

**TRENDS IN SOLAR DRYERS' UPTAKE AND DRIED FOOD MARKETS DEVELOPMENT IN
KENYA**

MARKET ANALYSIS

AFRICAN CENTER FOR TECHNOLOGY STUDIES (ACTS)

October 2023



Executive Summary

Postharvest loss (PHL) of food crops is a global challenge derailing the attainment of the Sustainable Development Goals such as zero hunger (SDG 2) and responsible consumption and production (SDG 12). It is against this background, that different stakeholders in Africa have through innovation-led enterprising has undertaken to reduce the losses. The focus has been on technology transfer while maximizing the economic returns realizable among the primary producers. However, there is a dearth of information regarding the market size and space for both the drying technologies and the dried products. Questions of where is the market, who forms the market and what are the acceptable business models that catalyse demand of these drying technologies still remain largely unanswered. Therefore, detailed market analysis and exploration for the proposed technologies was conducted to understand the viability of the proposed business. The study was guided by the following objectives: to analyse the size of the market for solar dryers; determine cost of production and the selling prices of different sizes of solar dryers existing in market; and evaluate the willingness to pay for solar dryers by the target market and the appropriate financing models. The study methodology included desktop review of available literature documenting the business model used in the acquisition of solar dryers among different players among other components. The primary data collection was conducted using semi-structured questionnaire administered to selected market players dealing in solar drying technologies to evaluate market and demand size of the solar dryers, successful business models deployed and pricing of the dryers in the market. The demand of the dryers currently emerges from a myriad of players, which includes individual farmers, cooperatives, agro-processing MSMES, NGOS, and governments. On the supply side: They are approximately 36 solar dryers' fabricators mapped across the across-different counties Kenya. The fabricators are producing different kinds of dryer that is; tunnel, green house, hybrid, and cabinet solar dryers with sizes ranging between 5 kg-1000 kgs. The cost of producing the dryers also ranges between USD 60 - USD 4,000 and they are sold at KES 20000 to KES 1,600,000. The finding also indicated the willing to acquire the solar dryers among the stakeholders engaged. They also identified credit to be a viable financing model in the acquisition of the solar dryers. The awareness and consumption of dried food products is growing both locally and internationally. Different business models have been identified to fit the needs of different stakeholders interested in accessing the fabricated solar dryers. The following are some of the financing models; Private sector partnerships, Public-private partnerships and Partnerships with Microfinance institutions to provide credit to technology users. Finally, global dehydrated food market is forecasted to register a compound annual growth rate (CAGR) of 5.2 % during the forecast period (2021 - 2026). In Kenya the demand for dried products has risen by up to 30 percent seeing smallholder farmers increase income by up-to 50 percent.

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Introduction

Postharvest losses (PHL) remain a threat to food and nutrition security and sustainable livelihoods in sub-Saharan Africa (SSA). In Kenya, PHL majorly contributes to approximately \$500million - \$1.5billion food losses annually mainly due to poor harvesting, drying, processing and storage. Foods that are highly perishable such as the fruits and vegetables have invariably higher losses that can exceed 50% of the total harvest (Paltrinieri, n.d.). Moreover, the smallholder farmers have limited access to appropriate and affordable postharvest technologies, where majority use artisanal techniques for PHL management such as open sun-drying causing less optimal aesthetic, sensory and nutritional quality dried products thus a low marketability.

Other than the threat to food security, PHL also contributes to loss of production resources such as water and increased greenhouse gas emissions, derailing efforts aimed at achieving sustainable production of resources. To catalyse the uptake of the technologies, require input from the market analysis that will detail the demand of the products, appropriate business models for uptake and space of the products. These are aimed at achieving a sustainable uptake of the innovative solutions through a demand-driven approach that will not only contribute towards the food and nutrition security of the smallholder producers but also improved economic returns.

The Institute of Food Technologists (IFT) through the **Seeding The Future Global Food System Challenge** under the growth phase funding awarded a grant to the African Center of Technology Studies (ACTS), in partnership with Kenya Industrial Research and Development Institute and UNEP to implement a project entitled *Scaling-Up Solar Drying to Reduce Post-Harvest Losses (Phl) In Kenya– Opportunities for Inclusive Climate-Action Enterprises*. The project seeks to scale the proof-of-concept of climate-action low-cost solar drying technology enterprises to reduce PHL and drive realization of multiple Sustainable Development Goals (SDGs). The project leverages on lessons from the UNEP Ecosystem Based Adaptation for Food Security (EBAFOSA) initiative that promoted solar drying technology and dryers as “pay-as-you go” business models through collective action among smallholder communities in Kenya

As an entry point the solar dryer project, the ACTS, KIRDI and UNEP consortium, conducted a detailed market analysis and exploration for the proposed technology to understand the viability of the proposed business.

Objectives

General Objective:

To provide watertight data demonstrating viability of the solar dryer technology commercialization business and develop a practical business.

Specific Objectives

- a. To analyze the size of the market for solar dryers based on their use and potential demand for “drying as a service business” by farmers cooperatives, youth and women groups and even individual agro-processing (drying) SMEs.
- b. To determine the cost of different sizes of solar dryers existing in market, including both the cost of production and the margins for the fabricators.
- c. To evaluate possible selling prices by assessing the optimal willingness to pay for solar dryers by the target market and financing models (including debt management) that would work best to support solar dryer (asset) acquisition.
- d. To analyze the value chain or combination of value chains (and other add-on service offerings) can provide the optimal utilization of the solar dryers that will translate in viable “drying as service” business. Including possible technical support that would be need for such businesses, related to technology or drying and other aspects of the products (e.g., marketing, packaging etc.)

Methodology

To achieve the above-mentioned objectives the following methodology was used.

- i) **Desk Reviews:** A desk review of all grey and published materials from reports and other secondary information was undertaken to collect information already available in the public domain and to identify information gaps and inform the market analysis. This method was used to collect information on the following components.
- The size of the market for solar dryers based on their use and potential demand for “drying as a service business” by farmers cooperatives, youth and women groups and even individual agro-processing (drying) SMEs.
 - Cost of different sizes of solar dryers existing in market.
 - Possible selling prices by assessing the optimal willingness to pay for solar dryers by the target market (i.e., those in point a) and financing models (including debt management) that would work best to support solar dryer (asset) acquisition.
 - Technical support that would be needed for such businesses, related to the technology, or drying and other aspects of the products (e.g., marketing, packaging etc.)
- ii) **Market analysis:** To fill the gaps in the desktop study particularly on the cost of producing solar dryers, the willingness to pay among different potential offtakes of the solar dryer other, a market analysis was conducted. The data was collected using an online self-administered questionnaires and it was used to collect data from participants identified for the project inception/ launch webinar, which constituted participants for different sectors; Table 1 is the summary of all the stakeholders involved in the market analysis.

Table 1: Summary of categories stakeholders engaged in the market analysis.

Actors	No. of Actors: Questionnaires Sent	No. of Actors Filled Questionnaires
Farmers Associations/Cooperatives	26	18
Agro- processing MSMEs	27	12
Learning Institutions	18	5
NGOs and Donor Organizations	17	1
Government (National/County/Departments)	10	4
Financial Including Micro finance institutions	3	1
Private Sector/Youth Led Groups in Fabrication and Distribution of Solar Dryers	26	23

Findings

A. Size of the market for solar dryers In Kenya

To understand and arrive at an estimation of the market (size) of solar dryers, this study focused on demand and supply side of various nodes of the solar drying value chain.

i) Buyers/Users of solar Dryers in Kenya

Solar dryers are used for industrial and domestic drying processes, where the adoption of solar drying is spread across different stakeholders in the agri –value chains. From the review, the players in the market of the solar dryers include:

- Individual farmers,
- Youth/women/farmers associations/cooperatives,
- Micro, Small and medium agro-processors,
- NGOs and government departments focusing on post-harvest loss (Figure 1).

The need for acquiring and owning solar dryers among the farmers and other stakeholders has been growing due to the need to reduce the high levels of post-harvest losses using low-cost technologies. This is attributed to the fact that drying with artificial drying with fossil fuels or electricity is expensive and has been estimated through calculations at US\$ 0.02-0.03/kg of raw produce to be dried or about US\$ 0.20-0.30/kg for dried fruits or vegetables (Ndirangu et al., 2018). Furthermore, most regions in Kenya are not supplied with electricity and where connected, it's too costly to run drying systems and hence, beyond the reach of most farmers who would be in need of value addition and preservation methods like drying of vegetables.

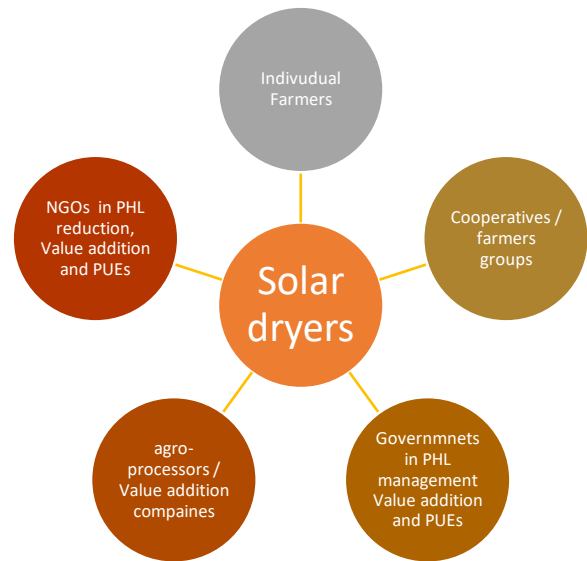


Figure 1: : Buyers/Users of solar dryers in Kenya

Additionally, the need for value addition has also been a driver of the solar dryer's acquisition; this is because the price of value-added products is products are more expensive than fresh farm produce. For instance, two raw banana fingers weighing an average of 200 to 240 grams will sell for Sh50 to Sh60 while the same volume of bananas dried sell for Sh150 at local health stores¹.

The market for solar dryers is growing due to increased awareness of the potential benefits of the dried products within the Kenyan food market as well international market. The demand has risen by up to 30 percent seeing smallholder farmers increase income by up-to 50 percent². A recent study indicated that approximately 79% of consumers are aware of solar-dried vegetables and horticulture products in the domestic market (Mujuka et al., 2021). This is attributed to increased investment in the value addition of vegetable and fruits summers, particularly in the urban areas where people are willing to pay an average premium of an estimated 29% for totally preserved dried mangoes. Therefore, the solar dryer presents a secondary market opportunity for farmers and cooperatives among others.

In Kenya, they are a myriad of agro-processing MSMEs who are the potential users of the solar dryers. The majority of the MSMEs are involved in some aspect of solar drying- either doing it directly or purchasing solar dried products or ingredients. Through literature review as well as MSMEs identified during the solar dryer project launch, they were around 21 MSMEs focusing on dried food products such as fruits, vegetables, herbs, tubers and grains among others. This includes.

¹<https://farmbizafrica.com/profit-boosters/1426-farmers-stem-food-waste-with-low-cost-drying-technologies>

² <https://farmbizafrica.com/profit-boosters/1426-farmers-stem-food-waste-with-low-cost-drying-technologies>

Table 2: Agro Processor in Solar drying value Chain in Kenya

Agro Processing MSMEs	Location
Boitangare banana growers.	Kenya-Nairobi
Africa natural products ltd(agritech)	Parklands park place business center 1st floor
Agricycle Global	Kenya Nairobi
BioAfric Energy Limited	Machakos
Osprey grain industry	Kisumu, Kenya
Primoza Enterprises	Kisii county
Desiccated Sweetness	Nyamira
Village Industrial Power (VIP) Kenya Ltd.	Wote, Makueni
Jiranisam Enterprise	Kisumu, Kenya
Lijam Eco-stimulus	Oyugis, Homabay County
Shaju Women Enterprise	Kisii
Osprey grain industry	Kisumu, Kenya
Agri Innovation Hub Kenya	Narok
ALMA ORGANIC	Kilifi
Delight Grocers	Mombasa, Kenya
Organic ilemba	Taita Taveta, Kenya
Joma Junior Educational Centre	Meru, Kenya
Sweet 'N' dried enterprises	Meru
Miyonga Fresh Greens Limited	Coastal regions
Azuri Health Limited	Thika
Burton and Bamber (Sweet Tunda)	Thika
Eco Dudu	Juja, Kiambu County
Kitui Enterprise Promotion Company (KEPC)	Kitui

Additionally, NGOs have also been critical actors in solar drying value chain, where they act as the intermediaries between solar dryer's suppliers and end users. The Table 3 below outlines some of the projects/programmes that have been implemented/ongoing in the country to support deployment of solar dryers in various parts of the Country.

Table 3: List of programs deploying solar dryers in Kenya.

Programme/project name	Funders of the programme/project	Number /Name of beneficiaries	Region in Kenya	Type of solar dryer deployed	Focus value chain	Market of dried products
Kenya value chains enterprises (kaves) -project and The Feed the Future program (Completed) ³	United States Agency for International Development (USAID) /Financial Transactions and Reports Analysis Centre of Canada (FINTRAC)	Sweet 'N dried enterprises	Tharaka Nithi County, Chuka town	Hybrid solar dryer (Automated air dryer)	Fruits (mango, banana, pineapple) African leafy Vegetables)	Local market but they aim to tap into international markets
The Lake Turkana project (Completed in 2018) ⁴	Kenya Marine and Fisheries Research Institute (KMFRI) and Government of Kenya,	Beach Management Units and Fishermen (Total of 74 solar dryers)	Turkana County	Tunnel Solar dryers, polyethylene fish solar dryers	Fish	Local market (Busia, Nariokotome, Kalokol and Kisumu)
Enhancing climate resilience and nutrition uptake through value addition to the mango fruit in Kitui County (Completed in 2016) ⁵	Green Africa Foundation with support from IGAD	3 farmer group in each of the 3 identified sub counties	Kitui County (Mwingi west, Mwingi North and Kitui Central sub counties)	Hybrid of biomass solar dryers	Mango (turning it into powder) and mango flakes, cassava, millet, sorghum	Local market
Solar powered pineapple project (Completed in 2018) ⁶	World Vision	Women farmer group of 47 women	Kilifi county	Tunnel solar dryer	Pineapples	Local markets
	Implemented by NARIGP and funded by the World bank and National Government (Implemented in 2021)	Mango cooperatives in Kitui County (10 solar dryers)	Kitui County	Tunnel solar dryers	Mango, tomatoes and vegetables	Local and international markets
	University of Nairobi in partnership with the Ewaso Ng'iro North Development Authority (ENNDA) (Implemented in 2018) ⁷	Farmer groups in Isiolo	Isiolo	Solar Tunnel dryers	Vegetables, Cattle and camel meat	Local market
County government project (Ongoing) ⁸	Kisii county government in collaboration with Kisii University,	Banana and vegetable Farmers	45 wards in Kisii county	Solar tunnel dryers	Vegetables and bananas	Household consumption and local market

³ <https://farmbizafrika.com/profit-boosters/257-usaid-funds-automated-air-drier-to-boost-factory-s-processing-capacity>

⁴ https://www.kmfri.co.ke/images/Fresh_Water_Systems/Solar-drier_PC-_Turkana_PC-2017-18.pd

⁵ <https://www.netfund.go.ke/igad-funded-project/>

⁶ <https://deeply.thenewhumanitarian.org/womensadvancement/articles/2018/08/10/solar-powered-pineapples-a-lifeline-for-women-thrown-off-their-land>

⁷ [https://farmbizafrika.com/machinery/2322-uon-launches-a-project-to-help-isiolo-livestock-farmers-preserve-meat-using-solar-driers#:~:text=The%20University%20of%20Nairobi%20\(UoN,tunnel%20dryer%20hence%20reducing%20losses.](https://farmbizafrika.com/machinery/2322-uon-launches-a-project-to-help-isiolo-livestock-farmers-preserve-meat-using-solar-driers#:~:text=The%20University%20of%20Nairobi%20(UoN,tunnel%20dryer%20hence%20reducing%20losses.)

⁸ [https://farmbizafrika.com/machinery/2322-uon-launches-a-project-to-help-isiolo-livestock-farmers-preserve-meat-using-solar-driers#:~:text=The%20University%20of%20Nairobi%20\(UoN,tunnel%20dryer%20hence%20reducing%20losses.](https://farmbizafrika.com/machinery/2322-uon-launches-a-project-to-help-isiolo-livestock-farmers-preserve-meat-using-solar-driers#:~:text=The%20University%20of%20Nairobi%20(UoN,tunnel%20dryer%20hence%20reducing%20losses.)

The project flying food (Completed in 2018) ⁹	The Interchurch Organisation for Development Cooperation (ICCO)	4,000 small scale cricket farmers in Kenya & Uganda and 200,000 bottom of the pyramid consumers in Kenya	Nyanza and Uganda	Solar tunnel dryers	crickets	Local market
Renewable Energy for Food processing (RE4Food) (Completed in 2017) ¹⁰	United Kingdom Agency for International Development (UKAID)	Farmers	Western region: Kakamega and Bungoma	Hybrid solar biomass dryer	Green amaranth, cowpeas, black nightshade, kales	Local market
Making Value Chains Work for Food and Nutrition Security of Vulnerable Populations in East Africa (Completed in 2019) ¹¹	International Center for Tropical Agriculture (CIAT)	Beans farmers in Kenya and Uganda	Kenya	Solar powered bubble dryer	Beans	Local market
SECUREFISH project ¹² ₁₃	European Commission (EU)	Fishermen and seafood industry	Kenya, Ghana and Namibia	hybrid solar tunnel drier, (with windmill or biomass burner)	Fish	Local and regional markets

⁹ <https://www.rvo.nl/sites/default/files/2021/01/Evaluation%20of%20Flying%20Food%20Project%20Kenya.pdf>

¹⁰ http://www.jkuat.ac.ke/departments/abed/wp-content/uploads/2017/09/RE4Food_Report_jkuat.pdf

¹¹ <https://ciat.cgiar.org/ciat-projects/making-value-chains-work-for-food-and-nutrition-security-of-vulnerable-populations-in-east-africa/#:~:text=in%20East%20Africa-,Making%20value%20chains%20work%20for%20food%20and%20nutrition,vulnerable%20populations%20in%20East%20Africa&text=This%20three%2Dyear%20project%20is,%2C%20safe%2C%20and%20nutritious%20foods.>

¹² <https://cordis.europa.eu/project/id/289282/reporting>

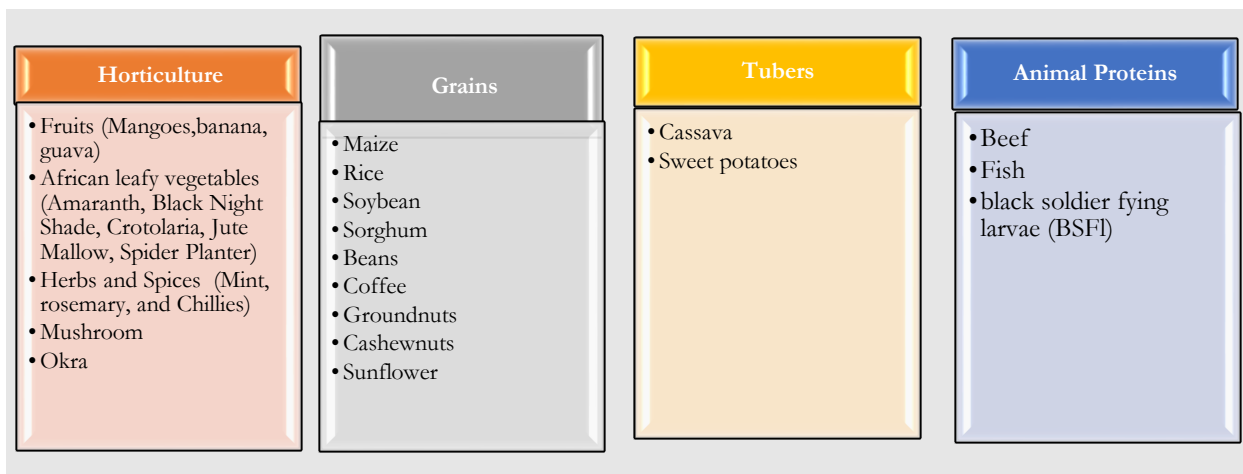


Figure 3: Value Chains

To optimize the utilization of the solar dryers, there is a need to train farmers on food handling, food processing and packaging. This is to ensure the products are dried, within the moisture threshold for the product. This is to minimize the degradation of their nutritional value as well as post-harvest losses that this project seeks to solve. Additionally, the training will ensure farmers produce quality products that will create an opportunity to explore the market of dried products both locally and internationally.

Additionally, the project can foster farmers and other stakeholders to focus such as dried food processors to diversify their income streams by converting dried mangoes into powder form to create additional value and preserve food products for a longer time. This can also create additional markets for the farm products.

Majority of farmers in Kenya are small-scale farmers who do not have financial capacity to purchase the solar dryers. Therefore, to ensure farmers utilize those solar dryers optimally, there is need support farmers financially to access these solar dryers. Therefore, identification of an inclusive business model will be ideal such as fostering of “pay as you dry” services among owners of the solar dryers would be ideal business model.

Solar dryers are seasonally stranded assets with a long payback time that limits adoption. Multi-seasonal uses of solar dryers with growing can greatly reduce payback time by over 50% and increase adoption. For instance, greenhouse solar dryers can be used for differently during harvesting and planting seasons. Like in the case of tobacco in the USA or chilies in India the dryers can be used for drying during harvesting seasons and can be used as nurseries after the harvesting seasons¹⁴. This is because the greenhouse dryers and greenhouses used for growing have a similar structural design. This model can be ideal for number of high-value crops, e.g., chili, capsicum, tomato, eggplant, cauliflower, and onion which requires transplanting.

Operational flexibility from increased size: To optimally use the dryers, multi-use service-based operational models can be used to carry significant risk and substantial sensitivity to drying service pricing, turnover days based on weather or dryer efficiency. Using small dryers, limits multi-farmer participation, therefore use of bigger dryers can be ideal.

iv) Income potential of uptake of solar dryers for farmers

Adoption of solar dryers holds a huge potential in generating socio-economic benefits among different users across the country including smallholder farmers, dryer fabricators and food processors. Linkage of all these actors need appropriate business models that would ensure sustainable participation of each.

¹⁴ <https://www.sciencedirect.com/science/article/pii/S0973082622000229>

For instance, Ebagropamoja is a youth-led social enterprise based in Nairobi, focusing on creating solutions targeted toward helping youths and communities. The organization fabricates and deploys greenhouse type low-cost solar dryers to communities via solar drying centers where cooperatives/farmer groups will access the dryers through “drying as a service model”. Ebagropamoja mobilizes accountable group of beneficiaries, who would host the dryers while taking care and protecting the dryers and collecting data on the impact of applying the dryers. In this model, the youth groups are trained as solar dryer fabricators using affordable locally available materials, who would sell the dryers to the farmers groups who in turn set up solar drying centres and generate income through solar drying as a service. The fabricated solar dryers deployed in this model have the capacity of 400kg and are sold through a flexible financial model agreed with the buyers at a cost of \$2950.

Through this model, farmers have achieved a myriad of benefits. For instance, Khaki women group have generated massive economic benefits just from the use of solar dryers such as saved proceeds from the use of the dryers by recouping postharvest losses, proceeds from additional market of the dried products and increased profit since dried products fetch higher prices compared to fresh products. Moreover, the model has also enhanced access of solar drying technology among the resource-constrained smallholder farmers. See case below.

Case study: Khaki Women Group in Kirinyaga

Khaki women group has 60 women with each representing a household. Previously, they were losing 100 kg per harvest of vegetables, which is approximately KES 2000. Therefore, annually they are losing approximately KES12,000. Using of EbagroPamoja’s solar drying Centre has reversed this post-harvest loss, increasing its annual earnings to 12,000 per year, saving the 12,000, which would have been lost due to PHL. The women’s income has increased by 100% since previously their harvest was spoiled and they could not sell anything and whatever remained they would consume at their homes. Just to ensure that there is no major loss, efficiently drying the main value chain, which is greens, has even increased the income they get. For instance, they sell fresh greens for KES 20 per kilo and when dried they sell them at 50 shillings. They would make a profit of 30 Kenya shillings for every batch they have dried, meaning that on top of reversing their post-harvest losses, they are able to increase their income.

B. Solar Dryer Suppliers in Kenya

There are different stakeholders that are active in the supplying solar dryers in Kenya. They include solar dryers' fabricators (both public and private stakeholders, which are either local, regional, or internationally based), locally based distributors selling to end users, and various actors in between.

i) Solar Dryers fabricators and Distributors in Kenya:

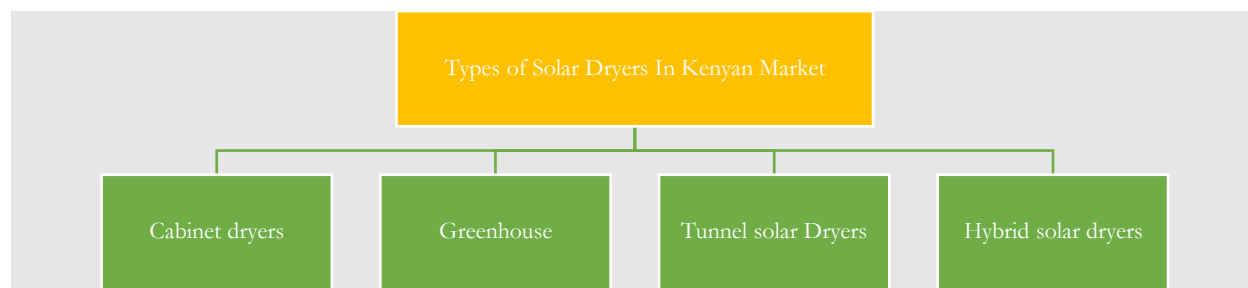
The assessment (both literature review and participants from the webinar) mapped around 36 solar dryers’ fabricators (table 4). List of all identified fabricators and distributors, See Annex

Table 4: Number of fabricators identified.

Categories	No. of fabricators
Learning Institutions and research Institution	7
Private Sector /Youth Groups/Women Groups	29

a) Types of Solar dryers

The identified fabricators are producing different types of solar dryers, which includes cabinet solar dryers, hybrid solar dryers, green house solar dryers and tunnel solar dryers. The hybrid solar dryers are a combination of natural sunlight drying and other sources of energy such as biogas, briquette, charcoal and solar panel systems figure. For instance, Grekkon limited uses a hybrid solar dryer, which is a combination of natural sunlight drying which is complemented with solar panel system.



b) Capacity of Solar and Cost of Production

The drying capacity of the fabricated solar dryers' range is between 5 Kgs – 1000 Kgs where majority of used dryers are below 450 Kgs. The small one is mostly targeted to individual farmers who can dehydrate small quantities of units, vegetables or herbs. The medium scale dryers are also often individuals and groups, cooperatives or associations and big sized dryers are often targeted to agro processors since they require greater capitalization and are designed to dry very large quantities of products for village cooperatives as well as large commercial farming operations (National Environmental Management Authority, 2013).

The cost of putting up the dryers, range between USD 60 - USD 4,000 in Kenya where majority of greenhouse dryers are fabricated between USD 1500- USD 2000. The cost production is often depended on the size, and type and availability of the materials used for instance the wooden greenhouse dryers are cheaper than the one using the galvanized steel dryers. The range of costs gives an alternative for the different categories of entrepreneurs (Ndirangu et al., 2018). The findings from the desktop review and the questionnaires highlights the following as some of solar dryer's fabricators and distributors in Kenya as well as the cost of producing the dryers.

Table 5: Fabricators and Distributors identified in Kenya.

Name of organization	Fabricator/Distributors	Type of solar dryers	Size/capacity of the solar dryers	Cost of production
Grekkon Limited	Fabricators; Distributors	Natural air-circulation solar dryers	40-50kgs 50-90kgs 80-100kgs 90-110kgs 100-130kgs	KES 60,000 KES 65,000 KES 85,000 KES 90,000 KES 110,000
EBAGROPAMOJA AFRICA	Fabricators;	Natural air-circulation solar dryers	450kgs-500kgs	Kes 300,000 approximately
Kisii University, Department of Agricultural Sciences and Natural resources	Distributors;	Solar Conduction Dryer (SCD)	2 M x 2 M, takes 2 to 3 hours to desiccate banana chips. This can be repeated 4 times a day	Kes. 350, 000 (US \$ 3,500) per unit, Communally used by groups, portable
Macro Consultants Consortium Ltd	Fabricators; Distributors; Operate a solar dryer to provide drying service to farmers	Solar Conduction Dryer (SCD), Made in India. Local fabrication was tried bunt grant support was lacking. Macro has MoU with inventors to train locally in Kenya artisans	2 M x 2 M, takes 2 to 3 hours to completely desiccate banana chips. This could be repeated 4 times a day	KES. 350,000 (US \$ 3,500), Macro through collaboration acquired 75 units funded by USAID India to Kisii University
Maridadi Farm Enterprises	Fabricators; Distributors;	Hybrid Solar Dryers	10 tonnes (150 cob bags) of maize, scalable to 1000 cob bags.	KES 800,000

Elite Youth Group	Operate a solar dryer to provide drying service to farmers	Hybrid Solar Dryers	5KW Hybrid system	KES 850,000
Savanna Circuit Tech Limited	Fabricators; Distributors;	Hybrid Solar Dryers	Its a mixed mode dryer with a direct solar radiation area of 50x100CM with a solar powered air inlet fan, 50x50x50CM drying chamber with 6 trays made from foodgrade material with a hygrometer for humidity and temperature control.	KES 90,000
NYAKWERIGERI A DISABLED SHG	Operate a solar dryer to provide drying service to farmers	Natural air-circulation solar dryers	300M BY 200 BY 300	KES 150,000
NYABOMOKE WOMEN GROUP	Operate a solar dryer to provide drying service to farmer	Natural air-circulation solar dryers	400M BY 300M BY 400M	KES 250000
Alma's pure honey enterprises	Operate a solar dryer to provide drying service to farmers	Hybrid Solar Dryers	3*6	KES 20000
KIRDI	Fabricator and operate a solar dryer to provide drying service to farmers	Hybrid Solar dryer	90kgs 400-500kgs 1000kgs	Between KES 250,000 – KES 300,000 Between KES 750,000- KES 800,000 KES 1.6 million
Afya Choice CBO	Fabricator and operate a solar dryer to provide drying service to farmers	Green house solar dryer	0-20kg 30-120kg 150-400 kg	KES 36000 KES 86000 KES 120000
Agricycle	Fabricator/Manufacture	Passive solar dehydrators-. They are the dehytrays-	3-5Kgs-	USD> 139.5
BioAfriq Energy limited	Fabricators	Hybrid solar dryers (Greenhouse type with fuel from biomass briquettes and biomass pellets	100, 250 and 500 kilograms	
Claphijo enterprise	Fabricator	Direct, Tunnel type dryer and portable dehydrator	9.5 kg	KES 34,500-KES 80,700

c) Selling Prices of the fabricated solar dryers and Fabrication Margins

The study also indicates that the cost of dryers is varied leading to varied choice and ultimately an opportunity for higher adoption of different types of solar dryers. The selling prices of solar dryers range between KES 20000- and KES 1,600,000. The selling price is also dependent on the size, materials used and the additional facilities installed, with those with concrete floors and metallic frames being more expensive. The literature indicates that solar dryers are sold through cash or credit. For instance, a cooperative indicated that they own a solar dryer which they bought on hire purchase and they were paying KES 6000 instalments per month. Additionally, the findings also indicated that “drying as service” models have been used as a way for farmers to access the solar dryers rather than actually purchasing the dryers. For instance, KIRDI, have installed a 90 Kgs solar dryer in Kisumu which is mostly used by SMEs and they charge two shillings. Similarly, Ebagropamoja has established solar drying centres, where groups are charged KES 5 per Kilogram.

Below are some type of solar dryers and their selling price;

Table 6: Types of dryers and their selling prices

Type	Size of the solar dryer	Capacity	Selling price range	Design and specification
Greenhouse solar dryer	8.1m ² - 72m ²	50kg - 300kg	Ksh 173100-Ksh 461,600	Heat insulated, indoor cabinet structures, steel frame and PVC
Hybrid solar dryer (made from local wood)	1.15m*1.5m*1.5m 2m*2m*2m 2m*3m*2m 2m*4m*2m 2m*5m*2m	40kgs-50kgs 50kgs-80kgs 80kgs-90kgs 90kgs-100kgs 100kgs-130kgs	60,000ksh 65000ksh 85,000ksh 90,000ksh 110,000ksh	UV treated translucent polythene paper, Heavy UV treated geomembrane and UV treated heavy gauge netting
Turnell type solar dryer	No specific size	9.5kgs	34,620ksh -80,780 ksh	No specific design specification but the price is based on the material used
Hybrid indirect solar dryer (made of steel frames)	1.5m*6m 3m*4m 3m*6m	0-20kgs 30kg-120kgs 150-400kgs	58,000ksh 136,00ksh 19,8000ksh	Drying sheet, polythene film, drying mesh and steel frames
Cabinet solar dryer	4.00m2-7.5 m2	15kgs-30kgs	150,085ksh-196,265 ksh	Cement, galvanized iron, bricks and plywood
Creadis Dryers	The greenhouse is a thermal tunnel with Gothic arch shape on a base area of 74.4 m2 and height of 3.7m.	700 to 1000 kg	KES 895,385.36	It was made of untreated wooden structure members and a PVC film covering
Bukura systems	Hybrid solar dryers	450 Kgs	575,249.72	The structure has been installed, the fan system fixed and integrated to the stove and the green house. The system can be used to dry fruits, meat, fish and vegetables

Case study: The margins for the fabricators Suncatcher Solar Dryer

The Sun Catcher is a small-scale solar dryer that helps preserve food and prevent wastage. The Sun Catcher dries produce quickly and efficiently using locally sourced materials that meet the standard food-grade requirement. The Sun Catcher costs \$120 to manufacture, can be built by two people in just two days, and pays for itself within one harvest season. The sun's energy heats up the air flowing through the dryer chamber, and thus results in faster and safer drying.

The organization sells solar dryers to businesses such as Azuri Health and VegPro International. These businesses will then provide the dryers to their network of farms and farmers. It also has an option for independent entrepreneurs and farmers to buy the dryer directly, which are not only their primary strategy. Azuri Health and VegPro will then buy the dried food off the farmers and sell it in the national as well as export market. This provides the farmer the link to the market that he is missing and provides the businesses a steady supply of dried food.

Revenue Streams

Revenue per Sun Catcher Kit: \$192 (Our price for distributors)

-160 (Cost of one Sun Catcher)

\$ 32 (Profit)

Their revenue comes directly from Azuri Health, VegPro and other major dried food distributors to whom they sell the dryers. These distributors yield increased revenue from the farmers who are able to produce more because of the Sun Catcher.

This price point comes directly from how much Sun Catcher LLC will need to continue to increase production as well as pay for a small, managerial staff.

Projected Income Statement for Sun Catcher LLC (per solar dryer)

	Per Solar Dryer
Sales	\$ 192.00
Cost of Sales	\$ -
Other	\$ -
Total Cost of Sales	\$ -
Gross Margin	\$ 192.00
Gross Margin Percent	100%
Expenses:	
Material Costs	\$ 120.00
Operating Expenses:	
Overhead (including utilities and rent)	\$ 28.00
Employee Wages	\$ 10.00
Total Expenses	\$ 158.00
Profit Margin	22%

Source: (The Sun Catcher Solar Dryer, n.d.)

C. Financing Models for acquiring solar dryers

a) Willingness to acquire solar dryer

In assessing the optimal amount, the stakeholders were willing to pay for solar dryers by the target market, the market analysis shows that majority of the stakeholders were willing to pay to acquire the solar driers. For instance, the food processor are willing to pay up to 400,000 shillings to acquire the drier and this is through credit (table 7). Similarly, farmer cooperatives societies, were willing to pay up to 2,000,000 Kenya shillings to acquire the driers (table 8)

Table 7: Willingness to Pay among Food processors MSMEs engaged

Size (kg) of a dryer interested	Amount (KES) be willing to pay to acquire the solar dryer	Mode of acquiring
1tone and above	400,000	Credit;
Biogas drier		Credit;
2500Kg	20,000	Credit;
100 kilos	100,000	Credit; Cash;
Big size, drying up to 20-50 kg	1,000-2,000 per month	Credit;
5000	100,000 shillings	Credit;
It depends with the prices and we will choose the cheapest	10000	Credit;
20kg	For now, I have less money to pay but I will try to 6000	Credit;

Table 8: Cooperatives willingness to pay

Amount Willing to Pay (KES)	Mode of acquiring
30,000 depending on how effective it's and market.	Credit
2,000,000	Credit
500,000	Cash
100000	Cash
Not sure	Credit
50000	Credit
150000	Credit
8000	Cash
20000	Credit
25000	Credit
10,000 to 50,000	Credit

b) ACTS Proposed Financing Models

ACTS proposes to develop different models that fit the needs of different stakeholders' interest in accessing the fabricated solar dryers. The following are some of the financing models.

i) Azuri based business model/Distribution model

This solar dryer distribution chain is primarily through the firms that will buy our dryers. Regardless of the dryers are relatively cheaper than the market – an individual farmer is often unable to purchase on their own. As a result of this, farmers will be reached through the networks established by the firms that are in the dried food business. Like

in the case of sun catcher’s model, the solar dryers are distributed through Azuri Health, which has a network of 600 farmers. Thus, instead of trying to sell directly to farmers, the dryers are sold to Azuri Health and they’ll provide the dryers to the farmers for free. The farmers, in return, have to provide Azuri Health with a fixed quota of dried food that Azuri will use in its products (The Sun Catcher Solar Dryer, n.d.). A visual example of the distribution chain is given below;

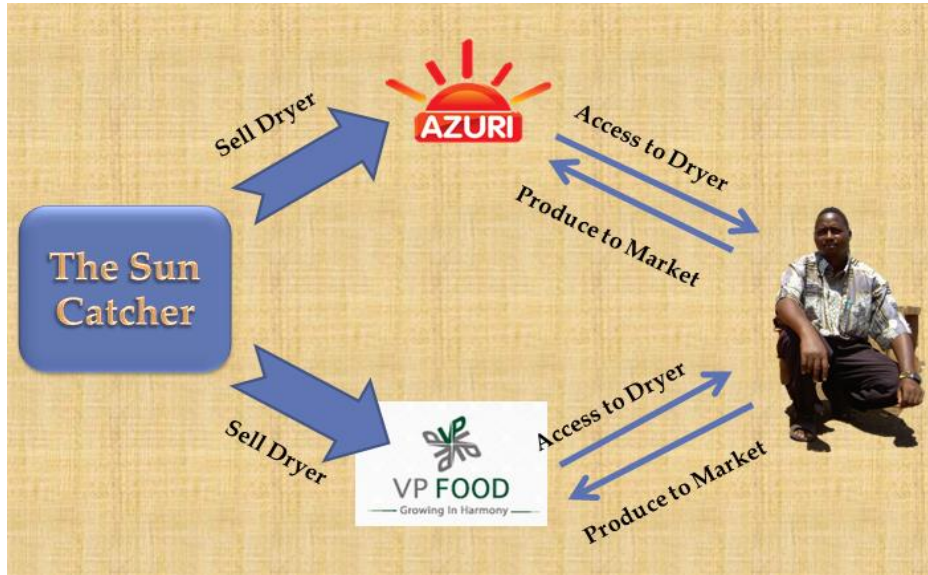


Figure 4: Azuri Distribution Model

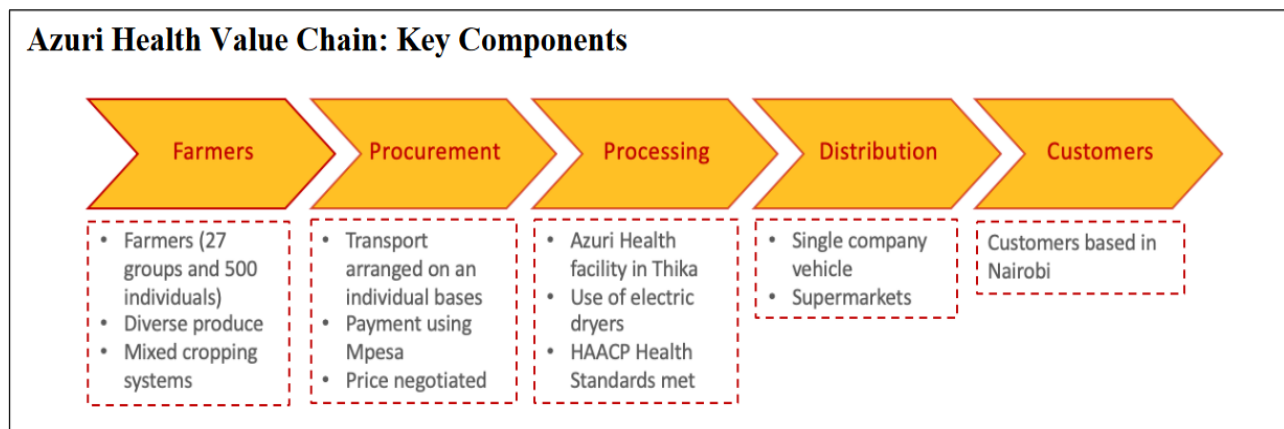


Figure 5: Azuri Operation

Model flexibility: We permit both credit and cash purchases. The cash purchase should have lower pricing than the credit. Those interested in the support services should be brought on inboard but the support services cost.

Role of ACTS: For those doing cash purchases,

- ACTS will support the fabricators in getting the raw materials by providing the finance.
- ACTS will earn from the markup on the agreement with the fabricators. The fabricators are to identify potential buyers.
- Charge training after the flagship project

For those purchasing on credit,

- ACTS will pay the fabricator's total sum but work with the fabricator to ensure compliance in the repayment. Any non-payment the fabricator should help repossess the dryer.

ii) Private Sector Partnering

ACTS will collaborate with two commodity buyers, who can benefit by helping producers improve the quality of their food products through better postharvest handling practices. By investing in solar dryers and supplying associated services, they can strengthen the farmer relationship and ensure more reliable supplies of higher quality products. This can be done directly by investing in solar dryers for their own use or through lending to aggregators who supply them. Since these companies are aiming to recover the total cost of equipment against an outlay of only 50%, they can potentially re-lend to more aggregators in the future and grow the business for themselves, the aggregators, and the farmers on a sustainable basis (Bountifield International, 2020).

Model operation: ACTS/consortium will work with a private sector partner such as KCIC that will provide financing such as 50%. In this ACTS will insist on a commitment from the buyer and the dryer is co-owned until the repayment is finalized.

Model flexibility: We permit both credit and cash purchases. The commitment fee should be at a minimum of 20% and the repayment plan be agreed. Those wishing to join the support services only be permitted to. We also allow 100% financing by the private sector partner, and this will be equal to cash payment by the buyer then they repay the Private Sector partner.

Role of ACTS:

- Provide credit to the buyers.
- Provide financing to the fabricators to purchase raw materials.
- Provide support services such as food safety training, business development services and technical services to the buyers.
- ACTS to do the due diligence for credit buyers. Fabricators will assist in debt management.

iii) Public- Private Partnerships

ACTS will collaborate with County government, who will support in the deployment of the solar dryers to farmers. This will be through the provision of financial support from the government.

Model operation: ACTS/consortium will work with a public entity such as County Government. This model should have both a cash payment and a credit payment plan. The county government will do due diligence for the credit buyers.

Model flexibility: It should be that the dryer will be co-owned with the consortium during the repayment period. Those willing to join only the support services be permitted. It be permitted that the county government be allowed to do both cash and credit purchase for its players.

Role of ACTS:

- Provide credit.
- Provide financing to the fabricators to purchase raw materials.
- Provide support services such as food safety training, business development services and technical services to the buyers.

iv) Microfinance Institution (MFI)

ACTS will work with the savings and loan enterprise of a farmer association – Savings and Credit Cooperative (SACCO) – to finance loans to MSMEs providing services to their members and others. The SACCO is already financially sustainable, and, through this partnership, they will add a completely new service and technology, based on the ACTS business model.

ACTS will collaborate with a SACCO who will be willing to loan to farmers, cooperatives, or agro-processing MSMEs who are interested in acquiring the solar dryers from youth's fabricators.

Model operation: ACTS/consortium will work with an MFI who will partly or fully finance the solar dryers purchased by the buyers.

Model flexibility: Possibility of offering an incentive of % reduction of costs to sellers who meet some level of daily processing of dried products.

Role of ACTS:

- Provide credit.
- Provide financing to the fabricators to purchase raw materials.
- Provide support services such as food safety training, business development services and technical services to the buyers.

E. Dried Food Market

The awareness and consumption of dried food products is growing both locally and internationally. The decision to purchase solar dried products has been found to be influenced by age, gender, awareness, education, occupation quality attributes such as taste and market price. Older generation prefer dried products because dried fruit is perceived to lower the risk of cancer and heart disease among Dutch, Polish and French consumers.

Globally, there has been a rise in demand in relation to drying. Dried foods like chips, nuts, s, popcorn, and others are observing increased demand from consumers. For instance, freeze-dried food is becoming increasingly popular among consumers, particularly in North America and Europe. Further, the global dehydrated food market is forecasted to register a compound annual growth rate (CAGR) of 5.2 % during the forecast period (2021 - 2026)¹⁵. This is because the technique used retains the original flavour and taste of the food product, while also providing a long shelf life. In Kenya, the drying of horticulture food has been a common post-harvest practice with statistics showing that in 2009, Kenya exported about 4000 metric Tonnes of dried vegetables, with the highest export being experienced in 2007 when 40,000 Tonnes of vegetables were exported (Ndirangu et al, 2018).

Internationally, the largest market for dried mangoes is the UK while in EU the awareness of dried mangoes as a snack is still very low hence the potential market for the Kenyan dried products. Fresh and dried mangoes from Kenya are mainly destined to the Middle East, with the United Arab Emirates (UAE) taking up about 40% of all Kenyan exports. Besides the UAE, Saudi Arabia, Bahrain, and Qatar are the other top mango export destinations. Whilst the demand for dried mangoes in the European Union market has grown, it is yet to attract big investors in Kenya like those in mango pulp processing¹⁶. Nevertheless, different stakeholder, have been accessing the international market with dried products, for instance, Agricycle buys dried fruits, brands, markets, and sells them to consumers in the United States of America, Azuri Health exports dried mangoes to rope, America, Asia and the Middle East (Dubia & Japan).

Locally, the awareness of dried products particularly vegetables and mangoes are high this is attributed to donor interest in the vegetable sub-sector, in both Kenya and Tanzania. This has led to increased investment in the value addition of vegetables and awareness of solar-dried vegetables. Consequently, consumer awareness of solar-dried vegetables is higher and estimated at 79% and 36% in Kenya and Tanzania, respectively.

The consumption of the dried products particularly in Kenya is low since high consumption is highly concentrated in the urban food retail premium niche market such as Muthaiga, Lavington or Westlands, where expatriate communities from Thailand, Philippines and Europe are used to buying dried food¹⁷. This is attributed to the fact

¹⁵ <https://www.researchandmarkets.com/reports/4602398/dehydrated-food-market-growth-industry-trends>

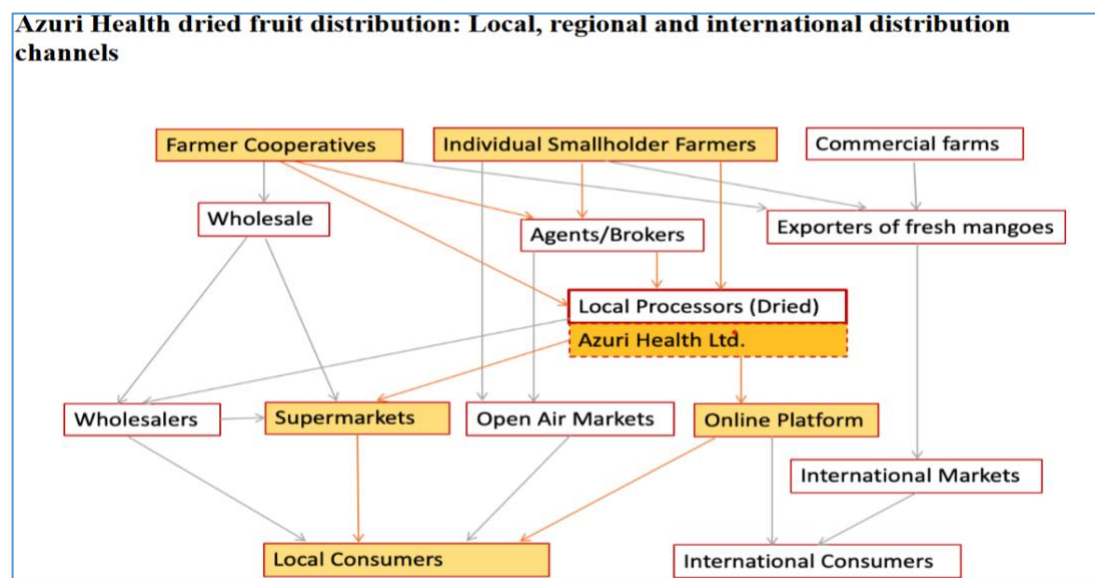
¹⁶ https://snv.org/assets/explore/download/exporting_mango_from_kenya_to_europe.pdf

¹⁷ <https://fambizafrika.com/profit-boosters/1426-farmers-stem-food-waste-with-low-cost-drying-technologies>

these products are relatively expensive compared to open sun dried where consumers tend to make choices based on price particularly among consumers with poor socio-economic background.

According to Mujuka et al., (2021) consumers are willing to pay for premium solar dried products particularly those who have tasted the products. In addition, the willingness to pay is attributed to the fact that the solar dried products are safe, hygienic and lack preservatives which people consider not healthy. This is an indication that, there is a potential market for dried products, hence a need to enhance product promotion strategies in retail stores through mass media.

Case of Azuri health market and distribution channel for dried Mango



Source: (Fleming, 2020)¹⁸

Conclusion

The market assessment has found the growing demand of solar dryers in Kenya and this stems from the need to reduce the high levels of post-harvest losses using low-cost technologies as well as the need for value addition, which creates a secondary market for farmers and other stakeholders in the agro-value chain in Kenya. The solar dryers use is spread across different regions of the country and the mostly used to dry fruits and horticulture among other farm products. The acquisition of these dryers among farmers is fostered through different programmes from both government institutions and other developmental organizations such as USAID among others. Private sector stakeholder has also played a role in supplying these dryers where they are currently 27 fabricators and distributors mapped by this assessment. The capacity of the dryers being traded in Kenya ranges between 5kg- 1000kg, where the small sized dryers are targeted to individual farmers, while medium sized are targeted towards cooperatives of associations and some agro processors while big sized are mostly used for commercial purposes. These dryers are mostly sold between 20000- KES 1,600,000 and they are produced approximately between USD 60 – USD 4000 where majority of greenhouse dryers are fabricated between USD 1500- USD 2000. To optimally use the dryers inclusive business model such as “pay as you dry” service can be used by different owners of the solar dryers

¹⁸ https://ecommons.cornell.edu/bitstream/handle/1813/72652/Marie_Fleming_MPS_Capstone.pdf?sequence=1

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Annex 1: List of Mapped Fabricators and Distributors In Kenya

Fabricators	Name
Learning Institutions and research Institution (4)	<ul style="list-style-type: none"> ▪ KIRDI ▪ University Of Nairobi ▪ University of Eldoret ▪ Jomo Kenyatta University of Science and Technology ▪ Kisii University ▪ Kenya school of agriculture, Nyeri ▪ Moi University
Private Sector /Youth Groups/Women Groups	<ul style="list-style-type: none"> ▪ EbagroPamoja ▪ Grekkon Limited ▪ Macro Consultants Consortium Ltd ▪ Maridadi Farm Enterprises ▪ ELITE YOUTH GROUP ▪ Natural Resource Forum ▪ SAVANNA CIRCUIT TECHNOLOGIES LTD ▪ Ntashart Eco Green ▪ CHEPKALWAL VISIONARY YOUTH GROUP. ▪ Macro consultants Consortium Ltd ▪ Savanna Circuit Tech Limited ▪ Memo Agro Grains ▪ NYAKWERIGERIA DISABLED SHG ▪ NYABOMOKE WOMEN GROUP ▪ Alma's pure honey enterprises ▪ Runyenje Ladies ▪ Ndiru school Agroforestry Group ▪ Savanna Circuit Tech Limited ▪ Millennium media Houese-Radio Mikayi ▪ Agricycle ▪ Tree of life Africa ▪ Claphijo enterprise ▪ Africa Choice ▪ Greenhouse Company Limited ▪ Kenya Agribusiness and Agroindustry Alliance ▪ Maharata Agri Machinery ▪ Malnutrition Matters, in partnership with SolarFlex Inc. (Small Farm Dryers) ▪ BioAfric Energy limited ▪ Sun catcher solar dryer LLC