

THESIS

MARKET ACCESS THROUGH INNOVATION: THE CASE FOR DRIED WATERMELON IN
MALAWI

Submitted by

Brooke E. Banning

Agricultural and Resource Economics

In partial fulfillment of the requirements

For the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

Spring 2025

Master's Committee:

Advisor: Nicholas Magnan

Marco Costanigro

Jessica Davis

Copyright by Brooke E. Banning 2025

All Rights Reserved

ABSTRACT

MARKET ACCESS THROUGH INNOVATION: THE CASE FOR DRIED WATERMELON IN MALAWI

Farmers in Malawi face the dual challenges of low income and substantial post-harvest losses. Drying fruit offers a viable solution by preserving produce that would otherwise be wasted and allowing farmers to access high-value markets. However, no existing literature examines the demand for dried fruits in Malawi or the profitability of selling them domestically. This study investigates the feasibility of drying watermelon as a value-added product and assesses consumer willingness to pay (WTP) in Lilongwe, Malawi. A multiple price listing mechanism was used to elicit WTP for both solar- and electric-dried watermelon, along with a cost-benefit analysis comparing the two drying methods. The findings indicate that, while dried watermelon is unfamiliar to Malawian consumers, there is considerable demand. According to findings only electric dried watermelon is profitable at mean WTP.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my advisor, Dr. Nick Magnan, for his incredible support and guidance throughout this project—and for having the faith to send a student he had just met to Malawi.

Thank you as well to my committee members, Dr. Marco Costanigro and Dr. Jessica Davis. Your thoughtful feedback not only strengthened this paper but also made me a better researcher.

I am especially grateful to Madelon Kempenaar for making my integration in Malawi seamless, for showing me the ropes, and for being both a wonderful colleague and a great friend. Thank you to Tim Van der Linden for welcoming me so warmly to aQysta and for filling my days there with laughter and encouragement. The entire aQysta team provided unparalleled support during my fieldwork and played a crucial role in ensuring the research went smoothly.

A heartfelt thank you to my amazing enumerators—Nubile Melinda Chitsulo, Ulemu Munthali, Shah Chiwaya, and Richard Lupiya—without whom this experiment would not have been possible. I also deeply appreciate Dr. Kingsley Masamba and Agnes Mwangwela for connecting me with the enumerators and offering their guidance during my time in Malawi.

Lastly, thank you to my family and friends for their unwavering support and for always being just a phone call away when I needed them most.

TABLE OF CONTENTS

ABSTRACT	ii
ACKNOWLEDGEMENTS	iii
LIST OF TABLES	v
LIST OF FIGURES	vi
Chapter 1 Introduction	1
Chapter 2 Background	5
2.1 Economic Conditions	5
2.2 Agriculture Production in Malawi	6
Chapter 3 Methods	7
3.1 Consumer Survey & WTP Elicitation	7
3.1.1 Consumer Survey	7
3.1.2 Willingness to Pay Elicitation	8
3.2 Cost-Benefit Analysis	10
Chapter 4 Data and Results	13
4.1 Descriptive Statistics	13
4.2 Consumer Survey	15
4.3 Willingness to Pay	17
4.4 Cost-Benefit Analysis	19
Chapter 5 Discussion	21
5.1 Break-Even Analyses	21
5.2 Sensitivity Analyses	22
5.3 Limitations	26

LIST OF TABLES

4.1	Summary Statistics for Respondents Socio-Demographic Variables	14
4.2	Summary Statistics for Respondents Consumption Habits	15
4.3	Most Preferred Dried Fruit	16
4.4	Ranking Order	16
4.5	Summary Statistics for WTP, Random Draw, and Given Away	18
4.6	Variable Costs of Solar and Electric Drying Per Bag	20
4.7	Mean WTP, Costs, and Profits	20
5.1	Electric Price Elasticity and Bags and Shoppers Needed to Break-Even	23
5.2	Solar Price Elasticity and Bags and Shoppers needed to Break-Even	23

LIST OF FIGURES

2.1	Share of Population Below the National Poverty Line [1]	5
3.1	Multiple Price Listings – Ascending	10
3.2	Multiple Price Listings – Descending	10
4.1	Enjoyment Ratings	17
4.2	Enjoyment Ratings	18
4.3	Percentages of TVC	20
5.1	Required Package Sales to Break Even on Dryer Costs	22
5.2	Sensitivity Analysis of Profit at Various Whole Fruit Prices	24
5.3	Sensitivity Analysis of Profit at Various Packaging Prices	25

Chapter 1

Introduction

Farmers in many developing countries face the dual challenges of low incomes and substantial post-harvest losses. Since agriculture often forms the backbone of these economies, such obstacles can severely impact rural livelihoods and threaten food security [2]. Malawi, a small landlocked country in southeastern Africa, is one such nation. Agriculture accounts for approximately a quarter of the Gross Domestic Product (GDP), with 80% of residents employed in the sector [3, 4]. Despite this dependence on agriculture, 59% of small-holder farmers live below the national poverty line [5]. Although numerous factors influence farmers' income, low earnings are often attributed to small landholdings, low productivity, reliance on rainfed agriculture, and limited market access [6, 7, 8]. Post-harvest losses (PHL) in Malawi are estimated to exceed 60%, primarily due to perishability and lack of effective processing methods [9]. Furthermore, limited access to formal markets, poor transportation and marketing infrastructure, and insufficient storage facilities weaken market connectivity and contribute to high PHL [10]. These challenges are especially pronounced for fruit, as these products are typically heavy, fragile, and highly perishable.

Processing presents a promising strategy for increasing farmer income in developing countries by addressing PHL and facilitating access to high-value and export markets. Most PHL occurs between harvest and the point at which the product reaches consumers [11]. Drying, in particular, allows farmers to convert surplus produce into value-added products, enhancing their marketability and generating essential rural employment opportunities [12, 13]. Electric drying, which may rely on fossil fuel or solar photovoltaic inputs, often requires substantial capital investment, a reliable grid connection, and adequate infrastructure, making it feasible only in specific contexts. Solar thermal dryers, on the other hand, offer a less energy-intensive alternative, providing a more accessible solution for rural and developing communities [14]. However, there are variations in food attributes depending on the drying technology used. Electric dryers offer precise temperature control, resulting in crisper and more consistent products. In contrast, solar thermal dryers rely

on external temperatures and sunshine, leading to frequent fluctuations. As a result, the processes takes longer and resulting products tend to be chewier and have unavoidable inconsistencies.

Consumption of dried fruit is uncommon in Malawi and the high cost of available products makes them inaccessible to most consumers. However, urban residents have greater purchasing power and are more likely to shop in formal retail environments where luxury goods and dried fruits are available. Local demand for dried fruit remains uncertain, and while exporting offers a potential opportunity, its feasibility is limited by high transportation costs and stringent international food safety regulations.

This paper addresses the following research questions: What is the willingness to pay (WTP) for electric and solar thermal dried watermelon in Malawi? Is there sufficient demand to sell these products profitably in formal Malawian markets? How do electric and solar thermal drying methods influence consumer preferences and profitability? Addressing these questions will offer valuable insight into the market potential for dried watermelon in Malawi and, if successful, provide a pathway to increase farmer incomes by mitigating post-harvest losses and enabling access to high-value markets. We chose watermelon for this study due to its seasonal availability during the research period, the uniqueness of the dried product, and its quick return timeline for farmers. Unlike most fruits grown in Malawi, which are tree-based and require long growth periods, farmers can harvest watermelon three months after planting [15].

To address these questions, we conduct a survey outside three major grocery stores in Lilongwe, Malawi. The survey includes taste tests of dried watermelon and dried mango samples, collects essential organoleptic feedback, and records participants' consumption habits and demographic information. Additionally, we use a multiple price list (MPL) experimental auction to elicit WTP for electric and solar dried watermelon. We find no strong consumer preference between the two resulting products. WTP for electric dried watermelon was only slightly higher than that for solar dried, with mean values of 2,727.46 MWK (USD 1.57) and 2,233.33 MWK (USD 1.29), respectively.

In addition, we carefully quantify all variable production costs and conduct a cost-benefit analysis to assess whether local demand is sufficient to cover these expenses. Variable costs include the price of fresh fruit, labor for preparation and drying, packaging materials, and electricity where applicable. The most significant cost driver is the price of fresh fruit, which can be reduced by sourcing watermelons directly from farmers. When analyzing variable costs per bag and using mean WTP, only electric drying yields a profit—generating 269.48 MWK (USD 0.16) per bag. However, at this profit margin, recovering the capital investment for the electric dryer remains unfeasible.

Previous literature shows solar drying as a sustainable and economically viable solution for preserving fruits and vegetables in developing countries, where access to fuel and reliable electricity is limited. Solar drying reduces PHL and increases the market value of goods by 29-200% [16]. However, it is essential to note that dried watermelon yields significantly less than other fruits due to its high moisture content. Solar drying reduces the risk of microorganism growth and can be a valuable tool to extend shelf life and maintain nutritional value [17]. In Ethiopia, another East African country with high PHL, solar drying has been proposed to improve shelf life and increase employment opportunities [18]. Although solar dryers offer potential benefits for developing countries, more research is needed to evaluate their effectiveness and cost-effectiveness in real world applications.

Although dried watermelon has yet to be commercially available on a large scale, existing literature examines drying as a method to maintain nutritional value and extend shelf life. Various techniques for drying watermelon have been studied, including freeze drying, hot air drying, and foam-mat drying. Freeze drying preserves more nutrients and antinutrients compared to hot air drying [19]. Foam mat drying at 60-70° C retains high levels of vitamin C and antioxidants in watermelon flakes [20]. Dried watermelon products maintain beneficial compounds such as vitamin C, dietary fiber, and citrulline, which offer antioxidant effects [19]. In general, these drying techniques effectively preserve watermelon while retaining its nutritional qualities, making it a viable option to reduce waste and extend product availability.

The current literature examines consumer preferences and WTP for dried fruits in various countries. In Pakistan, factors such as gender, education, income, and health awareness influence WTP for dried mangoes [21]. Similarly, Italian millennials showed a higher WTP for dried fruits based on novelty, convenience, and emotional aspects, with income and education playing a significant role [22]. European consumers, particularly in Norway, demonstrate preferences for specific sensory characteristics and were willing to pay premiums for organic and fair-trade dried fruits [23]. In Turkey, sensory characteristics affect the acceptance of dried tropical fruits, with taste improvements and health promotion suggested to increase demand [24].

The existing literature shows that WTP elicitation is a powerful tool that can be used in developing contexts despite challenges. The Becker-DeGroot-Marschak mechanism, multiple price lists, multiple price lists with stated quantities, and real choice experiments give similar results in traditional African markets and are easy to explain, quick to perform, and survey a single participant at a time [25]. Multiple price listings (MPL) are expressly noted for their simplicity and robust valuations, but can lead to biases from framing and ordering effects [26]. However, different methods exist to counteract these biases [27]. Under these recommendations, we varied the order of binary choices (ascending and descending cash amounts) within the MPL and modeled each binary choice with a latent utility model, applying an appropriately scaled random-effects probit estimation for WTP.

This paper makes two key contributions to the existing literature. First, it is the only study to compare the real-world applicability and cost effectiveness of electric and solar thermal drying methods. Second, it is one of the first studies to employ a multiple price listing method to estimate demand for novel foods in Africa. This assessment provides valuable information on local acceptance and demand for a new high-value product.

Chapter 2

Background

2.1 Economic Conditions

Malawi is one of the poorest countries in the world, with over 70% of its population living below the international poverty line [28].¹ Figure 2.1 shows 52% of Malawians fall below the national poverty line, with rural populations facing greater vulnerability at 60% [1].² In contrast, urban areas exhibit significantly lower poverty rates, with only 18% of residents falling below the national poverty line [1]. This disparity highlights the potential for urban consumers to drive demand for locally produced agricultural goods, particularly those sourced from rural communities.

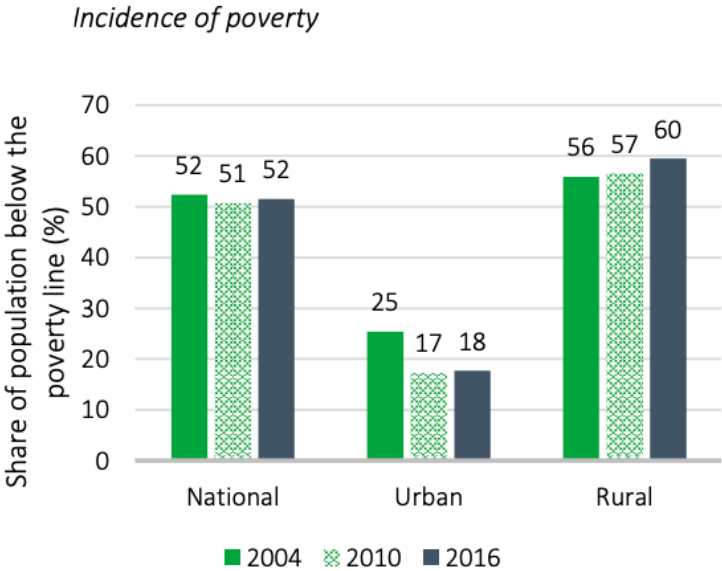


Figure 2.1: Share of Population Below the National Poverty Line [1]

¹The international poverty line is defined by the World Bank as \$2.15 per person per day at 2017 purchasing power adjusted prices [28].

²The national poverty line is defined by the Malawian government as 164,191 MWK (\$94.75) per person annually in January 2017 values, or approximately \$0.26 per person per day [1].

2.2 Agriculture Production in Malawi

Agriculture is the backbone of Malawi's economy, contributing more than a quarter to GDP [3]. An estimated 94% of rural residents engage in agriculture, with most operating on less than one hectare of land [29]. Many rural Malawians rely on subsistence farming to feed their families [30]. This type of farming includes smallholder farmers cultivating small plots to produce food primarily for household consumption rather than for commercial sale. Although tobacco, dried legumes, sugar and tea are Malawi's main cash crops, Fatch et al. proposes agricultural diversification as a way to increase farmer income, create employment opportunities, alleviate poverty and promote conservation of natural resources [3, 31]. Malawi produces an estimated 75,000 metric tons of fruit annually, with 37.3% of farmers cultivating mangoes and 11.6% bananas [9, 32]. Discussions with local agricultural specialists revealed that farmers generally have at least one fruit tree on their plots, be it mango, banana, or papaya.³

A significant portion of the watermelon sold in Malawi is imported from South Africa. However, local watermelon production offers unique advantages. As a non-tree fruit, watermelon can be harvested approximately three months after planting and generally commands a higher market price than mangoes or bananas [15]. Its low production rates in Malawi are largely attributed to the high cost of seeds and the need for irrigation. aQysta, a social enterprise collaborating on this project, operates under a loan model that supplies seeds and irrigation on credit, allowing farmers to repay with their harvest. This approach makes watermelon cultivation more accessible to farmers. aQysta, originally focused on irrigation, has since expanded to dry fruit production, with watermelon emerging as a promising product. Their primary goal is to provide income stream diversification to smallholder farmers by connecting them to markets. Watermelon shows promise as a dried fruit product primarily due to its novelty and potential as a healthy snack option. As a relatively uncommon dried fruit, it offers a unique alternative to traditional dried snacks like mangoes and bananas, which could attract consumers seeking new flavors.

³Personal communication with Tim Van der Linden, June 2024

Chapter 3

Methods

3.1 Consumer Survey & WTP Elicitation

We provided samples and conducted a survey in conjunction with an experimental auction to assess consumer preferences and WTP for dried watermelon. In addition, we collected data on the demographics and consumption habits. We administered the study over four weeks outside of three local grocery stores: Chipiku Game, Chipuku City Center, and Kanengo Food Lovers. These locations sell non-essential and value-added products, such as dried fruit snack mixes, bakery items, and imported goods. Although this sampling approach captures the preferences and WTP of only a segment of Malawi's population, urban shoppers in these locations are more likely to frequent formal markets and have sufficient disposable income to afford non-essential goods. Given that urban residents experience lower poverty rates, we hypothesize that this group will drive initial demand, ultimately enabling farmers to diversify their revenue streams.

3.1.1 Consumer Survey

Four enumerators from Lilongwe University of Agriculture and Natural Resources administered the survey, allowing it to be conducted in both English and Chichewa. The survey began with taste tests of three dried fruit samples: dried mango, electric dried watermelon, and solar dried watermelon. The dried mango served as a reference point, as it is a familiar product commonly found on supermarket shelves in Lilongwe, helping respondents contextualize their preferences for dried watermelon. After the taste test, respondents ranked the samples from most to least preferred and answered questions about key food attributes such as size, color, thickness, sweetness, and texture. This feedback provided aQysta with valuable consumer insights to refine drying techniques and processing methods in accordance with consumer preferences. Finally, survey enumerators collected data on respondents' consumption habits and demographics.

3.1.2 Willingness to Pay Elicitation

The survey concluded with a MPL exercise designed to elicit respondents' WTP for their preferred type of dried watermelon. We employ a random-effects probit model grounded in a latent utility framework to estimate WTP from the MPL data. Each MPL task presents respondents with a series of binary choices between a 50g bag of dried watermelon and a cash amount that varies across rows. These repeated choices allow us to model the unobserved (latent) utility difference that drives individual decision-making while accounting for individual-specific preference heterogeneity and choice-specific error.

Formally, let $y_{it} = 1$ if respondent i chooses dried watermelon in choice t , and $y_{it} = 0$ if they choose cash. The respondent selects dried watermelon when their latent utility from the good exceeds the utility from the cash alternative:

$$y_{it} = \begin{cases} 1 & \text{if } U_i^{\text{DW}} + \epsilon_{it}^{\text{DW}} > U_i^{\text{Cash}} + \epsilon_{it}^{\text{Cash}} \\ 0 & \text{otherwise} \end{cases}$$

Rewriting this as a function of the latent utility difference, the observed choice y_{it} equals 1 if the net benefit from selecting dried watermelon exceeds some unobserved error term:

$$y_{it} = \begin{cases} 1 & \text{if } \text{WTP}_i + \Delta_t + b_{m(t)} + s_{m(t)} > \epsilon_{it} \\ 0 & \text{otherwise} \end{cases}$$

where:

- $\text{WTP}_i = \alpha + u_i$ is the individual-specific willingness to pay, decomposed into a population mean α and a respondent-level random effect $u_i \sim \mathcal{N}(0, \sigma_u^2)$,
- $\Delta_t = v_t^{\text{DW}} - v_t^{\text{Cash}}$ is the monetary difference between the dried watermelon and cash options in row t ,
- $b_{m(t)}$ captures order bias from ascending versus descending MPL framing,

- $s_{m(t)}$ captures position effects within each binary choice (e.g., left/right ordering),
- $\varepsilon_{it} \sim \mathcal{N}(0, 1)$ is the idiosyncratic choice error, normalized for identification.

For identification, we normalize $\sigma_\varepsilon^2 = 1$ and estimate the model using maximum likelihood via a random-effects probit estimator. This approach allows us to recover:

- the mean willingness to pay α ,
- the dispersion in WTP across individuals, σ_u ,
- and the presence and magnitude of order or framing biases through $b_{m(t)}$ and $s_{m(t)}$.

Available dried fruit in Lilongwe grocery stores averages 1,825 MWK per 50g (\$1.05), with prices varying between dried mango, pineapple, banana and plantains. The lowest recorded price for a 50g bag of dried fruit was 291 MWK (\$0.17), while the highest was 3,750 MWK (\$2.16). These data informed the minimum and maximum values used in the MPL exercise. Although we did not find dried watermelon available in Lilongwe, it is sold online and in stores in the US, primarily through Etsy, Walmart, and Trader Joe's. The prices of a 50g bag vary significantly, ranging from 1,852 MWK (\$1.07) to 33,740 MWK (\$19.47).

Figure 3.1 and 3.2 present the MPLs in ascending and descending order, which was picked at random randomized for each respondent to minimize potential bias from framing effects. The MPL began at 250 MWK (\$0.14) or 5,000 MWK (\$2.89) and then increased or decreased incrementally. The primary objective was to determine the price point at which the respondents switched their preference between dried watermelon and cash, providing an upper bound estimate of their WTP. Upon completion of the MPL exercise, the enumerators conducted a random draw with potential values that matched the cash amounts presented during the exercise. If a respondent had chosen dried watermelon at the drawn value, they received a 50g bag of dried watermelon; if they had preferred cash, they were given the corresponding amount. Providing a cash intensive at the end of the experiment helped prevent participants from underquoting their true WTP.

Would you prefer a 50g bag of dried watermelon, or would you prefer _____ MWK?

	50g Bag of Dried Watermelon	Cash Amount
250	<input type="radio"/>	<input type="radio"/>
500	<input type="radio"/>	<input type="radio"/>
1000	<input type="radio"/>	<input type="radio"/>
1500	<input type="radio"/>	<input type="radio"/>
2000	<input type="radio"/>	<input type="radio"/>
2500	<input type="radio"/>	<input type="radio"/>
3000	<input type="radio"/>	<input type="radio"/>
3500	<input type="radio"/>	<input type="radio"/>
4000	<input type="radio"/>	<input type="radio"/>
4500	<input type="radio"/>	<input type="radio"/>
5000	<input type="radio"/>	<input type="radio"/>

Figure 3.1: Multiple Price Listings – Ascending

Would you prefer a 50g bag of dried watermelon, or would you prefer _____ MWK?

	50g Bag of Dried Watermelon	MWK
5000	<input type="radio"/>	<input type="radio"/>
4500	<input type="radio"/>	<input type="radio"/>
4000	<input type="radio"/>	<input type="radio"/>
3500	<input type="radio"/>	<input type="radio"/>
3000	<input type="radio"/>	<input type="radio"/>
2500	<input type="radio"/>	<input type="radio"/>
2000	<input type="radio"/>	<input type="radio"/>
1500	<input type="radio"/>	<input type="radio"/>
1000	<input type="radio"/>	<input type="radio"/>
500	<input type="radio"/>	<input type="radio"/>
250	<input type="radio"/>	<input type="radio"/>

Figure 3.2: Multiple Price Listings – Descending

3.2 Cost-Benefit Analysis

We meticulously quantified all variable costs associated with electric and solar drying to conduct a comprehensive cost-benefit analysis. Input costs included the market price of fresh watermelon, labor expenses, packaging costs, and electricity. To determine an average cost per kilogram, we weighed and recorded the price of each watermelon purchased for the experiment. All fruit was sourced from local street vendors, with payments reflecting retail prices rather than farmgate prices. In the future, aQysta plans to establish direct relationships with farmers to help reduce costs. After weighing the watermelons, we removed the rinds and sliced them, recording the processing time,

as well as the time spent loading and cleaning the dryers. These data were used to estimate labor costs, based on a monthly salary of 200,000 MWK (\$115.42)—the amount aQysta pays its workers, which exceeds the typical earnings of individuals with similar skill levels. Packaging costs were estimated using online prices, averaging 225.27 MWK (\$0.12) per bag. Packages are significantly cheaper to buy in the US with similar bags found in Malawi at 700 MWK (\$0.40) per bag. Given this discrepancy, we adjust for packaging costs in the sensitivity analysis. The electricity rates were obtained from ESCOM Limited, the main electricity grid that serves Lilongwe. To estimate the dry yield, we weighed the watermelon before and after drying, determining the amount of fresh watermelon required to produce a 50g bag of dried product.

To facilitate a direct comparison between electric and solar drying methods, we distinguish variable costs from fixed costs, using only variable costs to inform the cost-benefit analysis. Fixed costs, including dryer prices, are incorporated once profitability is determined at a per-unit level. The electric dryer costs 2,945,818.94 MWK (\$1,700), while the solar dryer costs 2,599,252 MWK (\$1,500). By incorporating fixed costs after establishing per-unit profitability, we can determine the minimum number of bags that must be sold to recover the initial investment. The cost per bag is aggregated into the total variable cost (TVC) formulas outlined below. These formulas capture the key cost drivers of each drying method, providing a structured framework for cost-benefit analysis.

Variable Costs of Electric Drying:

$$\begin{aligned}
 TVC_e = & \text{(Whole fruit input} \times \text{Cost/unit)} \\
 & + \text{(Fruit prep worker days} \times \text{Cost/unit)} \\
 & + \text{(Energy (Kwh)} \times \text{Cost/unit)} \\
 & + \text{(Dryer loading worker days} \times \text{Cost/unit)} \\
 & + \text{(Dryer cleaning worker days} \times \text{Cost/unit)} \\
 & + \text{(Packaged units} \times \text{Cost/unit)}
 \end{aligned}$$

Variable Costs of Solar Drying:

$$\begin{aligned} \text{TVC}_s &= (\text{Whole fruit input} \times \text{Cost/unit}) \\ &+ (\text{Fruit prep worker days} \times \text{Cost/unit}) \\ &+ (\text{Dryer loading worker days} \times \text{Cost/unit}) \\ &+ (\text{Dryer cleaning worker days} \times \text{Cost/unit}) \\ &+ (\text{Packaged units} \times \text{Cost/unit}) \end{aligned}$$

Chapter 4

Data and Results

4.1 Descriptive Statistics

During the survey period, we collect 294 responses. We exclude 21 responses due to errors in the recorded WTP values, where the stated WTP is less than the amount given away during the random draw. These instances are likely attributable to enumerator error or respondent misunderstanding and are deemed incentive-incompatible. The final dataset comprises 273 responses across three locations: 102 from Chipiku in City Center, 110 from Chipiku in Game Center, and 61 from Food Lovers in Kanengo.

Table 4.1 summarizes key sociodemographic characteristics of the respondents. The sample is gender-balanced, with 52.38% male and 47.62% female participants. Education levels are relatively high; 89.02% of the respondents have completed at least secondary school and 32.98% completed at least a bachelors. Current data shows the percentage of the population that has at least a lower secondary population education is 15% while those have have at least a bachelors is 1.3% [33, 34]. The sample is predominantly Malawian (92.31%), with small representations from other African, North American, European, and Asian backgrounds. The size of the household is diverse, with most households comprising 4-7 members, and the average age of the respondents is approximately 39 years ($SD = 15.16$). The data shown in Table 4.1 align with our expectations of market shoppers; however, there is no available data on these specific demographics.

Table 4.2 provides information on the consumption habits and preferences of the respondents for dried and fresh fruits. More than half of the sample (57.14%) reported having previously eaten dried fruit, although only 2.93% had tried dried watermelon, indicating that this product is new for consumers in Malawi. Furthermore, only 38.83% had purchased dried fruit, suggesting that dried fruit consumption remains relatively limited. Most of the respondents consume between 3-5 servings of fresh fruit per week (35.53%), with a smaller but notable segment (16.85%) consuming

Variable	Categories	Statistics
Number of Respondents		273
Gender	Male	52.38%
	Female	47.62%
Education (highest completed)	Some primary school	0.37%
	Completed primary school	2.56%
	Some secondary school	8.06%
	Completed secondary school	30.40%
	Some bachelor's degree	25.64%
	Completed bachelor's degree	24.91%
	Some Master's degree	1.10%
	Completed Master's degree	5.13%
	Some PhD or doctorate	0.37%
Completed PhD or doctorate	1.47%	
Nationality	Malawian	92.31%
	Other African	4.4%
	North American	1.47%
	European	1.47%
	Asian	0.37%
Household Size	1	5.86%
	2-3	23.81%
	4-5	36.63%
	6-7	26.01%
	8 or more	7.33%
	NA	0.37%
Number of Children	1	24.54%
	2	23.44%
	3	16.48%
	4 or more	8.06%
	None	27.47%
Age	Mean (SD)	38.97 (15.16)

Table 4.1: Summary Statistics for Respondents Socio-Demographic Variables

ten or more servings. Consumers reported liking dried fruits, with 64.47% and 69.96% of the respondents, respectively, indicating a high level of liking for these fruits. These preferences may suggest a demand for similar flavors in dried form, potentially positioning dried watermelon as a viable product.

Variable	Categories	Statistics
Has Eaten Dried Fruit	No	42.86
	Yes	57.14
Has Eaten Dried Watermelon	No	97.07
	Yes	2.93
Has Purchased Dried Fruit	No	61.17
	Yes	38.83
Servings of Fruit Eaten Weekly	1-2 servings	25.64
	3-5 servings	35.53
	6-9 servings	13.19
	10 or more servings	16.85
	None	8.79
Preference for Fresh Watermelon	Dislike a great deal	2.20
	Dislike somewhat	2.56
	Neither like nor dislike	8.79
	Like somewhat	21.61
	Like a great deal	64.47
	NA	0.37
Preference for Fresh Mango	Dislike a great deal	1.83
	Dislike somewhat	2.56
	Neither like nor dislike	2.93
	Like somewhat	22.71
	Like a great deal	69.96

Table 4.2: Summary Statistics for Respondents Consumption Habits

4.2 Consumer Survey

We find no evidence of strong relative preferences on average. As shown in Table 4.3, each type was ranked as the most preferred by approximately 30% of respondents. Electric-dried watermelon was rated as the most liked sample only 1.14% more often than solar-dried watermelon, suggesting that both drying methods yield equally preferred products. Furthermore, this indicates that dried watermelon - regardless of the drying method - is as popular as dried mango, which is the dried fruit most widely available in Malawi.

Table 4.4 provides a detailed breakdown of how often each dried fruit was ranked in specific positions. For example, the most common ranking order was electric in first place, mango in second

Table 4.3: Most Preferred Dried Fruit

Fruit	Rank	Count	Percentage
Electric	1	92	34.85
Solar	1	89	33.71
Mango	1	83	31.44

place, and solar in third. Of particular note, mango was ranked in the middle more frequently than in the first or last position. This suggests that the respondents did not view electric and solar watermelon as direct substitutes but as distinct products and that the two drying methods are not interchangeable. Being more familiar, mango served as a clear divider in consumer preferences. There were 12 instances in which multiple fruits were ranked at the same level. Upon reviewing the data, these equal rankings were ranked second or third. This pattern suggests the possibility of data entry errors or that the respondents did not have strong preferences for any particular fruit but instead had negative preferences towards all of them.

Table 4.4: Ranking Order

Category	Count
E>M>S	54
M>S>E	48
S>M>E	48
S>E>M	40
E>S>M	37
M>E>S	34
E=S	5
M=S	4
M=E	3

Key: E = Electric Dried Watermelon, M = Dried Mango, S = Solar Dried Watermelon,
E=S = Electric & Solar Ranked the Same,
M=S = Mango & Solar Ranked the Same,
M=E = Electric & Mango Ranked the Same.

In general, solar-dried watermelon was ranked higher than electric-dried watermelon 52% at the time. However, when comparing the demand curves for electric and solar dried watermelon

(Figure 4.2), we observe that respondents who prefer solar dried watermelon were willing to pay less for it than those who preferred electric dried watermelon were willing to pay for the electric dried option. Furthermore, during the taste test, participants rated their general enjoyment of electric and solar dried watermelon on a scale of 1 to 5, with 5 indicating strong enjoyment and 1 indicating strong dislike. The results are summarized in 4.1. Consistent with the previous results, the solar-dried samples had a higher average rating than the electric-dried ones. However, both samples scored above 3.5, with only a 0.3 point difference between their mean.

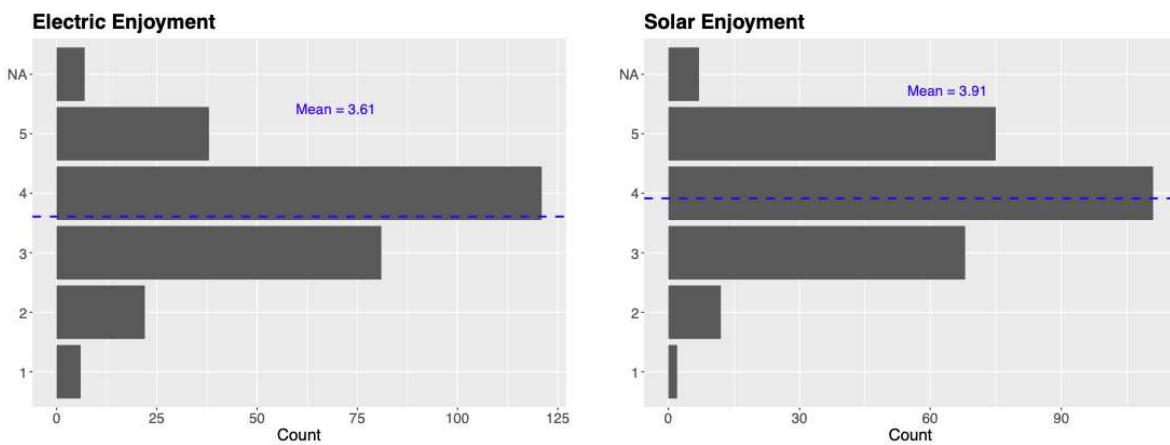


Figure 4.1: Enjoyment Ratings

4.3 Willingness to Pay

Table 4.5 presents the summary statistics for all MPL data. Mean WTP for dried watermelon is 2,433.15 MWK (USD 1.40; SD = 1,812.78 MWK, USD 1.05), highlighting the variation in respondents' valuations. Following the random draw, cash was given away 53.5% of the time. Among those who received watermelon, that is, respondents with WTP values at or below the random draw, 27.5% received solar dried watermelon. This result aligns with expectations, as more respondents ranked solar dried watermelon higher than electric dried. The preference for solar drying may reflect perceived differences in product quality.

Statistic	Value (MWK)	Value (USD)
WTP	Mean: 2433.15 SD: 1812.78	Mean: 1.40 SD: 1.05
Random Draw	Mean: 2919.414 SD: 1557.39	Mean: 1.68 SD: 0.90
Given Away	Cash: 53.5% Mean: 3469 SD: 1367 Electric Watermelon: 19% Solar Watermelon: 27.5%	Mean: 2.00 SD: 0.79

Table 4.5: Summary Statistics for WTP, Random Draw, and Given Away

The demand curves for dried electric and solar watermelon are shown in Figure 4.2. The WTP for electric dried watermelon is nearly 500 MWK (\$0.29) higher than for solar dried watermelon, with mean values of 2,727.46 MWK (\$1.57) and 2,233.33 MWK (\$1.29), respectively. Furthermore, 25.40% of the participants who preferred electric dried watermelon were willing to pay 5,000 MWK per bag (\$2.89/bag) or more, compared to 18.51% of those who preferred solar dried watermelon. At every MPL value, the percentage of participants willing to pay that amount is consistently higher for electric than solar.

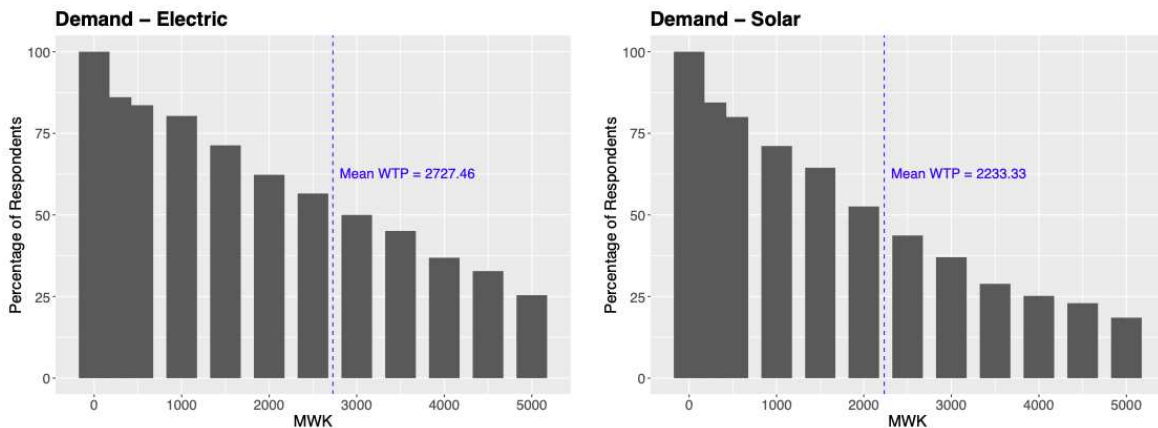


Figure 4.2: Enjoyment Ratings

4.4 Cost-Benefit Analysis

Variable costs of producing dried watermelon include price of fresh fruit, labor for preparation and drying, packaging materials, and electricity. Drying took about 14 hours for electric and 30 hours for solar. Based on data collected during processing, cutting a watermelon took an average of 5 minutes and 36 seconds. All cutting must be done by hand, as the fruit loses too much volume when processed with commercial slicers. It took on average 1 minute and 37 seconds to slice 1 kg of whole watermelon. With this efficiency, 296.88 kg of whole watermelon can be processed per worker per day. The average yield from whole to dried watermelon is 3.95%, meaning 1.28 kg of whole watermelon is required for a 50g bag of dried product.

Variable costs per bag are outlined and compared in Table 4.6 and Figure 4.3. TVC for producing a bag of dried watermelon is 2,457.98 MWK (\$1.40) and 2,428.51 MWK (\$1.42) for electric and solar respectively. The most significant expense is whole fruit, which is 1,612.07 MWK (\$0.93) per kg or 2,063.36 MWK (\$1.19) per bag. This represents approximately 85–86% of TVC. The second largest expense is packaging, accounting for approximately 9% of TVC. Labor costs include fruit preparation, dryer loading, and dryer cleaning. For an employee earning a monthly salary of 200,000 MWK (\$115.42), labor costs 62.81 MWK (\$0.04) for electric and 139.88 MWK (\$0.08) for solar. This discrepancy is primarily due to the additional time required to clean and load the solar dryers, which are more spread out and require greater effort and maneuvering to load efficiently due to their design. Local electricity rates are included in the TVC for electric drying, with ESCOM charging 68.35 MWK/kWh. Based on this rate and the energy consumption of the dryers, the cost to dry 1.28 kg of whole watermelon is 106.54 MWK (\$0.06).

In the future, costs can be reduced by purchasing watermelons in bulk directly from farmers instead of paying full retail prices from vendors. Alternatively, individual packaging costs could be avoided altogether by selling in bulk on the international market, although this would introduce additional costs that would require further research.

Table 4.7 compares the TVC costs with the mean WTP data collected in the MPL. By using mean WTP as a proxy for revenue and TVC as the per-unit cost, we estimate profit per bag. Electric

Variable Costs	Electric		Solar	
	MWK	USD	MWK	USD
Whole Fruit	2,063.36	1.19	2,063.36	1.19
Packaging	225.27	0.13	225.27	0.13
Electricity	106.54	0.06	–	–
Labor	62.81	0.04	139.88	0.08
TVC	2,457.98	1.40	2,428.51	1.42

Table 4.6: Variable Costs of Solar and Electric Drying Per Bag

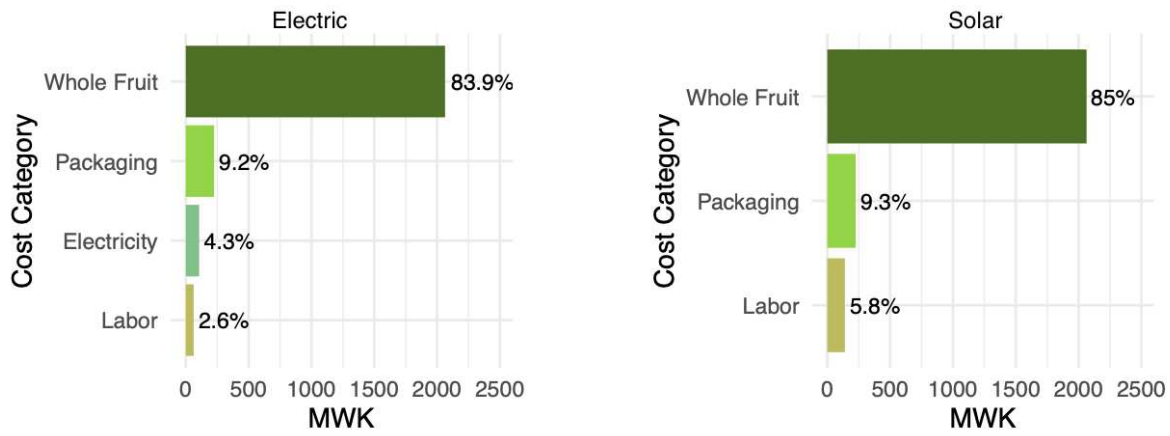


Figure 4.3: Percentages of TVC

drying is profitable based on variable costs alone, generating a margin of 269.48 MWK (\$0.16) per bag. In contrast, solar drying does not fully cover its variable costs, resulting in a loss of 195.18 MWK (\$0.11) per bag. In the future, costs could be reduced by purchasing watermelons in bulk directly from farmers rather than paying full retail prices to vendors. Alternatively, selling in bulk on the international market could eliminate individual packaging costs, though this approach may incur additional expenses that warrant further investigation.

Type	Mean WTP (MWK)	TVC (MWK)	Profit (MWK)	Profit (USD)
Electric	2,727.46	2,457.98	269.48	0.16
Solar	2,233.33	2,428.51	-195.18	-0.11

Table 4.7: Mean WTP, Costs, and Profits

Chapter 5

Discussion

5.1 Break-Even Analyses

While electric dried watermelon is profitable when just considering TVC and mean WTP, recovering the cost of an electric dryer would take considerable time. The dryer used by aQysta costs 2,945,818.94 MWK (\$1,700), a substantial investment in Malawi. As shown in Figure 5.1, 10,000 packages must be sold to recover the initial cost, assuming a profit of 269.48 MWK (\$0.16) per bag—excluding maintenance expenses. At this point, the total expenditure exceeds \$15,000, making long-term profitability unlikely at current input costs and a revenue of 2,727.46 MWK (\$1.57) per bag.

However, it may be more beneficial to sell the packages at prices above the mean, targeting fewer consumers at higher price points. Tables 5.1 and 5.2 presents all the prices included in the MPL and the corresponding price elasticity of demand (PED), calculated using the midpoint (arc elasticity) formula. As prices increase, demand becomes increasingly elastic. The table also shows the estimated percentage of shoppers who would purchase the bags at each price point, along with the profit per bag based on TVC.

Table 5.1 shows profits for electric-dried watermelon becoming positive around 2,500 MWK (\$1.44), requiring the sale of 70,105.16 bags to recover the cost of the electric dryer. Assuming 56.56% of shoppers would purchase the bags at this price, approximately 1,239,483 shoppers would need to enter the store to break even. As the price increases, profit per bag rises, meaning fewer bags must be sold—and fewer shoppers are needed—to cover costs. For example, if the bags are sold at 5,000 MWK (\$2.89), the profit per bag increases to 2,542.02 MWK (\$1.47). Assuming 25.41% of shoppers make a purchase at this price, only 45,606.06 shoppers would need to enter the store to reach the break-even point.

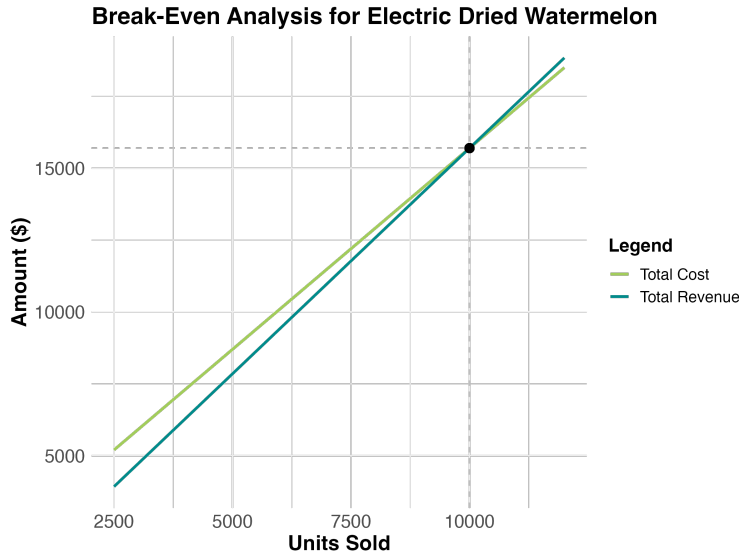


Figure 5.1: Required Package Sales to Break Even on Dryer Costs

Table 5.2 presents the same values for solar-dried watermelon. Similar to electric drying, solar-dried watermelon becomes profitable at a price of approximately 2,500 MWK (\$1.44). At this price point, 36,382.56 bags would need to be sold to recover the cost of the solar dryer, which is 2,599,132.50 MWK (\$1,500). Assuming 43.70% of shoppers would make a purchase at this price, an estimated 832,552.86 shoppers would need to enter the store to break even. At a higher price point of 5,000 MWK (\$2.89) per bag, only 1,011.47 bags would need to be sold to cover the cost of the dryer. Assuming 18.52% of shoppers would purchase the bags at this price, just 54,615.01 shoppers would need to enter the store to break even.

5.2 Sensitivity Analyses

However, variable costs can be reduced by purchasing whole watermelons directly from farmers. Since whole fruit represents more than 80% of variable costs, lowering its price could significantly impact the results of the cost-benefit analysis. Figure 5.2 illustrates how the profit per bag changes with fruit prices. The solar dried watermelon breaks even, *ceteris paribus*, when the whole fruit costs 1,868.18 MWK (\$1.08). Fresh watermelon was purchased at 2,063.36 MWK (\$1.19)

Price (MWK)	PED	% of Shoppers Purchase Bags	Profit/Bag (MWK)	Bags Needed to Break-Even	Total Shoppers Needed
250.00	-0.07	86.07	-2,207.98	NA	NA
500.00	-0.04	83.61	-1,957.98	NA	NA
1,000.00	-0.06	80.33	-1,457.98	NA	NA
1,500.00	-0.30	71.31	-957.98	NA	NA
2,000.00	-0.47	62.30	-457.98	NA	NA
2,500.00	-0.43	56.56	42.02	70,105.16	1,239,483.03
3,000.00	-0.68	50.00	542.02	5,434.89	108,697.80
3,500.00	-0.67	45.08	1,042.02	2,827.03	62,711.40
4,000.00	-1.50	36.89	1,542.02	1,910.36	51,785.31
4,500.00	-1.00	32.79	2,042.02	1,442.60	43,995.12
5,000.00	-2.41	25.41	2,542.02	1,158.85	45,606.06

Table 5.1: Electric Price Elasticity and Bags and Shoppers Needed to Break-Even

Price (MWK)	PED	% of Shoppers Purchase Bags	Profit/Bag (MWK)	Bags Needed to Break-Even	Total Shoppers Needed
250.00	-0.08	84.44	-2178.51	NA	NA
500.00	-0.08	80.00	-1928.51	NA	NA
1,000.00	-0.18	71.11	-1428.51	NA	NA
1,500.00	-0.25	64.44	-928.51	NA	NA
2,000.00	-0.71	52.59	-428.51	NA	NA
2,500.00	-0.83	43.70	71.49	36,382.56	832,552.86
3,000.00	-0.91	37.04	571.49	4,551.24	122,873.65
3,500.00	-1.61	28.89	1,071.49	2,427.45	84,023.88
4,000.00	-1.03	25.19	1,571.49	1,655.11	65,705.04
4,500.00	-0.78	22.96	2,071.49	1,255.61	54,686.85
5,000.00	-2.04	18.52	2,571.49	1,011.47	54,615.01

Table 5.2: Solar Price Elasticity and Bags and Shoppers needed to Break-Even

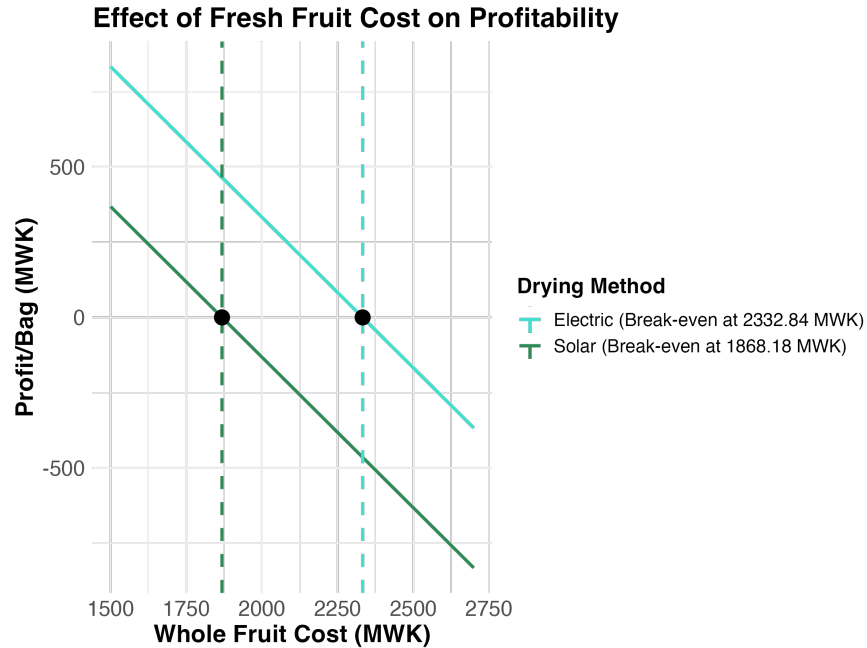


Figure 5.2: Sensitivity Analysis of Profit at Various Whole Fruit Prices

per bag, indicating that at lower prices, solar drying is profitable. For electric dried watermelon, the breakeven point is higher at 2,332.84 MWK (\$1.34) per bag of fresh fruit.

The second most significant cost, though minor compared to fresh fruit, is packaging. In Malawi, packaging costs approximately 700 MWK (\$0.40) per bag. Although sourcing packaging online from the US is cheaper, locally available products may sometimes be the only viable option. Figure 5.3 presents a sensitivity analysis similar to the previous one but examines the impact of packaging costs per unit. The analysis shows that for solar-dried watermelon, cost recovery is challenging: packaging would need to be 30.09 MWK (\$0.02) per bag or lower to break even. Such low prices are unrealistic, even in the US. Bags purchased from amazon are 225.27 MWK (\$0.13) meaning that reducing packaging costs alone will not make solar drying profitable. For electric dried watermelon, cost recovery is feasible at a packaging price of 494.75 MWK (\$0.28) per bag or less. However, using locally sourced bags in Malawi, while keeping all other factors constant, would not allow the electric dried watermelon to break even.

Although solar dried watermelon is not profitable at the mean WTP value, solar thermal dryers offer multiple potential benefits in rural areas near fruit production. Processing, drying, and pack-

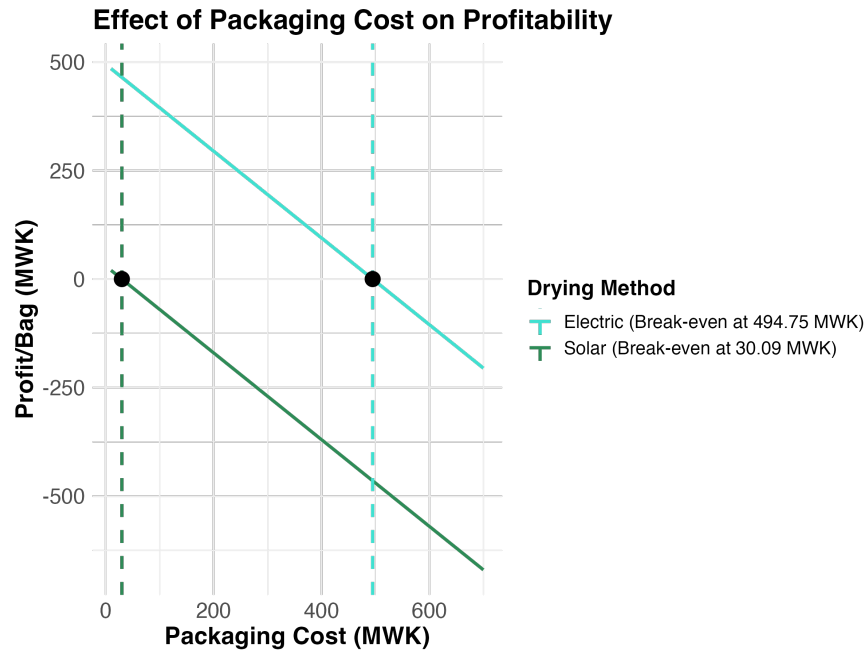


Figure 5.3: Sensitivity Analysis of Profit at Various Packaging Prices

aging at the source before shipping to urban centers can create and diversify rural employment opportunities. Expanding skill sets and increasing incomes without transportation or relocation are essential in regions where agriculture dominates employment. In addition, processing centers that operate independently of the grid are advantageous for rural and developing regions. Locating them near fruit production can help reduce PHL and farmers' expenses by lessening transportation costs.

However, processing fruit in this way presents its own challenges. Solar thermal dryers require significant capital investment and a specialized technician if the solar-voltaic cell needs repair. Although aQysta has reduced costs by more than half with its own design, dryers remain expensive for the average business in Malawi, costing 1,128,588.41 MWK (\$650). Additionally, their efficiency depends on weather conditions and temperature fluctuations, and exposure to the elements raises food safety concerns.

5.3 Limitations

Our study has three main limitations: potential house money and social desirability effects, MPL data restricted to the most preferred type of dried fruit, and the MPL cap failing to capture all upper bound WTP data. First, biases related to the house money effect may arise from the MPL and random draw design. Since respondents are not using their own money, they may perceive the cash or dried watermelon as a bonus, leading them to take greater risks or spend more freely. This perceived “free money” dynamic can inflate WTP estimates, as choosing the product over cash does not feel like a real loss. Second, social desirability bias may also affect responses—participants might select the watermelon because they believe it is the “correct” or expected answer, aiming to please the enumerators. This too could lead to artificially high WTP values.

Second, we only conducted the MPL on the most preferred type of dried watermelon. Obtaining WTP estimates for both electric and solar dried products from each consumer would have strengthened the comparison and provided a more comprehensive WTP value. However, time constraints made this infeasible. Each survey took an average of 10 to 15 minutes to complete and performing a second MPL would have significantly extended the duration of the survey. This could have led to respondent fatigue, lower participation rates, or a reluctance of grocery store managers to accommodate the study.

Second, we only conducted the MPL on the most preferred type of dried watermelon. Obtaining WTP estimates for both electric and solar dried products from each consumer would have strengthened the comparison and provided a more comprehensive WTP value. However, time constraints made this infeasible. Each survey took an average of 10 to 15 minutes to complete and performing a second MPL would have significantly extended the duration of the survey. This could have led to respondent fatigue, lower participation rates, or a reluctance of grocery store managers to accommodate the study. However, since participants only bid on their most preferred type of dried fruit, WTP values may be overstated.

Third, capping the MPL at 5,000 MWK potentially prevented us from fully capturing some respondents’ upper-bound WTP. While this limit aligned with locally available dried fruit prices,

a significant portion of respondents still chose dried fruit at the maximum bid, making it difficult to determine their true upper bound WTP. Expanding the MPL to include higher bid values could provide a more precise estimate and help us better understand demand. By not capturing all participants maximum WTP, current demand may be understated.

Bibliography

- [1] International Food Policy Research Institute. Key facts series malawi: Poverty in malawi, May 2019. Based on the Integrated Household Surveys conducted by the National Statistical Office of Malawi.
- [2] Joseph A. McMahon. International agricultural trade reform and developing countries: The case of the european community. *International and Comparative Law Quarterly*, 47(3):632–646, 1998.
- [3] International Trade Administration. Malawi - agricultural sector, 2023. Accessed: 2024-10-10.
- [4] World Bank. Malawi overview, 2024. Accessed: 2024-11-09.
- [5] Food and Agriculture Organization of the United Nations. Malawi small family farms country factsheet, 2018. Available at: <https://openknowledge.fao.org/server/api/core/bitstreams/162d69f3-dd28-4d02-8390-ec68737989fb/content>.
- [6] Milu Muyanga, Zephania Nyirenda, Yanjanani Lifeyo, and William J. Burke. The future of smallholder farming in malawi. Working Paper 20/03, MwAPATA Institute, Lilongwe, Malawi, August 2020. Available from MwAPATA Institute.
- [7] William Chirwa Mabedi, Thabiso DO, and Malewezi Masualle. An assessment of factors that lead to low agricultural productivity in malawi. *International Journal of Agricultural Economics, Extension and Rural Development*, 8(2):192–202, September 2022. Accepted on 25 May, 2022.
- [8] World Bank. Escaping poverty in malawi requires improved agricultural productivity, climate resilience, and structural transformation, November 2022. Accessed: 2024-12-10.
- [9] Wyckliffe Kazembe-Phiri. Approaches to successful development of low-cost fruit juice extraction technologies: A case study to improved rural livelihood in malawi, 2005.

- [10] Richard N. Kachule and Steven C. Franzel. The status of fruit production, processing and marketing in malawi, 2013.
- [11] Kent J. Bradford, Peetambar Dahal, Johan Van Asbrouck, Keshavulu Kunusoth, Pedro Bello, James Thompson, and Felicia Wu. The dry chain: Reducing postharvest losses and improving food safety in humid climates. *Trends in Food Science Technology*, 71:84–93, 2018.
- [12] Renee Threfall, Justin Morris, and Jean-Francois Meullenet. Product development and nutraceutical analysis to enhance the value of dried fruit. *Journal of Food Quality*, 30(4):552–566, 2007.
- [13] Eren Ozgen and Barbara D. Minsky. Opportunity recognition in rural entrepreneurship in developing countries. *International Journal of Entrepreneurship*, 11:49–73, 2007. ABI/INFORM Complete.
- [14] C L Hii, S P Ong, C L Chiang, and AS Menon. A review of quality characteristics of solar dried food crop product. *IOP Conference Series: Earth and Environmental Science*, 292(1):012054, jun 2019.
- [15] University of Florida Institute of Food and Agricultural Sciences. Watermelon. Online, n.d. Accessed September 30, 2024.
- [16] R.K. Aggarwal, Shyam Singh Chandel, Shiva Gorjian, and Rahul Chandel. Research outcome of sustainable solar drying technology dissemination for preserving perishable agriculture and horticulture crops in the north western himalayan region of india. *Sustainable Energy Technologies and Assessments*, 53:102732, 2022.
- [17] P.K. Devan, Chidambaranathan Bibin, I. Asburris Shabrin, R. Gokulnath, and D. Karthick. Solar drying of fruits – a comprehensive review. *Materials Today: Proceedings*, 33:253–260, 2020. International Conference on Future Generation Functional Materials and Research 2020.

- [18] Mulatu Wakjira. Solar drying of fruits and windows of opportunities in ethiopia. *African Journal of Food Science*, 4(13):790–802, December 2010. Accepted 22 October, 2010.
- [19] A. Mohan, S. Shanmugam, and V. Nithyalakshmi. Comparison of the nutritional, physico-chemical and anti-nutrient properties of freeze and hot air dried watermelon (*citrullus lanatus*) rind. *Biosciences Biotechnology Research Asia*, 13(2), 2016.
- [20] John Isa, Ayoola Olalusi, and Omoba Olufunmilayo. Quality evaluation of foam dried watermelon flakes. *Turkish Journal of Agricultural Engineering Research*, 3(2):245–264, 2022.
- [21] Waqas Mehmood, Sami Ullah, Shoaib Nasir, Mudasir Yasin, Abd ur Rehman, and Muhammad Arqam Iqbal. Consumer awareness and willingness to pay for dried mangoes: Evidence from punjab, pakistan. *Journal of Economic Impact*, 5(1):100–105, 2023. ISSN: 2664-9764 (Online), 2664-9756 (Print), Available Online.
- [22] Riccardo Testa, Giuseppina Rizzo, Giorgio Schifani, Ilenia Tinebra, Vittorio Farina, Francesco Vella, and Giuseppina Migliore. Can dried fruits replace unhealthy snacking among millennials? an empirical study on dried fruit consumption in italy. *Sustainability*, 2023. D.
- [23] Roselyne Alphonse, Anna Temu, and Valerie Lengard Almli. European consumer preference for african dried fruits. *British Food Journal*, 2015. Article publication date: 6 July 2015.
- [24] G. Cinar. Consumer perspective regarding dried tropical fruits in turkey. *Italian Journal of Food Science*, 30(4), 2018. Vol. 30 No. 4 (2018): Italian Journal of Food Science.
- [25] Roselyne Alphonse and Frode Alfnes. Eliciting consumer wtp for food characteristics in a developing context: Application of four valuation methods in an african market. *Journal of Agricultural Economics*, 68(1):123–142, 2017.
- [26] Morten I. Lau Steffen Anderson, Glenn W. Harrison and Rutstrom E. Elisabet. Valuation using multiple price list formats. *Applied Economics*, 39(6):675–682, 2007.

- [27] B. Kelsey Jack, Kathryn McDermott, and Anja Sautmann. Multiple price lists for willingness to pay elicitation. *Journal of Development Economics*, 159:102977, 2022.
- [28] World Bank. Malawi data, 2023. Accessed: 2024-10-10.
- [29] Noora-Lisa Aberman, Jan Meerman, and Todd Benson. Mapping the linkages between agriculture, food security and nutrition in malawi. Online, 2015. Accessed September 30, 2024.
- [30] Stephen Carr, Hanna Kool, and K.E. Giller. *Surviving on half a hectare of land: An introduction to the issues surrounding smallholder farming in Malawi*. Plant Production Systems, PE&RC, 2023. Professional Report.
- [31] Paul Fatch, Charles Masangano, Thomas Hilger, Irmgard Jordan, Isaac Mambo, Judith Francesca Mangani Kamoto, Alexander Kalimbira, and Ernst-August Nuppenau. Holistic agricultural diversity index as a measure of agricultural diversity: A cross-sectional study of smallholder farmers in lilongwe district of malawi. *Agricultural Systems*, 187:102991, 2021.
- [32] Malawi Government. The fifth integrated household survey (ihs5) 2020 report. Government report, National Statistical Office, November 2020.
- [33] UNESCO Institute for Statistics (UIS). UIS.Stat Bulk Data Download Service. <https://apiportal.uis.unesco.org/bdds>, 2024. Accessed September 30, 2024.
- [34] UNICEF. Malawi education fact sheets 2022: Analyses for learning and equity using mics data. Online, 2022. Accessed September 30, 2024.