Techno-Economic Analysis of a Refractance Window Dryer Prototype Developed by Kenya Industrial Research and Development Institute

Winstone Asugo Nyaguti*, George Wafula Wanjala*, Joseph Kamau and Samuel Warui

Department of Research Technology and Innovation, Kenya Industrial Research and Development Institute, P.O.Box 30650-00100 Nairobi, Kenya.

Authors’ contributions

This work was carried out in collaboration among all authors. Authors WAN and GWW designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors JK and SW managed the analyses of the study and managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2021/v40i2831531

(1) Dr. Nan Wu, University of Manitoba, Canada.
(2) Dr. Chien-Jen Wang, National University of Tainan, Taiwan.
(3) Dr. Alessandro Buccolieri, Università del Salento, Italy.

Reviewers:

(1) Prof. Manal Abdel Rahman Sorour, Food Technology Research Institute, Egypt.
(2) Saifuddin Muhammad Jali, Universitas Malikussaleh, Indonesia.

Complete Peer review History: https://www.sdiarticle4.com/review-history/73645

ABSTRACT

The Refractance window dryer (RWD) is a fourth generation dehydration technology. RWD is used to dry heat-sensitive materials because it retains high nutrient content, colour, flavour, aroma and bioactive compounds. The dehydrated products have a high sensory quality. There were no RWD in East Africa despite their excellent performance hence need for local fabrication of RWD Prototypes that can meet the technical, economical and socio-economical requirements. This paper describes the performance evaluation and economic analysis of the RWD prototype developed at the Kenya Industrial and Development Institute (KIRDI), Kenya. Indicators such as drying rate and drying time were used to assess its technical performance. The economic performance of the dryer was appraised using Net Present Value (NPV), Internal Rate of Return (IRR), Benefit-Cost Ratio (BCR), and Payback Period (PBP). Mango pulp and African leafy vegetables were dried using the RWD.
Mitigation of postharvest losses (PHL) is recognized as the most urgent development priority and a key pathway to food and nutrition security in sub-Saharan Africa [1-5]. According to the National Bureau of statistics, Kenya loses about a third of its agricultural produce to post-harvest losses annually. For example, in 2017, smallholder farmers cumulatively lost 1.9 million tons of food worth over KSH 150 billion. It is estimated that adoption of appropriate post-harvest technologies such as dehydration could save approximately 68% of these losses [6]. There is evidence that application of postharvest handling, storage and processing technologies results in significant reduction of postharvest losses of agricultural produce [7-10] even in humid climates [11].

Drying is one of the indispensable techniques for large-scale food preservation, but is one of the most energy-intensive operations [12]. Dried foods offer numerous benefits including storage stability, lowering packaging requirement, and reducing the bulk for transportation [13]. An ideal drying technology can confer many advantages such as a safer operation, higher capacities, and better product quality, less environmental impact, higher energy efficiency and at a lower cost [14].

The global demand for dehydrated foods has been increasing rapidly due to consumer demand for healthy and convenient products with a higher shelf-life [15]. Key market players dominating international trade in dehydrated products leverage on advanced dehydration technologies which produce products of superior quality as demanded by the elite consumers. Currently, dried natural products have gained importance as ingredients in different food products. Although drying of food products is widely applied in various industries globally, it has been a challenge for the Micro Small and Medium enterprises in Kenya, who still uses rudimentary drying technologies producing inferior products which are unable to compete with imported variants [16]. Upgrading drying technologies in Kenya’s food industry is therefore a matter of great national interest. The Refractance window dryer (RWD) is a fourth generation dehydration technology that is gentle, simple, and a relatively low-cost drying system [17]. It is used to dry heat-sensitive fresh produce that preserves the nutrient, colour, flavour, aroma and bioactive compounds as well as the sensory quality [18]. RWD is versatile technology that can be deployed to remote settings even at farm level. The larger capacity if the RWD is a continuous belt system based for industrial use although the mechanisms of operations remain the same.

Studies conducted on the RWD technology show that the system demonstrates high retention of product quality (colour, vitamins, and antioxidants) when compared with other conventional drying methods [19]. The quality of the dried products is comparable to those obtained by freeze drying, yet the cost of the equipment is several times lower. RWD achieves substantial reductions for total aerobic coliforms and E. coli. A number of foods that are difficult to spray dry without the addition of non-sugar carriers have also been handled successfully in the RWD dryer. These attributes of RW drying make it suitable for processing of high-value foods, nutraceuticals and food supplements where high standards of quality and safety are required.

The economic and technical appraisal of drying technologies is vital for their adoption by Micro, Small and Medium enterprises. Successful assessment of these low-cost technologies drives their scale-up from research laboratories to commercialization and adoption. This study
sought to assess the economic and technical performance of Refractance window dryer prototype developed by Kenya Industrial and Development Institute.

2. MATERIALS AND METHODS

2.1 Research Methodology

2.2 Technical Performance Study

2.2.1 Study site

The drying experiment was conducted at the Engineering Development Service Centre of Kenya Industrial Research and Development Institute (KIRDI) in Nairobi South C of Kenya.

2.2.2 Process flow
2.2.3 Dehydration procedure

The RWD prototype was used to dehydrate Mangifera indica (mango) pulp/puree and African leafy vegetables; Solanum nigrum L. (black night shade) and Cleome gynandries (spider plant, cat whiskers). The fruit and vegetables were bought from a popular supermarket chain, in Nairobi.

The raw materials were thoroughly cleaned and prepared; the mangoes were peeled, deseeded, and the flesh pulped using a commercial blender and spread thinly over Mylar, the vegetables were destalked, blanched using a boiling water bath for 2 minutes, cooled and spread over the Mylar. The materials were constantly being monitored until they reached the recommended moisture content of below 20% for mango leather and below 5% for the vegetables. The dried materials were moved to the cold water section for cooling and then scrapped off the Mylar.

2.2.4 Dryer description

The newly developed prototype of Refractance Window Dryer unit (RWD), shown schematically in drawing (Fig.1), was fabricated at department of Engineering and Development Services in KIRDI. The KIRDI version of RWD and consists of three major parts, namely; the drying chamber/mylar paper, the water system and the frame assembly. The parts are all fabricated and assembled together as a single unit. The system can be motorized to remote destinations and therefore provide drying services to the SMEs. The prototype design allows for continuous and batch systems with an approximate loading of 20 kg of fruit pulp per batch. The drying chamber has an overall dimension of 110*150 cm.

2.3 Dryer Performance Indices

Dryer performance indices such as drying rate was considered for the performance assessment of the KIRDI prototype RWD Equations (i) show the expressions that was used to determine the performance indices.

Determination of Drying Rate, DR

\[ DR = \frac{M_i - M_d}{t} \]  

Where \( M_i \) and \( M_d \) represented initial moisture content (% w.b.) and final moisture content (% w.b.) after drying respectively, and \( t \) = drying time.

2.4 Economic Performance Study

The economic assessment on the Refractance window drying system was appraised from the perspective of a Micro, Small and Medium enterprises using the discounted method where the time value of money was considered.
2.4.1 Case study scenario

The following assumptions were made for the scenario considered for the study:

a) An SME owns the refractance window dryer.
b) The SME buys the raw material in this case mango and African leafy vegetable.
c) The SME sells the dehydrated products.

2.4.2 Estimation of cost and revenue

The cost component was made up of the investment cost and cost of operation and maintenance. The investment cost consisted of all the expenses required to set up the complete drying system. The cost of acquiring raw material for drying plus any auxiliary raw material was considered, electricity for operating the drying system during operation and a flat rate of 2% of equipment and machinery cost was assumed to be operation and maintenance costs, respectively. The revenue generation stream was sourced from the price charged for sale of dried products. The prices and quantity of dried product were presented in the economic model to determine the annual total revenue generated

2.4.3 Economic appraisal

Discounting methods for investment analysis, including net present value (NPV) and internal rate of return (IRR) were used to analyze the financial viability of the RWD when drying mango pulp. However, the undiscounted method (payback period) was also used to determine how quickly the installed dryer generates enough funds to cover initial capital investments. Economic analysis was also performed to additionally highlight the potential for job creation for the youth in the study area from the scale-up of the KIRDI RWD. The number of SME-beneficiaries and potential economic loss of fruits/horticultural crops due to post-harvest loss prevented by using the dryer as against other common methods was also estimated. The economic output indicators were determined using Microsoft Excel analytical tool.

Net Present Value (NPV): NPV as a discounting method for evaluating the economic viability of investments that refers to the present worth of the net cash flow of a firm. NPV is the difference between the present value of an investment cash inflows (benefits) and the present value of the investment cash outflows (costs) at a given discount rate [20]. Positive NPV indicates an economically feasible investment or project while a negative value shows that it is not economically feasible to carry out such an investment or project. Mathematically, NPV is expressed as indicated in Equation (ii).

\[
NPV = \sum_{n=1}^{N} P_n (1 + i)^n - FC
\]

(ii)

Where: Where, \(P_n\) is the discounted present value to be invested in the \(n\) years in the future; the net cash flow at a specific time; \(n\) the number of years (10 years); \(i\) is the financial discount factor; \(FC\) total investment outlay

Internal rate of return (IRR): The IRR refers to the average annual percentage return expected from a project, where the sum of the discounted cash inflows over its life is equal to the sum of the discounted cash outflows. It therefore represents the discount rate that results in a zero NPV of cash flows [21]. Generally, the higher the IRR compared to NPV the more desirable it is to undertake the project [22].

Payback Period (PBP): The payback period estimates the number of years it takes to recover an investment’s initial capital. It provides a simple way to assess the economic merit of investments. Cash inflows for the PBP are undiscounted hence do not consider the time value of money. The payback period was mathematically expressed using Equation (iii)

\[
PBP = \frac{C_i}{S}
\]

(iii)

Where: \(C_i\) is the initial investment cost; \(S\) is the net cash flow

Financial Assumptions: The following financial assumptions were made during the assessment:

a) Cash flows were discounted over a ten-year period based on the expected useable lifetime of the RWD
b) An operation period of three hundred days per year is considered
c) The dryer is anticipated to dry 30 tons of mango pulp per year.
d) The dryer will be operated by two employees
e) Assumed price increment of 10% after five years
f) A discount rate of 24%, which is Kenya’s discount rate of August 2021, was used for the analysis.

g) A percentage of 2% of the investment cost was assumed to be maintenance cost in the financial analysis.

3. RESULTS AND DISCUSSION

3.1 Technical Performance Evaluation

3.1.1 Dryer performance specification

The Table 1 show results of KIRDI’s RWD technical performance, the result satisfied the drying needs of small and medium enterprises. The average temperature distribution of 88.5 ± 2.8 °C in the drying chamber was not too much of a drying temperature that can result in the loss of nutrients in a fruit paste viability. This is an essential consideration for adopting fruit pulp dryers. The prototype capacity matches most of the Micro, Small and Medium enterprises production rate, making the KIRDI RWD dryer suitable for most enterprises in food drying.

3.1.2 Drying of various food materials using KIRDI RWD prototype

Indigenous vegetables (African night shade and cat whiskers) and the ripe mango fruit were prepared and dried as mentioned previously. The materials dried sufficiently to below the required moisture content in a short time. The drying time was 40 minutes and 1 hour respectively for vegetable and mango pulp. This was a major reduction when compared with the hot air electric cabinet driers that take 8 hours and 16 hours to dry similar materials respectively.

### Table 1. RWD prototype technical performance

| Parameter                        | Value              |
|----------------------------------|--------------------|
| Dryer mode                       | Batch              |
| Initial mass of fresh material   | 20 kg              |
| Initial moisture content – mango fruit pulp | 86%              |
| Final moisture content- mango fruit leather | 15%              |
| Initial moisture content- African leafy vegetable | 88%              |
| Final moisture content- African leafy vegetable | 5%               |
| Average drying time (fruits)     | 1 hr               |
| Average drying time for vegetables | 40 minutes         |
| Drying rate                      | 71/1 hour          |
| Specific energy consumption      | 1kw per run        |
| Average hot water temperature    | 92°C               |

![Fig. 2. Pictorial presentation of vegetables preparation, spreading of the fresh materials on mylar sheet, dried vegetables and mango leather](image-url)
3.1.3 Drying Rate, DR of mango pulp using KIRDI version of RWD

\[
DR = \frac{M_i - M_d}{t}.
\]

Where \(M_i\) and \(M_d\) represented initial moisture content (% w.b.) and final moisture content (% w.b.) after drying respectively, and \(t\) = drying time.

\[
\frac{86\% - 15\%}{1\text{hr}} = 71/\text{hr}.
\]

The result achieved the recommended moisture content of 18\%-33\% (db) for intermediate moisture food like mango leather, even though the drying time was still high of 1 hr and did not conform to experiment conducted by Kaur, G et al who achieved similar result but within 12 minutes using RW dryer with Mylar sheet [23].

3.2 Economic Performance Evaluation

3.2.1 Technical and financial analysis of the drying system

The design capacity of the KIRDI RWD is 20 kg of mango pulp per batch and assumed to operate at five batches per day. Given that the dryer will operate 300 days/year, it’s anticipated that the dryer would be used to dry thirty tones (30,000kg) of mango/fruit pulp/year. To match the rise in the operating and maintenance cost due to inflation, the revenue items is projected to increase at 10\% after every five years of operation.

3.2.2 Cost of building KIRDI RWD

KIRDI RWD was estimated to cost Kenya shillings 1,571,500 to build/develop (Table 3), this is basically the material cost. The cost for RWD drying system presented in Table 3. The main cost component was the water tray assembly, estimated to be 34.4\% of the total investment cost for the dryer.

3.2.3 Estimated cost of manufacturing KIRDI RWD by a fabricator

The estimated material cost of KIRDI RWD is Kenya shillings 1,571,500 (table 4), this cost would shoot up after adoption of the technology by the fabricators. In this study we anticipate an estimated retail price of about Ksh 2,500,000 (table 4) for the dryer this inclusive all the relevant taxes plus direct cost and little profit margin' comparing the price with hot-air driers it would be affordable to most entrepreneurs.

3.2.4 Operational cost of KIRDI RWD

The costs associated with the operation and maintenance of the dryer is presented in Table 4. An amount of Ksh 50,000 representing 2\% of the dryer acquisition cost was allocated for maintenance and overhead expenses. A total power of 1050 kWh required in the beginning year of operation but it will increase to 1500 Kwh at the third year in which the dryer shall have achieved full scale operation, an amount of Ksh 42,000 was estimated as the cost of electricity for the operation of the drying system in the first year. The cost of electricity was estimated at Ksh 40 per kWh in Kenya. Labour cost was estimated at Ksh 800 per day and will require two people to operate the dryer, hence for 300 days in which dryer will be operation results to Ksh 480,000 as cost of labour for one year. The dryer will require water for its operation, and the project assumed water bill of Ksh 30,000 per annum.

3.2.5 Economic analysis - net present value

Net present value (NPV) is the difference between the present value of cash inflows and the present value of cash outflows over a period of time. NPV is used in capital budgeting and investment planning to analyze the profitability of a projected investment or project. From the financial result NPV was found to be positive and high at Khs. 808,223.515 using discounted rate of 24\%.

3.2.6 Payback period

The payback period was estimated by deducting cash flows to recover the initial capital invested. It provides a simple way to assess the economic merit of investments. Table 6 presented the estimated years it took to recover the initial investment.

The table indicates that the real payback period is located somewhere between Year 3 and Year 4. There is Ksh 734,700 of investment yet to be paid back at the end of Year 3, and there is Ksh. 1,190,100.00 of cash flow projected for Year 4. We assume the same monthly amount of cash flow in Year 4 which means that we can estimate final payback as being just short of 3.6 years.
Table 2. Financial and technical parameters

| Parameter                                      | Value                                                                 |
|------------------------------------------------|------------------------------------------------------------------------|
| Capacity of dryer (kg)*                        | 20 kg of Mango pulp                                                   |
| Number of batches                              | 5 per day                                                             |
| Number of hours required per batch of drying   | 1 hr for mango pulp and 45 minutes for vegetables                    |
| Number of operational days per year            | 300                                                                  |
| Number of operational hours per day            | 8                                                                    |
| Number of operational months per year          | 11                                                                   |
| Quantity of mango pulp processed per year      | 30,000 kg                                                            |
| Number of direct employments generated (persons)| 2                                                                   |
| Lifespan of the dryer (yr.)                    | 10                                                                   |
| Cost of purchasing mango pulp per kg (Ksh)     | 90                                                                   |
| Selling price of dried mango leather per kg(Ksh)| 1200                                                              |

Table 3. Capital cost of RWD system

| Assembly Description                              | QTY | Unit COST (KSH) | Total Cost   |
|--------------------------------------------------|-----|-----------------|--------------|
| Air systems (Blower and Hood Assembly)           | 1   | 147,500.00      | 147,500.00   |
| Water Assembly                                   | 3   | 180,000.00      | 540,000.00   |
| Drive (Assembly, Rollers, Motor, Sprocket, Mylar and Adjusters) | 1   | 409,000.00      | 409,000.00   |
| Tray and Hopper (feeding and product removal)    | 1   | 130,000.00      | 130,000.00   |
| Frame Sub-Assembly                               | 2   | 90,000.00       | 180,000.00   |
| Fixtures (Switches, Cabling, Temp Controller and Fasteners) | 1   | 130,000.00      | 130,000.00   |
| Finishing (Polishing and Painting)               | 1   | 35,000.00       | 35,000.00    |
| Total                                            |     |                 | 1,571,500.00 |

Table 4. Cost of KIRDI RWD

| Details                                         | Amount (Ksh) |
|------------------------------------------------|--------------|
| Material cost                                  | 1,571,500.00 |
| Overheads                                      | 598,660.00   |
| Taxes and levies                               | 339,840.00   |
| Total                                          | 2,500,000.00 |

Table 5. Cost of operating RWD

| Operations                                | Cost (Ksh)/Operation |
|-------------------------------------------|----------------------|
| Salary for 2 persons                      | 480,000              |
| Maintenance cost                          | 50,000               |
| Water bill                                | 30,000               |
| Cost of Electricity                       | 42,000               |
| Total                                     | 602,000              |

3.2.7 Summary of the financial analysis

The financial analysis indicates that the project is viable. This is indicated by the positive and high Net Present Value (NPV) of 808223.515 at 24% as well as the high Internal Rate of Return (IRR) of 31% as indicated in appendix II. The IRR of 31 per cent compared to 24 per cent discount rate or cost of capital is quite high and would favour the project even when compared to other investments. The plant will recover initial investment within a period of 3 years and 7 months after which it will start earning for the owners. In the case of unforeseen constraints, this could shift to the next year in which case the investment would be covered within 5 years.
Table 6. Net Present value for food dehydration business using KIRDI RWD Dryer

| Year | Equipment cost (Ksh) | Net cash flows | Interest(i) | Present value Factor | Discounted Net cash flows |
|------|----------------------|----------------|-------------|----------------------|--------------------------|
| 0    | 2,500,000            | -2500000       | 24%         | 1                    | -2500000                 |
| 1    | 131,700              | 131,700        | 24%         | 0.8065               | 106216.05                |
| 2    | 484,500              | 484,500        | 24%         | 0.6504               | 315118.8                 |
| 3    | 1,148,100            | 1,148,100      | 24%         | 0.5245               | 602178.45                |
| 4    | 1,190,100            | 1,190,100      | 24%         | 0.423                | 503412.3                 |
| 5    | 1,232,100            | 1,232,100      | 24%         | 0.3411               | 420269.31                |
| 6    | 1,438,810            | 1,438,810      | 24%         | 0.2751               | 395816.631               |
| 7    | 1,449,310            | 1,449,310      | 24%         | 0.2218               | 321456.958               |
| 8    | 1,449,310            | 1,449,310      | 24%         | 0.1789               | 259281.559               |
| 9    | 1,491,310            | 1,491,310      | 24%         | 0.1443               | 215196.033               |
| 10   | 15,33,310            | 15,33,310      | 24%         | 0.1104               | 169277.424               |
| Total|                      |                |             |                      | 808223.515               |

Table 7. Payback period for entrepreneur investing in KIRDI-RWD

| Year | Cash Flow (Ksh) | Net Invested Cash (Ksh) |
|------|----------------|-------------------------|
| 0    | -2,500,000     |                         |
| 1    | +131,700       | -2,368,300              |
| 2    | +484,500       | -1,882,800              |
| 3    | +1,148,100     | -734,700                |
| 4    | +1,190,100     | 0                       |

Table 8. Internal Rate of return/NPV

| Item/Year | 0  | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 |
|-----------|----|----|----|----|----|----|----|----|----|----|----|
| Total revenue | 381.7 | 734.5 | 1,398 | 1,440 | 1,482 | 1,468 | 1,699 | 1,499 | 1,741 | 1,783 |
| Total cost incurred | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0|
| Net cash flows | 250,00 | 250,00 | 250,00 | 250,00 | 250,00 | 250,00 | 250,00 | 250,00 | 250,00 | 250,00 |
| Discounted factor | 0 | 3 | 5 | 5 | 5 | 1 | 1 | 1 | 8 | 9 | 3 |
| Discounted net cash flows | 1 | 0.806 | 0.650 | 0.524 | 0.423 | 0.341 | 0.275 | 0.221 | 0.178 | 0.144 | 0.110 |

Net present value @ 24% is 808223.5
Internal rate of return: 31%
Payback Period: 3.6 years

In the case of unforeseen constraints, this could shift to the next year in which case the investment would be covered within 5 years. The economic indicators’ values prove the viability of the case scenario where an SME can invest in owning and running RWD dryer as a business in the study area. The study results agree with studies by Adams, who worked on the financial feasibility of a mango-chip processing and small-scale meat production, respectively, in Ghana [20]. In their studies, the authors reported the economic viability of their case studies in Ghana, where there were similar trends in NPV and IRR for the operational period of the individual start-ups.
4. CONCLUSION AND RECOMMENDATION

The techno-economic performance of a 20kg capacity RWD prototype was successfully assessed. Mango at 86% was dried to a final moisture content of 15% within a period of one hour. The average drying rate recorded during the study was 71%/h. The economic feasibility of the drying unit was assessed to be viable for an MSME or an investor, however, the applicability of the economic analysis in its present form is restricted to the assumptions made. The economic analysis over a 10-year lifespan operation of the dryer resulted to a positive Net Present Value (NPV) as well as the high Internal Rate of Return (IRR), it is worth mentioning that economic analysis depended upon the parameters used in the calculations. Finally, the positive performance indicators provide confidence for scale-up and adoption of the KIRDI RWD prototype by micro, small and medium enterprises in Kenya. It is recommended that the entrepreneurs who will adopt this technology should target high-end market since the products produced by the unit were of high quality. In order to facilitate this adoption, awareness creation to the micro small and medium enterprises in the dehydration industry particularly those dealing with fruits and vegetable should be undertaken, and the knowledge of the technical and economic performance of KIRDI version for the RWD system explained.

ACKNOWLEDGEMENTS

First and foremost, the project team would like to thank God for the gift of life and for giving them strength throughout the entire study. We wish to acknowledge Kenya Industrial Research and Development Institute Board of Management for facilitating the project, we acknowledge Bio-innovate for availing funds to undertake the project. We also acknowledge Director KIRDI and his office for efficient coordination of the project. We appreciate Deputy Director of Research, Technology and innovation department for her endless support, guidance and continuous motivation throughout the whole research period. Also we are very thankful to all the respondents who participated to make this research possible. Lastly, we sincerely thank supportive colleagues in Engineering Development and Service Center.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Stathers T, Holcroft D, Kitinoja L, Mvumi BM, English A, et al. Ascoping review of interventions for crop postharvest loss reduction in Sub-Saharan Africa and South Asia. Nature Sustainability. 2020;3:821-835.
2. Affognon H, Mutungi C, Sanginga P, Borgemeister C. Unpacking postharvest losses in sub-Saharan Africa: a meta-analysis. World Dev. 2015;66:49-68.
3. Sugri I, Abubakari M, Owusu RK, Bidzakin JK. Postharvest losses and mitigation technologies: evidence from Upper East Region of Ghana. Elsevier’s Sustainable Futures. 2021;3:100048.
4. FAO. State of Food and Agriculture. Moving Forward on Food Loss and Waste Reduction; 2019. Retrieved: http://www.fao.org/3/ca6030en/ca6030en.pdf
5. Kimiywe J. Food and nutrition security: Challenges of post-harvest handling in Kenya. Proceedings of the Nutrition Society. 2015;74(4):487-495.
6. Kenya National Bureau of Statistics. Economic Survey. Nairobi: Government Printer; 2018.
7. Makinya KJ, Wagacha JM, Odhiambo JA, Likhayo P, et al. The importance of store hygiene for reducing post-harvest losses in smallholder farmers' stores: Evidence from a maize-based farming system in Kenya. Elsevier’s Journal of Stored Products Research. 2021;90:101757.
8. Mujuka E, Mburu J, Ogutu A, Ambuko J. Returns to investment in postharvest loss reduction technologies among mango farmers in Embu County, Kenya. Food and Energy Security. 2020;9:e195.
9. Gogo EO, Opiyo A, Ulrichs C, Huyskens-Keil S. Postharvest treatments of African Leafy Vegetables for food security in Kenya: A review. African Journal of Horticultural Science. 2016;9:32-40.
10. Gogo EO, Opiyo A, Ulrichs C, Huyskens-Keil S. Nutritional and economic postharvest loss analysis of African indigenous leafy vegetables along the supply chain in Kenya. Elsevier’s...
Postharvest Biology and Technology. 2017;130:39-47.

11. Bradford KJ, Dahal P, Asbrouck JV, Kunosoth K, Bello P, Thomson J, Wu F. The dry chain: reducing postharvest losses and improving food safety in humid climates. Food Industry Wastes (second edition). 2020;375-389.

12. Bolin HR, Salunkhe DK, Daryl Lund. Food dehydration by solar energy, C R C Critical Reviews in Food Science and Nutrition. 1982;16(4):327-354. DOI: 10.1080/10408398209527339

13. Ahmed N, Singh J, Chauhan H, Gupta P, Anjum A, Kour H. Different Drying Methods: Their Applications and Recent Advances. International Journal of Food Nutrition and Safety. 2013;4(1):34-42.

14. Sosnik, Alejandro & Seremeta, Katia. Advantages and challenges of an Ideal-drying technology. Advances in Colloid and Interface Science. 2015;223. DOI:10.1016/j.cis.2015.05.003.

15. Kocheri S, Shreyansh Consumption of fruits and vegetables: Global and Asian perspective. Technical report. Euromonitor International, London; 2015. Available: http://de.slideshare.net/Euromonitor/consumption-of-fruits-and-vegetables-global-and-asian-perspective

16. Aliyu AB, Jibril H. Utilization of greenhouse effect for solar drying of cassava chips. International Journal of Physical Sciences. 2009;4(11):615-622.

17. Ochoa-Martinez CI, Quintero PT, Ayala AA, Ortiz MJ. Drying characteristics of mango slices using the Refractance WindowTM technique. J. Food Eng. 2012;109(1):69–75. DOI:10.1016/j.jfoodeng.2011.09.032

18. Tontul E, Eroğlu A. Topuz Convective and refractance window drying of cornelian cherry pulp: Effect on physicochemical properties. J. Food Process Eng. 2018;41(8):e12917. DOI:10.1111/jfpe.12917

19. Nindo CI, Tang J. Refractance window dehydration technology: a novel contact drying method. Dry. Technol. 2007;25(1):37–48. DOI:10.1080/07373930701152673

20. Adams F, Amankwah K, Wongnai CA, Honny EP, Peters DK, et al. Financial Analysis of Small-Scale Mango Chips Processing in Ghana. Cogent Food Agric. 2019;5:1679701.

21. Brigham E, Houston J. Fundamentals of Financial management. Thomson South Western, Ohio, USA; 1998.

22. Baum WC, Tolbert SM. Investing in Development Lessons of World Bank Experience. Dev. South. Afr. 1986;3:199–218.

23. Kaur G, Saha S, Kumari K, Datta AK. Mango pulp drying by refractance window method. Agricultural Engineering International: CIGR Journal. 2017;19(4):145–151.

© 2021 Nyaguti et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle4.com/review-history/73645