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Economic Analysis of Different Fuel Sources in the Preparation of Lima Beans (*Phaseolus Lunatus)* Varieties: Implication for Cooking Quality, Profitability and Upscaling

Omobolaji O. Obisesan*
Agricultural Value Addition Program, Institute of Agricultural Research and Training
Obafemi Awolowo University, Ibadan, Oyo State, Nigeria.

Omowonuola T. Oni
Federal College of Agriculture, Moor Plantation, Apata, Ibadan, Oyo State, Nigeria.

Elizabeth O. Farinde
Agricultural Value Addition Program, Institute of Agricultural Research and Training
Obafemi Awolowo University, Ibadan, Oyo State, Nigeria.

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Abstract: *This study conducts an economic analysis of Lima beans (Phaseolus lunatus) varieties using different fuel sources. Key factors analyzed include fuel cost, cooking time, energy efficiency, and the nutritional retention of the beans after cooking. Data were gathered through experimental cooking trials where each Lima bean variety was prepared using different fuel sources under controlled conditions. The results show that the choice of cooking fuel has a substantial impact on the overall cost and profitability of cooking Lima beans. Firewood and charcoal, though cheaper and easily accessible required longer cooking times. Although gas as a fuel source remains the best option for time-saving, its accessibility and affordability are barriers to widespread use, The study therefore underscores the need for more cost-efficient cooking fuels for cooking staples like Lima beans in Nigeria especially in the light of nutritional quality, profitability and upscaling.*

Keywords: economic analysis, Lima Beans varieties, different cooking times, cooking quality, upscaling.

INTRODUCTION

Lima beans, also known as butter beans or sieva beans, are nutritious legumes that belong to the *Phaseolus lunatus* species (Adebo, 2023). These beans are native to

Central and South America but are now cultivated in various regions worldwide, including Africa, Asia, and Europe. Lima beans are valued for their creamy texture and nutty flavor, making them a versatile ingredient in many cuisines. They are rich in protein, fiber, vitamins, and minerals, contributing to their reputation as a healthy and sustainable food source. Lima beans can be cooked, baked, fermented or processed into flour and used in a wide range of dishes, including soups, stews, salads, side dishes and snacks offering both culinary diversity and nutritional benefits to consumers (Farinde and 2011; Farinde, (2019); Farinde *et al.,* (2017). Cooking method and fuel choice plays a crucial role in food preparation processes, impacting not only economic considerations but also health, environmental sustainability, and societal well-being (Shah *et al.,* 2011). Understanding the economic implications of different fuel sources for cooking Lima varieties is essential for informed decision-making in both household and industrial settings. The cost of fuel represents a significant portion of the overall expenses in food preparation. Analyzing the economic costs associated with using firewood, gas, and charcoal for cooking Lima varieties provides valuable insights into cost-effectiveness and affordability, particularly for households and food processing industries operating on tight budgets. Different fuel sources may affect cooking efficiency and productivity, influencing the overall time required for cooking and the quantity of food produced. Investigating variations in cooking times and efficiency among firewood, gas, and charcoal offers practical insights into optimizing cooking processes to enhance productivity and resource utilization. For food processing industries and businesses involved in commercial food preparation, profitability is a critical consideration (Ugbabe *et al.,* 2017).

Assessing the profitability implications of using different fuel sources for cooking Lima varieties informs business decisions regarding production processes, pricing strategies, and investment in the cooking technologies with the least cost. By examining the economic aspects of fuel choices, this study contributes to understanding the trade-offs between economic benefits and transactional costs, facilitating the development of a sustainable cooking practices. This provides a comprehensive understanding of the economic considerations associated with using different fuel sources for cooking Lima varieties, offering practical insights for households, businesses, policymakers, and researchers to make informed decisions and promote sustainable cooking practices in food processing. The main objective of the study is to carry out an economic analysis of cooked lima beans varieties using different cooking fuel sources. The specific objectives are to: i) To assess the economic costs associated with cooking Lima varieties using three fuel sources. This objective aims to quantify and compare the direct monetary expenses incurred in cooking Lima varieties using different fuel sources, including the costs of fuel procurement, utilization, and associated labor, ii) To determine the profitability implications of using the three fuel sources. This objective aims to assess the financial returns and costs associated with cooking Lima varieties using different fuel sources, considering factors such as revenue generation, variable costs, and gross margins.

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LITERATURE/THEORETICAL UNDERPINNINGS

Some theoretical frameworks that underpin the economic analysis of different fuel sources in the preparation of Lima beans (Phaseolus lunatus) includes the Cost Benefit Analysis (CBA), production theory, theories of economies of scale and consumer theory. The Cost Benefit Analysis uses CBA tools in comparing the costs and benefits of different products with the aim to determine the most economically viable choice. It can quantify costs (e.g., fuel expenses, labor, time) and benefits (e.g., improved cooking quality, energy efficiency, reduced emissions) associated with each fuel source (Latu *et al.,* 2020; Obisesan *et al.,* 2024). In this context of Lima bean preparation, CBA helped with the evaluation of which fuel source offers the best balance between cost savings and cooking quality. Consequently, the production theory outlines the relationship between input factors (e.g., fuel, labor) and output (e.g., cooked Lima beans). It focuses on optimizing resource allocation to maximize production efficiency and minimize costs (Nonvide, 2020; Amasimeku and Anang, 2021; Rodino et al., 2022). By analyzing different fuel sources, production theory can identify the most efficient fuel for cooking Lima beans, leading to cost-effective and high-quality preparation.

Economies of scale on the other hand refers to the cost advantages that arise with increased production levels. As production scales up, the average cost per unit decreases due to factors like bulk purchasing, improved efficiency, and spreading fixed costs over more units. An analysis of the upscaling potential of different fuel sources helps determine which one offers the greatest economies of scale in large-scale Lima bean production. An understanding the energy economics of various fuels provides insights into their cost-effectiveness, sustainability, and impact on cooking quality and profitability. The Energy economics examined provided information on the energy efficiency, the environmental impact of different fuel sources, supply, demand, and distribution of energy resources (Cadoret and Padovano, 2016; Okorie *et al.,* 2020; Osman *et al.,* 2023). While, the consumer theory analyzes how individuals and households make decisions to allocate their limited resources (e.g., time, money) to maximize utility or satisfaction (Shirai, 2015). It includes considerations of preferences, income constraints, and substitution effects. Examining the consumer preferences for different cooking qualities and fuel sources helped in identifying which options were most likely to be adopted and scaled up. An integration of these theoretical frameworks, provides a comprehensive insight into cooking quality, profitability, and upscaling potentials of Lima beans. This approach ensures that the chosen fuel source is not only cost-effective but also sustainable and scalable.

METHODOLOGY

Use of different cooking fuel sources

Cooking Lima Beans with Firewood

Matured dried lima bean seeds were sorted, weighed, soaked overnight to reduce cooking time, washed in water and dispensed in a cooking pot. Adequate amount of water (twice the volume of the beans) was initially added and increased later depending on the hardness of the bean coat. The pot and the content were placed on firewood flame and the beans was allowed to cook until tendered textured. Cooking time was recorded.

Cooking Lima Beans with Charcoal

Lima bean seeds were weighed and soaked as done for firewood cooking, The soaked beans were washed and dispensed in cooking pot. Adequate amount of water was added. Charcoal flame was made by burning charcoal in the presence of air. The heated charcoal produced a hot and steady flame which was used in cooking of the beans. The beans were allowed to cook till tendered textured obtained. Cooking time was recorded. Cooking lima beans with charcoal provides a consistent heat source, resulting in evenly cooked beans.

Cooking Lima Beans with Gas

Soaked and washed lima bean seeds were dispensed in a cooking pot and adequate amount of water was added. The pot and the content were placed on a gas burner with the flame regulated to medium heat. The beans were cooked until tendered textured, adding more water when necessary. Cooking time was recorded. Cooking lima beans using a gas stove is convenient and allows for precise temperature control.

Economic Analysis of Lima Beans Varieties Using different cooking methods

The study involved cooking samples of Lima Beans using gas, firewood and charcoal methods under controlled conditions. Ten different samples (presented as VII, V8, VI, VI6, VI8, V7, V9, VI3, VI5 and VI4) were prepared and subjected to different cooking methods. Parameters such as weight before cooking, cost of Lima Beans (₦), cost of gas (₦), output after cooking (kg), cooking time (mins), price of gas per cooking time (₦), price of output (beans after cooking, ₦), total variable cost (₦), total revenue (₦) were recorded for each sample, while the gross margin were for each sample were calculated. Each row represents a different sample of the analysis. In order to establish the most economically viable method of cooking lima beans the aforementioned parameters were determined (Tables 2-4). There was a notable difference in the cooking times required for each sample, ranging from 80 to 160 minutes. Longer cooking times incur higher fuel consumption and costs, potentially impacting the overall profitability of the cooking process. While the total variable cost, comprising the cost of Lima Beans and the cost of gas, varies across the samples.

Profitability Analysis of Lima Beans Varieties Using different cooking methods

These consist of the contribution margin and the gross margin (Afework and Adam, 2018; Uwaoma, 2015). The contribution margin was calculated as the difference between total revenue and total variable costs, provides insights into the profitability of each sample. While the gross margin, calculated as the difference between the total revenue and the total variable cost all divided by the total revenue multiplied by hundred (100) (Abimbola, 2014), indicated profitability of actual profitability of using the fuel samples (Omotayo and Oladejo, 2016). Samples with positive gross margins indicate profitability, while negative margins suggest potential losses.

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Efficiency of the different cooking methods

$$\textit{Energy Efficiency}\ (\%) = \left(\frac{\textit{Ueful Energy output}}{\textit{Total Energy input}}\right) \text{X } 100 \qquad 1$$

We can also estimate the Energy Efficiencies using this formula:

$$\textit{Energy Efficiency}\ (\%) = \left(\frac{\textit{Output after cooking}}{\textit{Price of Gas per cooking time}\ (₦)}\right) \text{X } 100 \qquad 2$$

Total Variable Cost (TVC): Represents the costs directly tied to cooking activities (e.g., firewood and other variable inputs). Total Revenue (TR): Revenue generated from selling the cooked lima beans. Contribution Margin (CM): The income available to cover fixed costs and profits, calculated as:

CM=TR−TVC 3

Gross Margin (GM): Indicates the profitability on a per-unit revenue basis, computed as:

GM=CM 4

***Note that GM here is expressed directly in Naira rather than as a percentage.

Total variable Cost (TVC)	Equals	Quantity of output	X	variable cost per unit of input
		Qty before cooking	X	price/cost of gas per cooking time
Total Revenue (TR)	Equals	Quantity	X	Price of goods
Contribution Margin	Equals	TR	minus	TVC
Gross Margin	Equals	TR	Minus	TVC divided by TR

Table 1: Explanation of terms; Source: Experimental data, 2024.

RESULTS/FINDING

Analysis of the use of gas in cooking Lima beans

The economic analysis of cooked lima beans using gas fuel source presented in Table (2) provides insights into variables such as costs, cooking times, and profitability, which is crucial for decision-making in food processing industries or household budgeting.

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Samples	Weight before cooking (g)	Cost of Lima Beans per 150 (g)	Cost of gas (₦)	Output after cooking (g)	Cooking time (mins)	Price of Gas per cooking time (₦)	Price of output after cooking (₦)
V11	150	75	5400	214	94	417.09	250
V8	150	75	5400	386	160	709.94	250
V1	150	75	5400	336	108	479.21	250
V16	150	75	5400	335	122	541.33	250
V18	150	75	5400	324	136	603.45	250
V7	100	75	5400	218	120	532.46	250
V9	150	75	5400	359	122	541.33	250
V13	150	75	5400	364	115	510.27	250
V15	150	75	5400	353	160	709.94	250
V14	150	75	5400	365	80	354.97	250

Table 2: Analysis of use of gas in cooking lima beans;

Source: Experimental data, 2024. ***Conversion rate-1Naira = USD 1,500

Profitability analysis of use of gas in cooking lima beans

The outcome from Figure 1 shows that most samples VII, V8, V16, V18 exhibited negative contribution margin, indicating that the revenue generated does not cover the variable costs.

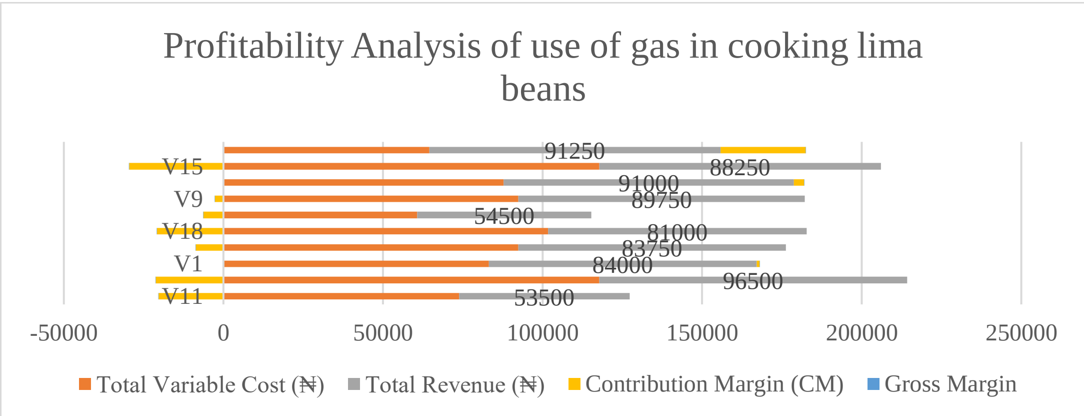

Figure 1: Profitability Analysis of use of gas in cooking lima beans,

Source: Experimental data, 2024. ***Conversion rate-1Naira = USD 1,500

Analysis of use of firewood in cooking Lima beans

The firewood method of cooking lima beans as presented in Table 3 shows data detailing various parameters associated with the cooking process and financial outcomes. The data presented in the table show variations in output weight after cooking, cooking time, total variable cost, total revenue, and gross margin across different samples of Lima beans cooked using the firewood method. Samples, such as V8, V1, and V16, have positive gross margins, indicating profitability from the cooking process.

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Samples	Weight before cooking (g)	Cost of Lima Beans per 150 (g)	Cost of firewood (₦)	Output after cooking (g)	Cooking time (mins)	Price of firewood per cooking time (₦)	Price of output after cooking (₦)
V11	150	75	4000	251	154	546.58	250
V8	150	75	4000	342	100	354.92	250
V1	150	75	4000	381	116	411.71	250
V16	150	75	4000	357	105	372.67	250
V18	150	75	4000	337	131	464.95	250
V7	150	75	4000	435	92	326.53	250
V9	150	75	4000	273	91	322.98	250
V13	150	75	4000	428	54	191.65	250
V15	150	75	4000	377	166	589.17	250
V14	150	75	4000	341	118	418.81	250

Table 3: Analysis of use of firewood in cooking lima beans varieties

Source: Experimental data, 2024. ***Conversion rate-1Naira = USD 1,500

Profitability analysis of use of firewood in cooking lima beans varieties

Samples V13, V7, V1 and V16 exhibit significant profitability as seen from Figure 2, however, sample V13 had the highest profitability with a contribution margin of ₦67,001.11, followed by V7 (₦48,520.41). These samples reflect high revenue relative to their costs, demonstrating efficient resource usage and/or favorable pricing strategies. Marginally profitable samples from table 5 are V9, V14 and V18 with lower margins compared to the leading samples.

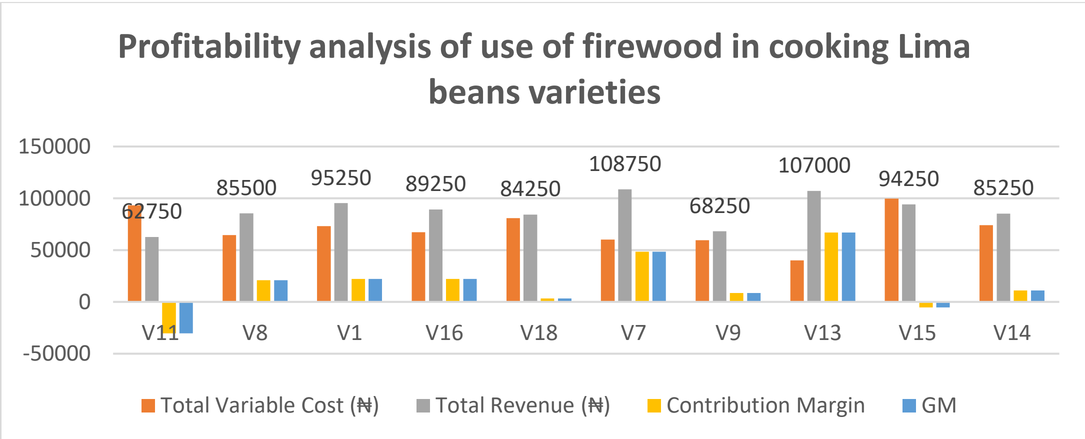

Figure 2: Profitability analysis of use of firewood in cooking Lima beans varieties; Source: Experimental data, 2024. ***Conversion rate-1Naira = USD 1,500.

Analysis of use of Charcoal in cooking Lima beans

The result of economic analysis of cooked lima beans using charcoal fuel source is presented in Table 4. All the samples had a positive contribution and gross margin.

Samples	Weight before cooking (g)	Cost of Lima Beans per 150 (g)	Cost of gas (₦)	Output after cooking (g)	Cooking time (mins)	Price of Gas per cooking time (₦)	Price of output after cooking (₦)
V11	150	75	3000	323	95	268.11	250
V8	150	75	3000	336	110	310.44	250
V1	150	75	3000	462	94	265.28	250
V16	150	75	3000	452	151	426.15	250
V18	150	75	3000	346	100	282.22	250
V7	150	75	3000	338	109	307.62	250
V9	150	75	3000	397	120	338.66	250
V13	150	75	3000	383	80	225.78	250
V15	150	75	3000	306	120	338.66	250
V14	150	75	3000	342	84	237.065	250

Table 4: Analysis of use of charcoal in cooking lima beans varieties

Sources: Experimental data, 2024. ***Conversion rate-1Naira = USD 1,500

Profitability Analysis of use of charcoal in cooking Lima beans varieties

Samples V1 has seen in Figure 3 has the highest profitability with a contribution margin of ₦64,456.96 and a GM of 55.81% which indicates that a unit kg of charcoal used in cooking lima beans will produce 55.81 GM and a contribution margin of 64,456.96 which is able to cover all cost incurred and still generate profit. Sample VI3 has a GM of 52.88, while VI4 has a GM of 45.2.

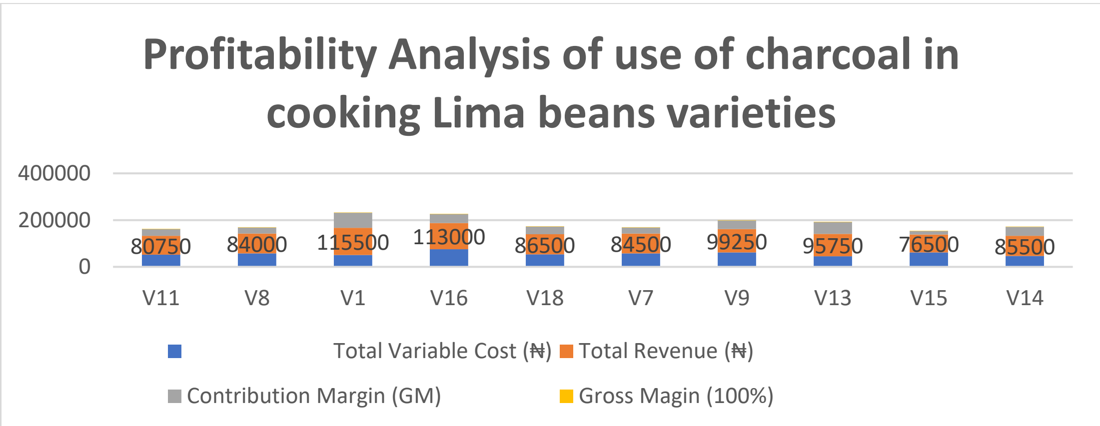

Figure 3: Profitability Analysis of use of charcoal in cooking Lima beans varieties; Sources: Experimental data, 2024. ***Conversion rate-1Naira = USD 1,500

Energy Efficiency of different cooking sources

The Energy Efficiency (EE) results highlight how effectively each lima bean variety utilizes gas for cooking, measured by the output of cooked beans per unit cost of gas. The most Energy-Efficient Variety as seen in Table 5 is V14 with an energy efficiency value of 1.028g/₦.

Samples	Output after cooking (g)	Price of Gas per cooking time (₦)	Energy Efficiency (g/₦)
V11	214	417.09	0.51
V8	386	709.94	0.54
V1	336	479.21	0.70
V16	335	541.33	0.62
V18	324	603.45	0.54
V7	218	532.46	0.41
V9	359	541.33	0.66
V13	364	510.27	0.71
V15	353	709.94	0.50
V14	365	354.97	1.03

Table 5: Energy Efficiency of Lima beans varieties using gas as fuel source.

Source: Experimental data, 2024. ***Conversion rate-1Naira = USD 1,500

Energy Efficiency of cooking Lima beans Varieties using firewood as fuel source

The most Energy-Efficient Variety from Table 6 is sample V13 with an output of 2.233 g/₦. It demonstrates a high energy efficiency with low firewood cost per cooking time at ₦191.66 and high output of 428g, making it the most cost-effective.

Samples	Output after cooking (g)	Price of firewood per cooking time (₦)	Energy Efficiency (g/₦)
V11	251	546.58	0.46
V8	342	354.93	0.99
V1	381	411.72	0.9
V16	357	372.67	0.96
V18	337	464.95	0.73
V7	435	326.53	1.33
V9	273	322.98	0.85
V13	428	191.65	2.23
V15	377	589.18	0.64
V14	341	418.81	0.82

Table 6: Energy Efficiency of cooking Lima beans Varieties using firewood as fuel source

Source: Experimental data, 2024. ***Conversion rate-1Naira = USD 1,500

Energy Efficiency of cooking Lima beans Varieties using charcoal as fuel source

From Table 7, sample VI is the most Energy-Efficient Variety with an EE value of 1.741 g/₦ indicative of the highest output per unit cost of charcoal. The second most Energy Efficient sample is V13 with an EE value of 1.697 g/₦), this also implies that low charcoal costs and usage contributes to its strong performance.

Samples	Output after cooking (g)	Price of Charcoal per cooking time (₦)	Energy Efficiency (g/₦)
V11	323	268.11	1.20
V8	336	310.44	1.08
V1	462	265.29	1.74
V16	452	426.15	1.06
V18	346	282.22	1.23
V7	338	307.62	1.10
V9	397	338.66	1.17
V13	383	225.78	1.70
V15	306	338.66	0.90
V14	342	237.06	1.44

Table 7: Energy Efficiency of cooking Lima beans Varieties using charcoal as fuel source

Source: Experimental data, 2024. ***Conversion rate-1Naira = USD 1,500

DISCUSSIONS

Analysis of use of gas in cooking lima beans

Upon analyzing the data presented in Table 2, several key findings emerged. There were variations in the following variables: output after cooking and cooking time. These factors contributed immensely to the Price of gas after cooking, Total Variable Cost and Total Revenue. The variation in cooking efficiency as indicated by the output after cooking, varies among the different samples. Samples V1, V13 and V14 gave positive outcomes. Total revenues were ₦84,000 (USD 56), ₦91,000 (USD 60.67) and ₦91,250 (USD 60.83), respectively, while TVC was ₦83,131.67 (USD 55,42), ₦87,790.63 (USD 55.53) and ₦64,495.69 (USD 43.00), respectively Their resultant Gross Margin was ₦868.32 (USD 0.59), ₦3,209.32 (USD 2.14) and ₦26,754 (USD 17.84), respectively. This result implies that samples V1, V13 and V14 are the three main samples that justified the use of gas in cooking them, while it is not cost-effective cooking method for the other samples.

Profitability analysis of use of gas in cooking lima beans

This outcome from Figure 1 shows that most samples VII, V8, V16, V18 exhibited negative contribution margin, indicating that the revenue generated does not cover the variable costs. This signals a loss-making scenario for those samples. However, samples V1, V13, and V14, have positive contribution margin, suggesting some level of profitability. Among these samples, V14 has the highest profitability, with a Gross Margin (GM) of 29.32%, this is followed by V13 with a GM of 3.53% and V1 with a GM of 1.03%, respectively. This implies that a unit Kg of gas used in cooking sample VI4 will produce 29.32kg of lima beans, while 3.53kg of VI3 was obtained from using a unit kg of gas and 1.03kg of VI was obtained from a unit kg of gas. Therefore, suggesting that sample V14 is the most profitable with significant and positive contribution margin and Gross Margin. In contrast, samples like V15 and V8 exhibited substantial losses with large negative Gross Margins (-33.42% and -22.01%, respectively). The high variable costs relative to revenue in many of the samples indicate inefficiencies, potentially from suboptimal gas use, poor pricing strategies, or high input costs. Consequently, the high TVC in most samples suggests the need to assess gas usage efficiency or explore alternative energy sources to reduce variable costs. For unprofitable samples, revenue does not sufficiently cover costs, which may require revisiting the pricing strategy to align with production expenses. It is therefore suggestive that profitable samples like V14 could serve as a benchmark. Analyzing these cases can highlight best practices in cost management and pricing, and only samples with positive profitability (V14 and V13) should be considered for scaling, while the rest require strategic interventions to improve financial viability. The outcome from table 3 therefore highlights significant variability in the profitability of using gas to cook lima beans across different samples. While some are profitable, the majority are not, signaling the need for targeted strategies to optimize costs, adjust pricing, and replicate successful practices from profitable cases.

Analysis of use of firewood in cooking Lima beans

The firewood method of cooking lima beans as presented in Table 3 shows data detailing various parameters associated with the cooking process and financial outcomes. The data presented in the table show variations in output weight after cooking, cooking time, total variable cost, total revenue, and gross margin across different samples of Lima beans cooked using the firewood method. Samples, such as V8, V1, and V16, have positive gross margins, indicating profitability from the cooking process. These samples generate revenue exceeding the total variable cost of cooking, resulting in a net profit. Furthermore, the price of firewood per cooking time varies among samples, indicating differences in fuel efficiency during the cooking process and as exhibited by the samples. Two of the samples, V11 and V15, have negative gross margins, indicating losses incurred from the cooking process. This suggests that the revenue generated from selling the cooked beans is insufficient to cover the costs of Lima beans and firewood used.

Profitability analysis of use of firewood in cooking lima beans varieties

Samples V13, V7, V1 and V16 exhibit significant profitability as seen from Figure 2, however, sample V13 had the highest profitability with a contribution margin of ₦67,001.11, followed by V7 (₦48,520.41). These samples reflect high revenue relative to their costs, demonstrating efficient resource usage and/or favorable pricing strategies. Marginally profitable samples from table 5 are V9, V14 and V18 with lower margins compared to the leading samples. For instance, sample V18's contribution margin is ₦3,237.32 indicating a very tight profit margins, potentially due to high variable costs. Subsequently, unprofitable samples showing negative profitability are samples V11 and V15 with V11 having the largest loss -₦30,487.58. This loss indicates that the costs of using firewood significantly outweigh the revenues generated. The cost and revenue efficiency of sample V13 stands out with both the lowest cost at

₦39,998.89 and one of the highest revenues at ₦107,000, showcasing exceptional efficiency. Conversely, V15 has high costs ₦99,626.22 but does not generate sufficient revenue ₦94,250 to break even. Samples V13 and V7 should be analyzed to identify best practices in firewood usage, process optimization, and cost control (Ologhobo and Fetuga, 2016). Samples with high TVC, such as V15 and V11 should explore strategies to reduce firewood consumption or substitute with more efficient alternatives. For marginally profitable samples V18 and V14, efforts should focus on increasing the selling price or value addition to boost revenues. Profitable samples represented by V13, V7, V1, and V16 are therefore ideal for scaling, as they demonstrate cost-effective operations with strong revenue streams. While firewood is traditionally cost-effective, losses in some cases suggest the need to evaluate alternative energy sources for specific varieties to balance costs and environmental sustainability (Tsvetkova *et al.,* 2020). The profitability of using firewood for cooking lima beans varies significantly across samples, with some showing strong financial performance while others incur losses. Strategies such as cost optimization, efficient resource management, and enhanced revenue generation should be implemented for unprofitable and marginally profitable samples (Weldegiorgis, 2018). Consequently, leveraging the success factors of top-performing samples can guide future improvements and scalability efforts.

Analysis of use of Charcoal in cooking Lima beans

The result of economic analysis of cooked lima beans using charcoal fuel source is presented in Table 4. This shows the variations in output weight after cooking, cooking time, total variable cost, total revenue, contribution margin, and gross margin across the different samples. All the samples had a positive contribution and gross margin. Sample V15 had the least gross margin of 18.89, followed by V8 (31.17). V1 has the highest gross margin of 55.81, followed by V13 (52.88). The implication of this is that for every 1 naira spent in the purchase of charcoal, samples V1 and V13 will produce 55.81 and 52.88 more lima beans saving ₦64,456.96 (USD 42.97) and ₦50,633 (USD 33.76), respectively

Profitability Analysis of use of charcoal in cooking Lima beans varieties

Samples V1 has seen in Figure 3 has the highest profitability with a contribution margin of ₦64,456.96 and a GM of 55.81% which indicates that a unit kg of charcoal used in cooking lima beans will produce 55.81 GM and a contribution margin of 64,456.96 which is able to cover all cost incurred and still generate profit. Sample VI3 has a GM of 52.88, while VI4 has a GM of 45.2. This implies that samples VI. These implies that samples VI, VI3 and VI4 demonstrates efficient cost management and strong revenue generation tendencies when charcoal was used in cooking it, indicating an optimal use of charcoal. Samples like VII with a gross margin of 36.26, VI8 (GM of 38.05) and V9 (GM of 37.48) are also profitable but with lower gross margins. Suggesting marginal performance with a potential for further optimization. On the other hand, V15 has the lowest profitability potential recorded after cooking with charcoal. With a contribution margin of ₦14,450.3 and a gross margin of 18.89%, indicating inefficiencies in managing costs or generating revenue relative to other samples. Furthermore, deeper insight into the relationship between cost and revenue shows that VI3 had significant profitability value with the lowest TVC of ₦45,116.42 and a high TR of ₦95,750. Suggesting that using charcoal to cook VI3 is more profitable with a profit of ₦50,633.58 after deducting TVC from TR. Conversely, V16 has a higher TVC ₦75,172.86 but still achieves moderate profitability due to a strong TR of ₦113,000, with an overall profit of ₦37,827.14. Sample V15's low profitability can be attributed to its high TVC of ₦62,049.62 combined with a relatively low TR of ₦76,500. The overall outcomes from table 7 shows best performing samples as VI, VI3 and VI4 when cooked with charcoal and these can serve as benchmarks for cost efficiency and revenue generation strategies. However, samples like V15 need targeted cost-reduction strategies, such as optimizing charcoal usage or negotiating better input prices, to improve margins. Samples with moderate profitability for instance V16, V11, and V18 could explore strategies to enhance revenue, such as better pricing, improving product quality, or value addition (Kalinichenko and Havrysh, 2019; Osabohien, 2022). Subsequently, high-performing samples like V1, V13, and V14 are strong candidates for scaling up due to their efficiency and profitability (Koutsandreas, *et al.,* 2022; Obisesan *et al.,* 2024). Focusing on replication of these samples will serve as best practices compared to other varieties. The use of charcoal for cooking lima beans is generally profitable across most samples, with significant variations in performance. High-performing samples demonstrated excellent cost-to-revenue ratios, while low-performing samples highlights the need for better cost control and revenue strategies.

Energy Efficiency of using gas in cooking Lima beans Varieties

The most Energy-Efficient Variety as seen in Table 5 is V14 with an energy efficiency value of 1.028g/₦. This variety provides the highest output per unit cost of gas, meaning it is the most cost-effective for cooking. It requires less gas expense relative to the quantity of cooked output achieved. On the other hand, the least Energy-Efficient Variety is V7 (0.409 g/₦), this variety is consuming significantly more gas for a smaller relative output. This might be due to factors like longer cooking times or less effective heat transfer during cooking or the specie type of the lima beans which might take longer to cook (El-Gohery, 2021). Samples V13, V1, V9 exhibit moderate efficiency (EE values around 0.7 g/₦). They are reasonably cost-effective but not the best. These may be good alternatives if other factors (e.g., taste, texture) make them preferable. Varieties like V8 and V15 show relatively lower efficiency despite high outputs because they require more gas due to longer cooking times.

Energy Efficiency of cooking Lima beans Varieties using firewood as fuel source

The most Energy-Efficient Variety from Table 6 is sample V13 with an output of 2.233 g/₦. It demonstrates a high energy efficiency with low firewood cost per cooking time at ₦191.66 and high output of 428g, making it the most cost-effective. The second most Efficient is sample V7 (1.333 g/₦). It is another efficient option, combining a high output (435g) with moderate firewood costs. Samples V8, V1, V16 show cases moderate Efficiency with EE values of ~0.9–0.96 g/₦), making them reliable but not the best options. The least Efficient Variety is V11 (0.459 g/₦). It uses the most firewood per unit of cooked output, indicating inefficiency and high cost. Thus, varieties with lower firewood costs (e.g., V13) tend to achieve higher efficiency, while varieties like V15 and V11 incur higher costs, reducing their EE. Therefore, V13 and V7 are the ideal choices for cost-conscious and energy-efficient lima beans varieties to be cooked with firewood as fuel source. Varieties like V11 and V15 should be reevaluated for cooking practices, as their inefficiency could stem from suboptimal heat transfer or longer cooking times.

Energy Efficiency of cooking Lima beans Varieties using charcoal as fuel source

From Table 7, sample VI is the most Energy-Efficient Variety with an EE value of 1.741 g/₦ indicative of the highest output per unit cost of charcoal. The second most Energy Efficient sample is V13 with an EE value of 1.697 g/₦), this also implies that low charcoal costs and usage contributes to its strong performance. Those with high Energy Efficiency are V14 (1.443 g/₦) and V18 (1.226 g/₦), respectively. Both varieties demonstrate good energy efficiency, balancing reasonable charcoal costs with substantial output. Least Efficient Variety V15 (0.904 g/₦) requires the most charcoal cost relative to its output, making it the least efficient. While moderate Energy Efficient varieties are V11, V8, V9, V7. These varieties achieve moderate EE values (~1.1–1.2 g/₦), indicating average performance. Therefore, consumers aiming to save on charcoal costs should prioritize samples V1, V13 and V14, which deliver better outputs for the cost. Inefficient varieties like V15 may benefit from adjustments in cooking methods to reduce charcoal consumption.

Implications to Research and Practice

Based on this research findings, the following recommendations were proposed: Conduct further studies to assess the long-term sustainability and environmental impact of these different cooking methods, especially the use of charcoal which according to this research has been found to have the least cost and a better Gross Margin. The environmentalist and sustainable development practitioners might want to fault the use of charcoal based on green gas emission and de-forestation. We therefore suggest the inclusion of biogas, electricity, and solar methods of cooking in future analysis of economics of cooking lima beans. We also suggest the exploration of strategies to improve cooking efficiency and reduce gas consumption, such as the use of energy-efficient appliances and optimized cooking techniques. There is the need to invest in research and development initiatives to innovate cooking technologies particularly for the under-utilized legumes which have household and industrial potentials for enhanced food and nutrition security and overall competitiveness of the food processing industry.

CONCLUSIONS

Evidence-based research on the economic analysis of cooking methods can inform consumers, processors and breeders on choice of lima beans suitable at promoting sustainable cooking practices with the least cost possible. Therefore, this research findings on the economic analysis of cooking lima beans with different cooking methods, underscore the importance of considering efficiency, costs, and profitability when evaluating different cooking methods for lima bean processing. Using efficient varieties like V1 and V13 will reduce the overall charcoal usage, resulting in cost savings and minimized environmental impact. Varieties with high EE, such as V13 and

V7, use less firewood, reducing deforestation and environmental impact. Therefore, since cost and energy savings are priorities, sample V14 is the best choice when gas usage is concerned. However, V13 and V1 are also strong options, offering good efficiency with possibly desirable cooking outcomes. For Producers and breeders, Energy-efficient varieties like V14 might appeal to markets sensitive to gas or energy costs. Promoting this variety can highlight its economic and environmental benefits. Efficient varieties reduce gas usage and related emissions, making them more environmentally friendly. Sample V14 therefore sets a benchmark for sustainable cooking.

Furthermore, while the gas fuel source offers convenience and versatility, its economic viability depends on factors such as cooking time, gas consumption, and market dynamics, which made the method highly expensive. The use of gas for cooking lima beans has the least economic value, as a result of high cost of gas compared to the other two methods (charcoal and firewood, respectively). The use of charcoal has the best returns on investment and is the best cooking method suggested, based on the research outcomes. Consequently, the use of charcoal had an overall positive gross margin while the use of firewood recorded two negative gross margins among the samples. Therefore, using charcoal to cook lima beans was found economically viable and this could serve as a potential cooking method for processing lima bean for enhanced food and nutrition security.

Future Research

There is a dearth of literature on economics of cooking and cooking efficiency for different cooking methods for cooking lima beans, hence this is an area future researchers can look into.

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