stages, i.e., agricultural production, post-harvest handling and storage, processing, distribution, and consumption.[2]

In developing countries, it is estimated that more than 40% of food losses occur at post-harvest and processing levels.[2] The application of adequate food preservation technologies during these stages may have a significant impact on decreasing food losses and help developing countries to improve food security for their populations.

In order to stop food from deteriorating, humans

have developed many food preservation methods from those simple and observed in nature without any human intervention (e.g., sun drying, freezing, and fermentation) to complex methods such as refrigeration, vacuum packing, spray drying, and irradiation. However, in developing countries, costly, complex, and energy-intensive food preservation technologies are not accessible to individual families and smallholder farmers.

Open-air sun drying, most probably discovered in nature by accident by early humans, is believed to be the oldest food preservation technology. This technology is still commonly applied in many parts of the world in the preservation of foods such as fish, meats, spices, nuts, coffee, cacao, fruits, vegetables, and herbs. The main advantage of open-air sun drying of foods is that the energy required to remove water is free. As a result, open-air sun drying of foods is a process with advantages, such as:

- Zero energy cost
- Low complexity
- Low investment on equipment
- Independence from scarce refrigeration and unreliable electricity in rural areas of developing countries, and
- Environment-friendly

Nevertheless, open-air sun drying also suffers from disadvantages, such as:

- Dependency on climatic conditions (i.e., limited to hot and dry days)
- Rewetting by unpredictable rain events
- Slow and time-consuming process
- Risk of infestation by insects, rodents, and birds
- Risk of mold contamination and production of toxins, and
- Risk of contamination by dirt, dust, and air pollutants

Response

Dehytray is an economical, portable, passive solar dryer made of food grade plastic that utilizes the advantages of sun drying but addresses some of its disadvantages. It was developed by Dr. Klein Ileleji, an immigrant from Nigeria and Professor of Agricultural and Biological Engineering at Purdue University, West Lafayette, Indiana.

The technology was developed with financial support from the U.S. Agency for International Development (USAID) through the Feed the Future Innovation Lab for Food Processing and Post-Harvest Handling led by Purdue University and is exclusively licensed by JUA Technologies International (JTI).[3] Dehytray is distributed and retailed in East Africa by Dehytech East Africa Limited, a subsidiary company of JTI based in Nairobi, Kenya.

Dehytray can help improve global food security by preserving food through a sustainable drying solution and, in turn, reduce post-harvest food losses. It can provide families with the means to hygienically dry different types of foods at a low cost for year-round consumption and can also

Training a women's cooperative group in Yovon District, Southern Tajikistan to assemble the Dehytray for use in drying vegetables, fruits, and spices as part of USAID Tajikistan Agriculture and Water Activity (TAWA) project (2019).

Photo: K. Ileleji (Purdue University)

drive increased profitability for small producers with better quality and nutritious sun-dried foods.[4]

In December 2018, the Dehytray portable solar dryer became commercially available for sale. The price per unit sold on its online Shopify store and on Amazon for the general public is US$139.50. For customers who intend to purchase for use in a developing country, a US$60 discount off the price per unit is offered lowering the price to US$79.50.

Post-harvest processing is a key strategy for increasing food availability by reducing food losses and waste. Because of its simplicity in design and operation, Dehytray is an appropriate food processing technology to reduce food losses and waste for families and smallholders in developing countries. During the high season, there is an oversupply of fruits and vegetables that results in high post-harvest losses. With the Dehytray portable solar drier, foods during the surplus season can be dried, stored and made available during the scarce period.

The device is composed of a black tray made of polypropylene copolymer, a protective cover with clear acrylic sheets that allows 92% light transmission, a hygrometer, and a scrapper.[5] Food engineering was key to designing the Dehytray portable dryer using solar radiation as the sole energy source to stop growth of spoilage microorganisms and metabolic activities after harvesting. The Dehytray enclosed chamber acts like a miniature greenhouse, trapping the heat generated by direct sunlight and radiation from the black walls of the tray to increase temperature above ambient temperatures. The clear acrylic windows on the cover allow light penetration and slotted vents, left open during drying, allow venting of moisture. During drying trials with plantain, pepper, and okra, chamber temperatures ranged between 55.5 and 61°C (at ambient temperatures between 25.5 and 34.3°C).[5]

Food safety is assured by manufacturing both the tray and cover with polymers approved by the U.S. Food and Drug Administration (FDA) for direct food contact. Unlike the conventional open-air sun drying process, the Dehytray device protects the product from rapidly rewetting due to an unforeseen rainfall event, providing some time for users to move it indoors. Additionally, food quality is improved since the covers prevent contamination of the product being dried from external factors such as dust, insects, rodents, livestock, and other contaminants.[6]

The Dehytray portable solar dryer is light (2.27 kg), easy to handle, and able to process a variety of crops–from seeds and leafy vegetables to slices of fruit, fruit leathers, and even dried flowers.[5] The majority of dryers commercially available are designed for large-scale production, whereas the Dehytray device is available at a small-scale, and most especially, it is portable. This makes it more accessible to families and farmers that wish to hygienically dehydrate vegetables and fruits from their gardens and small farms into nutrient-rich dried foods for year-round consumption. The portable nature of the Dehytray allows farmers to easily expand their drying capacity based on the quantities of crops they have available. For example, about 57 Dehytrays provide the same drying surface capacity (20 sq meters) as the solar tunnel dryer Type “Hohenheim” sold by Innotech Engineering, Germany.[7] However, because the Dehytray is portable, farmers can easily use only the number of units they need, and cooperatives can easily share units among members, without concern for where the solar dryer is located during use. This allows for the deployment of the Dehytray using several business models.

Results

Since its launch in 2018, Dehytray devices have been sold and shipped to more than 10 countries across four continents. A number of units were sold in eight countries (Nigeria, Ghana, Peru, India, Kenya, Senegal, and South Africa) to conduct a pilot research study with several crops and tested for introduction to farmers in six countries (Kenya, Senegal, Ghana, Tajikistan, and Belize). Sales have by far been the highest in Kenya. To date, a total of 9,780 units have been sold globally, of which 9,220 units were sold in Kenya alone.

In collaboration with the Kenya Agricultural and Livestock Research Institute (KALRO) and the University of Nairobi, JTI is working to inform farmers about the benefits of Dehytray as a tool to preserve nutrient-rich vegetables and fruits grown in kitchen gardens and small farms. The Food and Agricultural Organization of the United

Dr. Patrick Ketiem, a researcher at the Kenya Agricultural and Livestock Research Organization (KALRO) explaining the operations of the Dehytray to the Cabinet Secretary of the Ministry of Agriculture, Livestock, Fisheries and Cooperative (Kenya), Hon. Peter Gatirau Munya, during the launching of the 4-K Club activities in schools in Kenya at Kilimo House, Nairobi (2021)

Photo: P. Ketiem (KALRO, Kenya)

Nations (FAO), through its Country Programming Framework, purchased 1,000 units in order to support the Kenyan government in its efforts to improve food safety and minimize post-harvest losses and food waste. These Dehytray units were delivered to Kenya in the months prior to the declaration of COVID-19 pandemic in March 2020.

The strict lockdowns implemented by governments worldwide to reduce the transmission of COVID-19 resulted in disruptions in the food supply chain and increased food waste for some supply chain actors.[8] Food waste of horticultural produce such as fruits and vegetables were mostly affected, with huge losses incurred by farmers and traders. Conscious of the benefits of the Dehytray as a tool for household food preservation, the Kenyan government purchased additional units to mitigate the impact of COVID-19 on household nutrition and support 213,090 vulnerable households in 21 project counties in Kenya. JTI has shipped 8,000 additional Dehytray units to Kenya to allow households to preserve vegetables and fruits grown in their kitchen gardens for up to three months and through the lean cropping season without costly refrigeration or drying systems.

The Kenyan government has also explored the possibility of introducing Dehytray to 33,000 elementary schools in the country in order to support their school feeding programs through school kitchen gardens. In July 2021, 20 units of Dehytray were donated by KALRO to 20 schools during the launch of youth 4-K clubs (equivalent to the 4-H clubs in the U.S.).

Testimonials from Dehytray users from different regions (i.e., Kenya, Nigeria, and the U.S.) indicate personal and community benefits when used to dry surplus vegetables from home gardens and local orchards. Dehytrays have been used to dry many different types of fruits and vegetables such as African nightshades, apples, apricots, bananas, grapes, kales, leafy greens, mangoes, nectarines, nuts, okra, onions, peaches, peppers, persimmons, pineapples, plantain, plums, and tomatoes.

Some of the main advantages mentioned by users of the Dehytray portable solar drier include:

- Food hygiene since construction materials allow for easy cleaning
- Lack of complexity
- Ideal for low volumes
- Closed environment prevents access by rodents, stray domestic animals, and birds
- Portability allows flexibility on drying location in terms of sunlight and proximity to home

Nevertheless, users have also mentioned that current price could be a hindrance for adoption by low-income households.

Lessons learned

- Transition from research and development to commercialization is a difficult and complex process. There are many solar dryer designs available in the literature and the internet.

Testimonials from Dehytray users:

"Apart from acquiring several units for research purposes, I acquired one for my home use. I have a kitchen garden which I use to produce vegetables for household use. Since I am not able to consume all the vegetables at once, I have been able to dry some of the surplus which I can use later when there is scarcity of vegetables. I have also tried to promote the use of the Dehytray for household nutrition security because most of the vegetables are seasonal. During the high season there is an oversupply that results in high postharvest losses. On the other hand, during the low season, vegetables (and fruits) are scarce and highly priced and therefore many low-income households cannot afford them – leading to nutrition insecurity. With a Dehytray, households can dry the nutritious foods during the surplus season to have provision during the scarce period"

Dr. Jane Ambuko – Lukhachi, Associate Professor of Horticulture and Postharvest Specialist (University of Nairobi, Kenya)

"The search for suitable alternatives for hygienic drying of crops at the smallholder and household levels led to my quest for portable solar drying devices. Dehytray fits very well into this need as it offers a viable option to replace the open-air sun-drying method which is typical in sub-Saharan Africa where I work and do my research. One of the biggest benefits of this technology is food hygiene. The fact that rodents, stray domestic animals and birds no longer have access to the crop being dried is a plus. For instance, till date, many women and children in rural communities travel long distances to find the nearest tarred road to spread their produce which requires drying, with the Dehytray, they can dry within their communities. Many farmers and people living in rural households are poor, living below $1/day. Therefore, many can still not afford to procure several Dehytray units for personal use except through government interventions or through NGOs"

Dr. Mobolaji Oluyimika Omobowale, Research Engineer and Lecturer (University of Ibadan, Nigeria)

"I have volunteered for decades with a small, thriving, rural, monastic community in central California. This community serves the various needs of thousands of visitors each year as well as those living in the immediate area. The Dehytray was acquired to increase food preservation capabilities because of expanding orchards and access to cast offs/gleanings. This has allowed the transfer of more food to those who need it. With the Dehytray technology, we can produce faster and safer results with greater yield due to less loss to over-drying, slow drying, or pests. Also, the trays are easy to clean and refill, and portable so the location of trays can be adjusted to the best drying conditions in terms of sunlight/shade"

Thalia Hohenthal, Food Biochemist (California, U.S.)

However, most of these dryers have never been commercialized and ended mostly at the research testing phase.

- A sustainable and profitable business model for Dehytray must include:
    - Affordable price for all customers, especially those in the bottom income levels
    - Easily accessible, i.e., ease of purchase and delivery
    - A complete solution, including all secondary components, e.g., moisture meter, thermometer, scrapers, clear instructions and training
    - Rapid addressing and resolution of quality problems at all levels (e.g., manufacture, specifications, distribution, and logistics)
    - Local presence for sales, distribution, and training
    - Local manufacturing if quality, product supply, raw material, production, and distribution costs can be improved

- Introduction and promotion of Dehytray in Kenya were helped by creating local partnerships with:
    - Local technical experts, e.g., University of Nairobi
    - USAID through Purdue University-led Feed the Future Lab on Post-Harvest Handling and Food Processing project in Kenya and University of California-Davis USAID Horticultural Lab project in Tajikistan
    - International organizations with local presence, e.g., the FAO Country Programming Framework, and
    - Government institutions, e.g., Kenya Agricultural and Livestock Research Institute (KALRO) and the Ministry of Agriculture, Livestock, Fisheries and Cooperative (Kenya)
- Learnings from Kenya need to be applied to other countries to provide their families and small producers with means to hygienically dry different types of foods at low cost to enhance health and improve food security and nutrition.
- Working with local distributors is challenging. Establishing a subsidiary company in Kenya–Dehytech East Africa Limited–improved importing, warehousing, distribution, training, getting first-hand feedback from customers, as well as implementing a monitoring and evaluation plan.

Next steps / call to action

It is imperative to make the Dehytray affordable to low-income households and small-scale farmers. JTI is working on reducing the price to US$45-50 per unit through mass introductions, marketing campaigns, and partnerships with government, NGOs, faith-based groups, and cooperatives. JTI is also exploring the possibility of manufacturing the technology locally in Kenya, which would eliminate shipping costs and make the product more competitive.

JTI has also developed a prototype of a solar dryer that has a higher capacity compared to the Dehytray, the Dehymeleon™. It can hold 10 Dehytray units and can store extra solar energy for use as a power generator at night or with other beneficial/productive applications.[9] The Dehymeleon is still under development with funding from the Small Business Innovation Research (SBIR) program at the United States Department of Agriculture (USDA), and tests are being performed to determine rates of drying, determine nutrient profiles within the dried crops, and develop an automatic control system.[10]

In the long term, Dr. Ileleji and his team want Dehytray and Dehymeleon to become common household appliances in rural farming communities and home gardens around the globe. JTI intends to focus on the northern arid regions of Kenya, which are some of the most food insecure counties and explore introducing the Dehytray in West, Central and Southern Africa.

References

[1]FAO, IFAD, UNICEF, WFP and WHO, 2021. The State of Food Security and Nutrition in the World 2021. Rome, FAO. https://doi.org/10.4060/cb4474en

[2]FAO, 2011. Global Food Losses and Food Waste, https://www.fao.org/3/i2697e/i2697e.pdf (accessed February 7, 2022).

[3]Kayyali, Z., 2018. Purdue Solar Device to Dry Grains, other Food Products and Fight Waste Wins National Product Design Award. https://engineering.purdue.edu/Engr/AboutUs/News/Spotlights/2018/purdue-solar-device-to-dry-grains-other-food-products-and-fight-waste-wins-national-product-design-award (accessed August 16, 2021).

[4]Henry, H., 2017. JUA Technologies named in top 10 for All Africa Postharvest Technologies and Innovations Challenge. https://www.purdue.edu/newsroom/releases/2017/Q2/jua-technologies-named-in-top-10-for-all-africa-postharvest-technologies-and-innovations-challenge.html (Accessed August 16, 2021).

[5]Mobolaji, O., Olenloa A.E., Okoro N.E., 2021. Performance evaluation of the Dehytray™ solar drying device using plantain, pepper and okra under the tropical conditions of Oyo State, Nigeria. Journal of Stored Products and Postharvest Research. 12(2), 20-41.

[6]Thesis. Ramirez-Gutierrez, Diana Milena, 2019. Performance of Novel Portable Solar Drying Technologies for Small and Mid-Size Growers of Specialty Crops Under Indiana Weather Conditions (Dissertation). West Lafayette, Indiana: Purdue University.

[7]Innotech drying systems. https://www.innotech-ing.com/en/index.php (accessed February 25, 2022).

[8]Ellison, B. and Kalaitzandonakes M., 2020. "Food Waste and Covid-19: Impacts along the Supply Chain." farmdoc daily (10):164, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign.

[9]Matchar, E., 2019. This Solar-Powered dehydrator Could Help Small Farmers Reduce Food Waste. https://www.smithsonianmag.com/innovation/solar-powered-dehydrator-could-help-small-farmers-reduce-food-waste-180973221/ (accessed February 12, 2022).

[10]Adam, C., 2019. Startup developing solar-powered drop-drying devices for small farmers receives grants worth $150,000. https://www.purdue.edu/newsroom/releases/2019/Q3/startup-developing-solar-powered-crop-drying-devices-for-small-farmers-receives-grants-worth-150,000.html (accessed February 12, 2022).