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ECONOMIC ANALYSIS OF NSPRI PARABOLIC SHAPED SOLAR DRYER FOR TOMATO (*Solanum lycopersicum)* DRYING

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ABSTRACT
Tomato (*Solanum lycopersicum*) is a vital vegetable crop in Nigeria, notable for its high production and consumption levels. Rich in essential nutrients such as iron, phosphorus, beta-carotene, lycopene, and vitamins A and C, tomatoes offer significant health benefits. However, their short shelf life poses a considerable challenge to realizing their health and economic potential. Traditionally, sun drying has been the primary method employed by farmers for tomato preservation. However, this technique predisposes agricultural commodities to a lot of contaminants. Experimental research was conducted to evaluate the effectiveness and economic viability of the Parabolic Shaped Solar Dryer (PSSD), developed by the Nigerian Stored Products Research Institute (NSPRI). Four baskets of fresh tomatoes weighing 208kg were purchased from Yankaba Market, Kano, for the research. Over six days, the moisture content of the tomatoes was reduced from 96% (wet basis) to approximately 11.5%, compared to 12-14 days required for the open sun drying method to achieve similar moisture levels. The analysis revealed a life cycle cost of ₦23,578,194.33 and life cycle benefits of ₦27,585,909.08, resulting in a cost-benefit ratio of 1.17, indicating the PSSD's potential as a viable alternative to traditional drying methods. The net present value of ₦4,007,714.75 confirmed the economic feasibility of the system, while a moderate payback period of 5.69 years underscored its cost-effectiveness. The study concluded that investing in the NSPRI Parabolic Shaped Solar Dryer for tomato drying is both worthwhile and advantageous. Given the technology's viability and the significant initial investment required, NSPRI should focus on promoting it through farmers' organizations and cooperative groups to assist individual smallholder farmers in accessing it.
Keywords: Content, Dryer, Economic, Indicators and Moisture

INTRODUCTION
Tomato (*Solanum lycopersicum*) is one of the most important vegetable crops in terms of both production scale and consumption level (Abdul *et al.,* 2020). Nigeria is among the world's leading producers of tomatoes (ranked 16th), and also the leading producer among developing countries (Ugonna *et al*., 2015). The plant is a rich source of vitamins A and C, and also contains minerals like iron, and phosphorus, and is the richest source of nutrients, dietary fibers, antioxidants like lycopene and beta-carotene. Despite its contribution to poverty alleviation, the tomato industries are faced with a myriad of constraints along its value chain ranging from agronomic constraints like the incidence of pests and diseases and physiological disorders (cracking, sunburn, or scald); poor post-harvest technologies, which along with other factors such as short-shelf life has adversely affected the production, marketing and consumption pattern of quality tomatoes (Abdul *et al.*, 2020). This necessitates the search for technologies needed to extend the storage life, and value addition, and ensure proper packaging with ease of handling to the potential market, thereby harnessing its economic potential.

Drying is one of the techniques for extending the storage period and value addition with a concentrated form of nutrition (Incedayi *et al.*, 2016). Drying increases the longevity of produce and minimizes the space needed for storage, packaging, and transportation, which leads to cost savings. Nevertheless, many farmers focus exclusively on farming and find it difficult to invest in costly equipment for drying; instead, they rely on open drying under the

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sun. Sun drying involves simply laying the agricultural produce such as tomatoes in the sun on mats, roofs, or drying floors. This has several disadvantages since the farm produce is laid in the open sky and there is a greater risk of spoilage due to adverse climatic conditions like rain, wind, moist and dust; loss of produce to birds, insects, and rodents (pests); dependence on good weather; very slow drying rate with the danger of mold growth thereby causing deterioration and decomposition of the produce. The process also requires large areas of land, takes time, and is highly labor intensive.

Furthermore, it has been reported that drying consumes 6-30 times more energy than cooling and freezing (Machala *et al*., 2022). Given this, using fossil fuels to meet drying's heat demand will result in an enormous quantity of carbon emissions into the atmosphere (Ndukwu *et al.,* 2023). Hence, switching to clean energy sources from fossil fuel-based dryers is essential (Chowdhury *et al.,* 2020). Most countries are advocating for the transition from fossil energy-based dryers to renewable energy sources to safeguard the environment (Kumar *et al*., 2023). Solar drying is preferred for preserving fruit quality while protecting it from dust, dirt, and environmental organisms, all at minimal operational cost (Purohit *et al.,* 2006; Poonia *et al.,* 2017). Solar energy is readily accessible to rural farmers and offers both economic and environmental benefits (Sharma *et al.,* 2009). It has been demonstrated to be a superior option for processing high-value products such as tomatoes. Moreover, the drying system holds the potential to create employment opportunities in the local market. The economic evaluation of a business model for manufacturing solar drying technologies could also attract entrepreneurs (Singh et al. 2020). Therefore, this study aims to assess the economic potential of a parabolic-shaped solar dryer (PSSD) developed by the Nigerian Stored Products Research Institute (NSPRI) at Kano Station. The specific objectives are to; determine the moisture content of tomato before and after drying; assess the life cycle cost (LCC) and life cycle benefits (LCB) of the parabolic-shaped solar dryer for drying tomato; and lastly, determine the economic indicators (BCR, NPV & PBP) of parabolic shaped solar dryer for drying tomato.

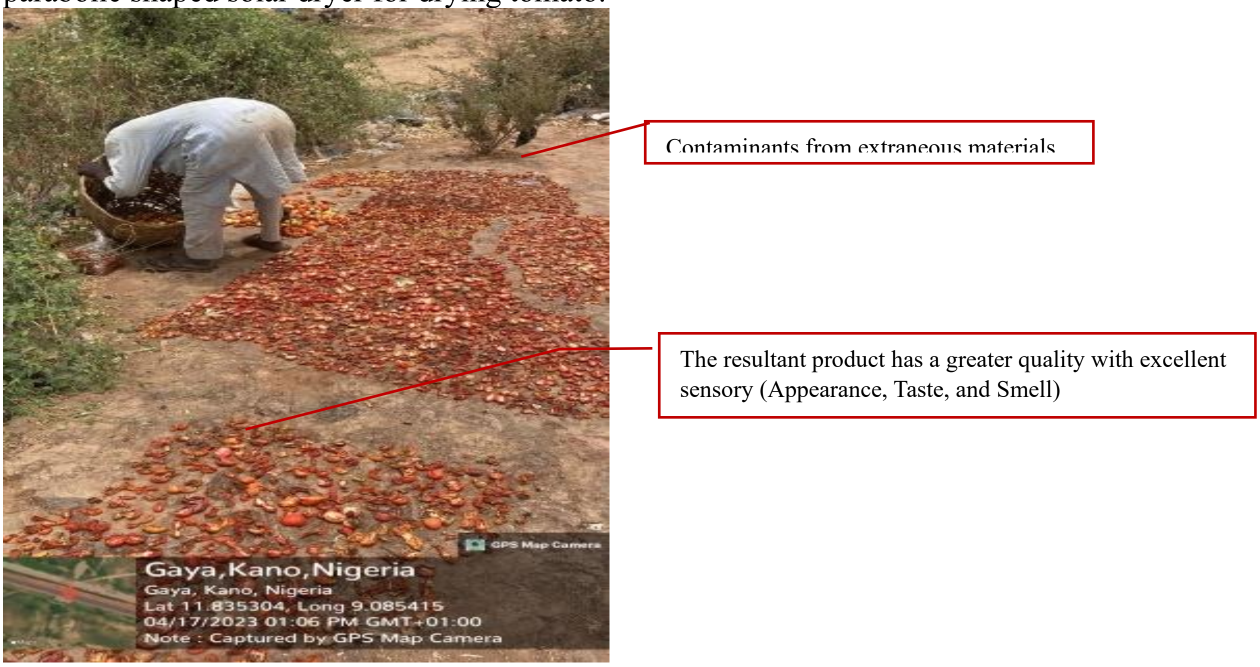

Figure 1: *Open Sun Drying*

Figure 2: *Parabolic-Shaped Solar Dryer (PSSD)*

MATERIALS AND METHODS

The Study Area

The study was carried out at the Nigerian Stored Products Research Institute, Kano Station, Kano State, Nigeria. The state is located between longitudes 7°45′E and 9°29′E and latitudes 10°33′N and 12°23′N. it covers an area of approximately 21,276.872 km², with 1,754,200 hectares of agricultural land (Abaje *et al*., 2014). The climate is characterized by a tropical wet and dry pattern, influenced by the movement of the Inter-Tropical Discontinuity (ITD), resulting in two distinct seasons: a wet season from May to mid-October, with high humidity levels peaking in August, and a dry season from mid-October to mid-May, humidity levels drop sharply particularly during Harmattan, when dust winds from Sahara reduce atmospheric moisture. The state experiences an annual rainfall between 800 mm and 900 mm, with an average temperature of around 26°C (Abaje *et al*., 2014).

Sample Collection and Preparation

The experimental research was initiated with the purchase of four baskets of fresh tomatoes weighing 208kg from Yankaba Market, Hadeija Road, Kano, Nigeria. Eka variety was chosen because ‘’Eka” has developed commercial tomato varieties that can outperform other varieties in terms of yield, disease resistance, and quality, with wide adaptability at different locations and also have excellent sensory characteristics in terms of taste, smell, appearance, and general acceptability after drying. The four baskets of the Eka varieties were transported to the Nigerian Stored Products Research Institute’s processing center where they were sorted, washed, drained, and sliced with knives to a thickness of 10mm and weighed 139.25 kg (Table 1). The drying experiments were conducted during the year 2022.

Parabolic Shaped Solar Dryer (PSSD)

NSPRI has developed various Parabolic Shaped Solar dryers in dimensions. This PSSD is 26ft x18ft with an effective drying area of 22ft x14ft as depicted in (Figure 2). The frame supports are made of steel which had been shaped into a parabola of height 7.5 ft. It has two steel drying racks comprising 28 trays with an effective drying space of 112 ft. The floor of the PSSD is a concrete floor sandwiched with polyurethane to avoid a heat sink. The concrete floor is tiled with glazed black tile which was painted with food-grade black enamel paint. The transparent material is made of a 2mm thick acrylic material with the trademark name Perspex. The Perspex sheet was laid on the parabolic frame support and fixed with bolts and nuts. The top of the PSSD is also installed with 2 units of pneumatic extractor fans of diameter 18” to aspirate the moisture being driven out by the hot air from the products undergoing the drying process.

Economic Analysis Methods

Machala *et al*. (2022) have raised concerns about the economic benefits of individual smallholder ownership of solar driers, considering the capital investment involved. The situation's obvious explanation is the economics of scale, where the capital input does not change linearly with capacity. Thus, the installation cost, cost of manufacturing, operational cost, and efficiency of the solar dryer become major constraints for farmers in solar dryer ownerships in several countries (Machala *et al*., 2022).

The economic analysis of the current parabolic-shaped solar dryer was conducted by calculating its life cycle cost (LCC) and life cycle benefit (LCB). In addition, three economic indicators—benefit-cost ratio (BCR), net present value (NPV), and payback period (PBP)—were assessed to determine the economic feasibility of the parabolic-shaped solar dryer at a discount or interest rate of 15.5% and inflation rate of 18.8% over 15 years.

Life Cycle Cost (LCC)

Life Cycle Cost (LCC) encompasses the total expenses associated with owning, operating, maintaining, and eventually disposing of an asset throughout its entire lifespan. This includes all costs from initial acquisition to final disposal.

Benefits of LCC:

Informed Decision-Making: LCC provides a comprehensive view of the total cost of ownership, aiding in better decision-making when comparing alternatives.

Long-Term Savings: By considering long-term costs, organizations can opt for choices that may have higher initial costs but lower operating and maintenance expenses.

Risk Management: Understanding LCC helps in identifying potential financial risks, such as high maintenance costs, and allows for effective planning.

Life Cycle Benefits (LCB)

Life Cycle Benefits (LCB) refer to the total value or advantages derived from an asset over its entire life. This includes not only direct financial returns but also environmental, social, and strategic benefits.

Benefits of LCB:

Holistic Value Assessment: LCB helps in understanding the full range of benefits an asset provides, extending beyond just financial returns.

Enhanced Decision-Making: By evaluating both the costs (LCC) and benefits (LCB), organizations can make more balanced and informed investment decisions.

When making investment decisions, it is crucial to consider both LCC and LCB. While LCC focuses on the total costs, LCB emphasizes the total benefits. An integrated approach allows for a comprehensive evaluation, ensuring that investments are not only cost-effective but also deliver the greatest overall value across their life cycle.

Economic Indicators

Benefit-Cost Ratio (BCR)

BCR is the ratio of the present value of the benefits to the present value of the costs. For a project to be viable, the BCR must exceed one; if so, the investment in the solar dryer can be deemed economically viable (Poonia *et al.*, 2021; Jain *et al.*, 2022). Researchers use the benefit-cost ratio (BCR) to compare the overall benefit of a solar dryer to the project's relative cost in monetary or qualitative terms (Kiburi *et al.,* 2020). The closer the BCR is to 1.0, the more likely the solar dryer will deliver positive returns; otherwise, if the BCR is less than 1.0, the capital investment outweighs the benefits. It is expressed as the ratio of discounted benefits to the discounted costs, calculated as LCB/LCC.

Net Present Value (NPV)

NPV represents the difference between the present value of the benefits and the present value of the costs (Zamalloa *et al.,* 2011). It is used to determine whether a project is worth investing in because it takes into account the time value of money (Gallo, 2014). The decision rule is that if the NPV is positive, the investment in the parabolic shaped solar dryer is considered economically viable, while investment in the parabolic shaped solar dryer with a negative NPV will result in financial losses and may not be made. It is the total of all discounted net benefits throughout the project's life, given as LCB - LCC.

Payback Period (PB)

The payback period is the amount of time required to recover the cost of the initial investment. The time required for the net benefits to cover the cost of capital investments (n for LCB - LCC = 0).

RESULTS AND DISCUSSION

Moisture Content Determination and Drying of Sliced Tomato

The initial moisture content of the fresh tomato was determined to be 96% (wet basis) using the oven method. The sliced tomato was sprayed on the 28 trays and put in the drying chamber of the PSSD to dry appropriately as seen in Figure 2. It was left to dry to a safe moisture content of 11.5 % (wb) and a final weight of 7.2 kg (Table 1) after six (6) days of processing cycle. Table 1 indicates the parameters used to estimate the potential economic returns associated with this parabolic-shaped solar drying technology.

Table 1: Full Load Capacity of the PSSD per Cycle

s/n	Tomato	Before Drying	After Drying
1	Variety	EKA	
2	Weight of four baskets of fresh tomatoes after purchase	208 kg	
3	Price of the market value of a fresh basket of tomato	₦ 3, 500	
4	Weight after sorting & slicing	139.25 kg	7.2 kg
5	Total number of mudu		12 Mudu
6	The market value of the unit (mudu) production of dried tomato		₦ 2, 000
7	Weight of dried tomato per mudu		0.6 kg

Source: Experimental Research (2022)

Costs and Revenue Structure

The result of the economic analysis of the parabolic-shaped solar dryer for the drying of tomatoes for 1 year is presented in Table 2 below. It reveals that the total production return per annum from the investment for the period under study was ₦1, 440 00. A total variable cost of ₦1,086, 000 was incurred on the purchase, logistics, and management cost of processing of tomato.

Table 2: Costs and Revenue Structure

S/n	Variable	Item	Price (₦)
1	**Fixed Inputs**	PSSD	1, 700, 500
		Land	42,000
		PSSD UV-Cover maintenance	42, 000
		Utensils (bowl, knives, trays, etc)	2, 000
	TFC		**1, 994, 500**
2	**Variable Inputs**	Tomatoes per annum (60 cycles)	840, 000
		Labor /Management cost (60 cycles)	144, 000
		Water (60 cycles)	12, 000
		Loading/offloading (60 cycles)	30, 000
		Transportation (60 cycles)	60, 000
	TVC		**1, 086, 000**
3	**Revenue**	Production returns of dried tomatoes (60 cycles)	1, 440, 000
	TR		**1, 440 000**

Source: Experimental Research (2022) **Note:** Assumed that fixed capital will be potentially operational for 15 years

Determination of Life Cycle Cost (LCC)

The life cycle cost (LCC) of the parabolic-shaped solar dryer includes all costs associated with the solar drying system over its lifespan, considering its present monetary value and accounting for the time value of money. The initial investment (Pi) for the dryer unit is ₦1950,500, as shown in Table 2. The annual operation and maintenance (O&M) costs (P_w), including labor, are estimated at ₦1,130,000 and n, be the life of the dryer in (years). The salvage value is considered to be 10% of the initial investment. Following the procedure of life cycle cost estimation adopted by (Poonia, Singh, Santra, and Jain, 2019), the LCC is calculated as:

LCC (Unit)= Initial cost of unit (Pi)+Pw(O & M Costs including labour)–Pw(SV) …(1)

$$\text{LCC} = \text{Pi} + \text{Pw}\frac{X(1-X^n)}{1-X} - \text{SV}(1+i)^{-n} \quad \ldots(2)$$

Substituting the values:

$$\text{LCC} = 1{,}950{,}500 + 1{,}130{,}000\frac{1.03(1-1.03^{15})}{1-1.03} - 170{,}050(1+0.155)^{-15}$$

Where n=15years; e = annual escalation in cost (in fraction); i = interest or discount rate (in fraction)

$X = \frac{1+e}{1+i}$, e=0.188, i=0.155

$X= \frac{1+0.188}{1+0.155} == \frac{1.188}{1.155} = 1.03$

LCC=₦23,578,194.33

Determination of Life Cycle Benefits (LCB)

The annual benefit(R) was determined through sixty (60) production cycles per year for Tomato. Approximately ₦840,000 worth of fresh tomatoes were dried, yielding ₦1,440,000 worth of dried product.

The LCB is given as: $\text{LCB} = \text{R}\frac{X(1-X^n)}{1-X}$ …(3)

Where R = annual benefit (₦) and $X = \frac{1+e}{1+i}$

. $\text{LCB} = \text{R}\frac{X(1-X^n)}{1-X} = 1{,}440{,}000\frac{1.03(1-1.03^{15})}{1-1.03}$

LCB= ₦27,585,909.08

Determination of Economic Indicators

(i) **BCR:** The benefit-cost ratio is calculated as:

Benefit-cost ratio (BCR) $= \frac{\text{Life cycle benefit of Parabolic shaped solar dryer}}{\text{Life cycle cost of Parabolic shaped solar dryer}}$ …(4)

Benefit-cost ratio (BCR) $= \frac{\text{LCB}}{\text{LCC}} = \frac{₦27{,}585{,}909.08}{₦23{,}578{,}194.33} = 1.17$

(ii) **NPV:** Calculated as LCB - LCC = ₦27,585,909.08-₦23,578,194.33

NPV=4,007,714.75

(iii) **PBP:** The pay-back period can be determined as follows: -LCC + LCB = 0 for n=payback period

$$1{,}950{,}500 + 1{,}130{,}000\frac{1.03(1-1.03^n)}{1-1.03} = 1{,}440{,}000\frac{1.03(1-1.03^n)}{1-1.03}$$

$$1{,}950{,}500 = 310{,}000\frac{1.03(1-1.03^n)}{1-1.03}$$

$$\frac{1{,}950{,}500(-0.03)}{310{,}000(1.03)} = 1 - 1.03^n$$

$$1.03^n = 1 - \frac{1{,}950{,}500(-0.03)}{310{,}000(1.03)}$$

$$1.03^n = 1 + \frac{1{,}950{,}500(0.03)}{310{,}000(1.03)}$$

$1.03^n = 1.183$

$\text{Log}(1.03^n) = \text{Log}(1.183)$

$\text{n} = 5.69\text{years}$

$\text{Hence, the Payback period} = 5.69\text{years}$

The values for the three economic indicators benefit-cost ratio (BCR), net present worth (NPW), and payback period (PBP) are presented in [Table 3]. The results indicate that the investment has a benefit-cost ratio of 1.17, meaning that for every ₦1 spent, there is a net benefit of 17 kobo. This positive BCR suggests that the benefits surpass the costs, making the investment worthwhile. Additionally, the NPV shows that the project is viable, with a positive Net Present Value of ₦4,007,714.75 over the 15-year duration of the business. Furthermore, the analysis reveals that the Payback Period (PBP) for drying tomatoes using the PSSD is 5 years and 8 months, indicating the time required for the investor to recover their initial investment.

Table 3: Summary of Economic Indicators

Economic indicators	Values
BCR	1.17
NPV	₦4,007,714.75
PBP	5years 8months

Source: Author's Computation, 2022.

CONCLUSION AND RECOMMENDATIONS

The experiment demonstrated that over a six-day period, the moisture content of the tomatoes decreased from 96% (wet basis) to approximately 11.5%. Additionally, the economic assessment of the parabolic-shaped solar dryer indicated a benefit-cost ratio (BCR) of ₦1.17, a net present value (NPV) of ₦4,007,714.75, and a reasonable payback period of 5.69 years, highlighting the dryer's cost-effectiveness. The parabolic-shaped solar dryer significantly reduces drying time and energy consumption while enhancing the quality of dried tomato products. Implementing these dryers in rural areas can substantially decrease post-harvest losses, promote value addition, reduce pollution, and greatly benefit farmers in developing countries. Therefore, the economic analysis confirms that investing in the NSPRI Parabolic Shaped Solar Dryer for tomato drying is both worthwhile and advantageous. In light of the technology's viability and the substantial initial capital investment needed, which may hinder individual smallholder farmers from obtaining it, NSPRI should prioritize the promotion of this technology through farmers' organizations and cooperative groups.

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