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Enhancement of Ripe Plantain Cake Production Using Work Study Approach

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Abstract

Ripe plantains have a very short post-harvest shelf life of just 3-5 days at room temperature due to their high moisture content of 70-80%. This research aims to enhance the production process of over-ripe plantain cake in Ikire Town, Osun State, latitude 7° 21' 36.00"N, Longitude 4° 11' 6.00"E, Nigeria, addressing critical inefficiencies and promoting sustainability within the industry. The study investigates the entire processing chain, from the peeling of over-ripe plantains to the final packaging of the cake, to identify key issues that hinder productivity, quality, and economic viability. A comprehensive work study, including time and motion analysis, resource allocation assessment, and process optimization, was conducted to uncover opportunities for reducing processing time, minimizing waste, and improving resource utilization. The research revealed significant inefficiencies in the manual processing methods currently used, leading to increased production costs, inconsistent product quality, and substantial post-harvest losses. The findings highlight the need for an optimized process flow that enhances productivity and ensures the sustainability of plantain cake production.

Keywords: *Work study, over-ripe plantain cake, production enhancement, Osun State.*

1. Introduction

Ripe plantains (Musa spp.) are a staple in tropical regions across Africa, Central America, and parts of Asia, providing essential nutrients and income for local communities [1-8]. Their high moisture content (70-80%) leads to a short shelf life of just 3-5 days, contributing to postharvest losses of up to 50% if not processed or consumed promptly [9, 15-19]. Processing ripe plantains into products like pastes, flours, and chips can reduce losses, improve food security, and generate income [10-14, 61].

Technological advancements, including automation in mixing and baking, have significantly improved production efficiency in plantain-based products [20-28]. Sensory evaluations show that consumers prefer plantain cakes with moderate sweetness and cinnamon, guiding product development [29-32, 38-40]. Additionally, innovative approaches, such as using overripe plantains for lactic acid production, provide value-added opportunities [33-36, 49].

Optimizing the entire processing chain through systematic analysis can enhance efficiency, product quality, and sustainability, making plantain processing more competitive and reducing economic losses [41-48, 54, 59].

This background highlights the importance of conducting a detailed work study on ripe plantain processing practices, with the aim of improving efficiency, product quality, and overall competitiveness in the industry [50-53, 55-58, 60].

2. Materials and Methods

2.1. Conceptual Framework of Research

The conceptual framework outlines the steps and methodologies used to conduct this research. It serves as a blueprint for systematically analyzing the production processes in the over-ripe plantain cake (Dodo Ikire) industries and developing new methods to improve productivity, efficiency, and resource utilization. Here's a detailed explanation of each step in the conceptual framework:

2.1.1. Gathering Data

The first step in the research involves collecting background information. This is achieved through:
Literature Review: A comprehensive review of existing research and academic literature related to over-ripe plantain cake production, time study techniques, work-study methods, and productivity improvement strategies. The literature review provides insights into the current state of the industry,

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identifies gaps in knowledge, and helps in understanding the challenges faced by production facilities.

Concept Development: Based on the literature review, the research conceptualizes the specific areas of focus, such as time optimization, resource allocation, and productivity improvement. Theoretical concepts and models relevant to the research are identified and used as the basis for the analysis.

2.1.2. Select the Over-ripe Plantain Cake Production Industries

This step involves identifying the specific industries that produce over-ripe plantain cakes in Ikire, Osun State. The industries are chosen based on:

Relevance: Industries that produce over-ripe plantain cakes using traditional methods that are representative of the broader industry in Ikire.

Accessibility: Industries that are accessible for data collection and observation.

Diversity: Ensuring a mix of small, medium, and large-scale production facilities to get a comprehensive understanding of the industry.

2.1.3. Select Production Facilities with Similar Methods of Processing

The next step is to select production facilities that use similar methods of processing over-ripe plantain cakes. This ensures that the comparison between facilities is fair and that the findings can be generalized across the industry. The selection is based on:

Process Uniformity: Facilities that follow similar steps in the production process, such as sorting, peeling, blending, frying, and packaging.

Production Scale: Facilities that operate on similar scales (e.g., small or medium enterprises) to allow for comparable data analysis.

2.1.4. Observe All Operations Along with Time Study

This step involves a detailed observation of all operations within the selected production facilities. The observations are focused on:

Time Study: Measuring the time taken for each operation in the production process. This involves recording the observed times, selecting the standard times, and calculating the basic and standard times for each operation.

Workflow Analysis: Understanding the sequence of operations, the flow of materials, and the utilization of resources (e.g., labor, machinery) in the production process.

Data Collection: Gathering quantitative data on production times, output rates, manpower usage, and plantain utilization.

2.1.5. Identify Existing Problems by Critical Questioning Technique

After the time study and workflow analysis, the next step is to identify existing problems within the production processes. This is achieved through:

Critical Questioning Technique: Engaging with workers, supervisors, and managers to identify pain points, inefficiencies, and challenges in the production process. Questions are asked about the reasons for delays, bottlenecks, and waste in the system.

Problem Identification: Using the data collected and feedback from stakeholders to pinpoint specific areas where the process is suboptimal or inefficient.

2.1.6. Analyze Problems and Develop New Techniques

Once the problems are identified, the research moves to the analysis phase. This involves:

Problem Analysis: Using tools like root cause analysis, Pareto charts, and fishbone diagrams to understand the underlying causes of the problems identified.

Development of New Techniques: Based on the analysis, new techniques and methods are proposed to address the identified issues. This could include the introduction of automation, process reengineering, or the adoption of lean manufacturing principles.

2.1.7. Suggest More Effective Process with Effective Layout to Improve

This step involves designing and suggesting a more effective production process that includes:

Process Optimization: Proposing changes to the production sequence, time allocation, and resource utilization to improve efficiency.

Effective Layout: Designing a more efficient facility layout that reduces movement, minimizes waste, and enhances workflow. This may involve rearranging workstations, optimizing material flow, and reducing transportation time within the facility.

2.2. Data Collection and Analysis

The following tools were employed to enable data collection and analysis. These include:

2.2.1. Time Observed

It is the time taken to carry out a single operation or series of operations, which can be determined through direct measurement.

2.2.2. Time Considered

The time chosen as being representative of a group time for an operation or group of work by calculating mean, median or mode.

2.2.3. Rating

Rating is the assessment of the worker's performance rate of working relative to the observer's concept of the rate corresponding to standard pace. The commonly used rating scale in use is shown in Table 1.

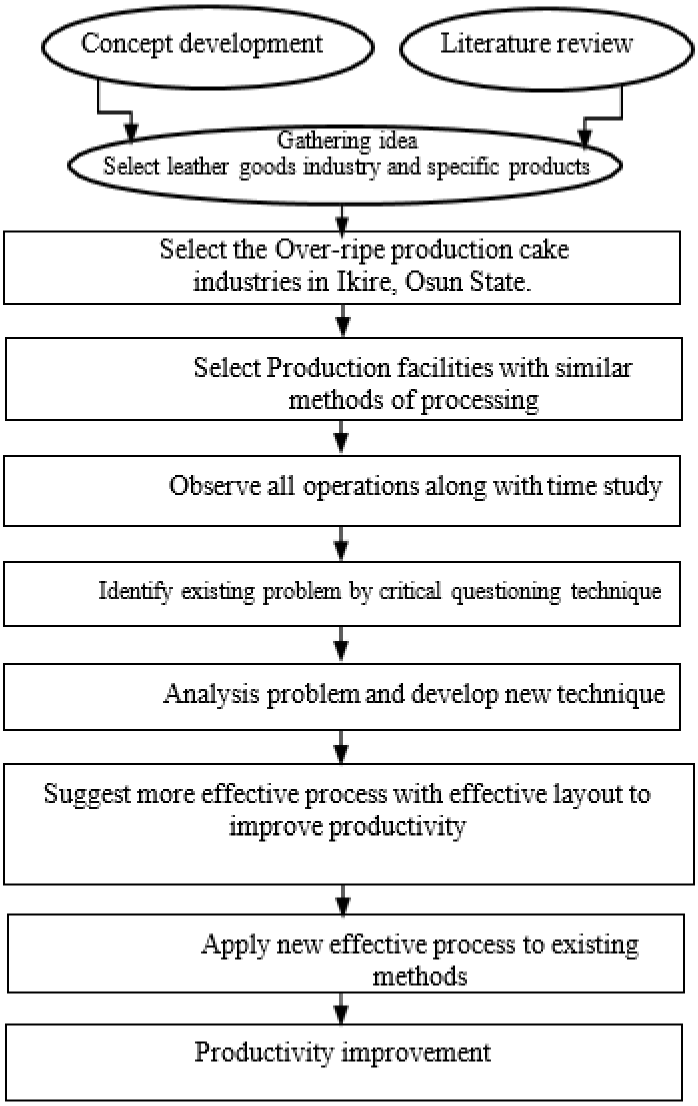

Figure 1: Conceptual Framework of Research

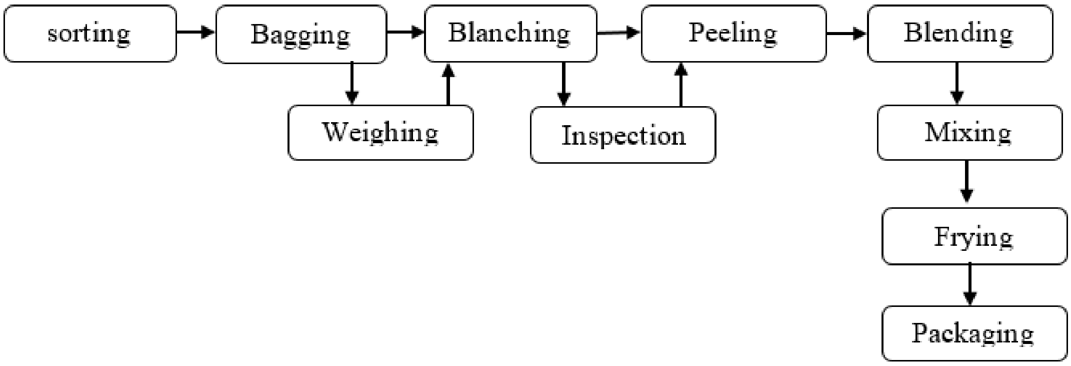

Figure 2: Production flow chart for the existing Method

Table 1: Rating Scale [37].

Rating scale	Description
0	No Activity
50	Very slow, clumsy, fumbling movements, operative appear half-asleep, with no interest in the job
75	Steady, deliberate, unhurried performance, as of a worker not on Piecework but under proper supervision, looks slow, but time not being intentionally wasted while under observation
100	Brisk. Business-like performance, as of an average qualified worker on piecework, necessary standard quality and accuracy standard rate achieved with confidence
125	Very fast, operative exhibits a high degree of assurance, dexterity and co-ordination of movement, well above that of an average works
150	Exceptionally fast, requires intense effort and concentration and is us-likely to be kept up for long periods, a performance achieved only by a few outstanding workers

Table 2: Productivity Comparison

Facility	Average Production Time (min)	Average Output (packs/day)	Total weekly Output (units)	Total Plantains Used
Oja Ale Market	394	388	12,018	2,404
Total Station Market	439	410	11,856	2,371
Gbongan Garage Market	338	367	11,244	2,249
Oja Tuntun Market	318	333	11,082	2,216

2.2.4. Basic Time

Basic time is the minimum time theoretically required to produce one unit of output, assuming optimal conditions. It represents the time needed to perform an element of work at a standard performance level without any delays or interruptions.

$$Basic\ time = \frac{observed\ time * observed\ rating}{standard\ rating} \quad (1)$$

2.2.5. Standard Time

Standard time is the total duration within which a job should be completed when performed at standard efficiency.

$$Standard\ Time = Basic\ Time + Allowances \quad (2)$$

For allowances, 15% relaxation allowances and 3% contingency allowances was considered.

2.2.6. Relaxation Allowances

Relaxation allowance is an addition to the basic time, providing workers the opportunity to recover from the physiological and psychological effects of performing a specified operation and to attend to personal needs. The amount of this allowance varies depending on the nature of the work. Typically, a relaxation allowance of 15% of the basic time was added to calculate the standard time from the basic time.

2.2.7. Contingency Allowances

A contingency allowance is a small amount of time included in the standard time for time studies to account for unexpected delays or minor interruptions. In this study, 3% contingency allowance of the basic time was considered to calculate the standard time.

$$Efficiency = \frac{Minutes\ output}{Minutes\ input} \quad (3)$$

$$Increasing\ efficiency = [\frac{(the\ efficiency\ of\ proposed\ line - present\ efficiency)}{Present\ efficiency}] * 100 \quad (4)$$

2.3. Comparative Analysis

Four production facilities were selected, Oja Ale Market, Total Station Market, Gbongan Garage Market, And Oja Tuntun Market; analysed and established to exhibit varying degrees of productivity, efficiency, time optimization, and resource allocation. A comprehensive comparison is presented below to identify areas for improvement and propose a more effective system.

2.3.1. Production Time and Output

The production time across all four facilities varies significantly. The average production time and corresponding output for each facility are summarized in Table 2.

Analysis

i. Oja Tuntun Market shows the shortest average production time at 318 minutes, which correlates with a reasonable average output of 333 packs per day.
ii. Total Station Market has the highest average production time of 439 minutes but also achieves a higher average output of 410 packs per day.
iii. Oja Ale Market strikes a balance between production time (394 minutes) and output (388 packs), resulting in the highest total production output of 12,018 units.
iv. Gbongan Garage Market operates with a shorter average production time (338 minutes) but has a slightly lower output compared to the other markets.

2.3.2. Efficiency Analysis

Efficiency is a crucial metric that indicates how well the resources (time and manpower) are utilized to achieve the output. The efficiency of each facility is calculated as the ratio of minute output to minute input.

Table 3: Production Facilities Efficiencies

Facility	Efficiency (%)
Oja Ale Market	81
Total Station Market	78
Gbongan Garage Market	66
Oja Tuntun Market	69

Table 4: Production Time Optimization

Facility	Average Production Time (min)	Average Output/Hour
Oja Ale Market	394	59
Total Station Market	439	56
Gbongan Garage Market	338	65
Oja Tuntun Market	318	63

Table 5: Comparison of Manpower and Machinery Utilization across Facilities

Facility	Average Manpower	Machinery Use
Oja Ale Market	3.0	2 operations
Total Station Market	3.1	2 operations
Gbongan Garage Market	4.0	1 operation
Oja Tuntun Market	3.5	1 operation

Analysis

i. Oja Ale Market demonstrates the highest efficiency at 81%, indicating better utilization of time and manpower to achieve higher output.
ii. Total Station Market follows closely with an efficiency of 78%, despite having the longest production time.
iii. Oja Tuntun Market and Gbongan Garage Market have lower efficiencies at 69% and 66%, respectively. While these facilities operate with shorter production times, they produce slightly lower outputs, affecting their overall efficiency.

2.3.3. Time Optimization Analysis

i. Oja Tuntun Market and Gbongan Garage Market exhibit the shortest average production times (318 and 338 minutes, respectively), leading to higher output per hour.
ii. Oja Ale Market strikes a balance between production time and output, achieving optimal time management while maintaining high productivity.

2.3.4. Resource Allocation

Resource allocation, particularly the allocation of manpower and machinery, plays a significant role in the production process. The comparison of manpower and machinery utilization across facilities is presented in Table 5.

Analysis

i. Oja Ale Market and Total Station Market utilize a similar amount of manpower (3.0 and 3.1, respectively) and have two operations that rely on machinery, which likely contributes to their higher efficiencies.
ii. Gbongan Garage Market has the highest average manpower utilization at 4.0 but only uses machinery for one operation. This may lead to increased labour costs without a corresponding increase in efficiency.
iii. Oja Tuntun Market uses 3.5 workers on average and relies on machinery for one operation. Despite the higher manpower, the facility still maintains a lower efficiency than Oja Ale Market.

Table 6: Comparison of Existing and Proposed Methods

Operation	Existing Method	Proposed Method
Sorting	Manual sorting by workers, leading to variable processing times	Automated sorting using conveyor belts to ensure consistent speed
Bagging & weighing	Manual bagging and weighing; prone to human error	Semi-automated bagging and weighing to improve accuracy and speed
Peeling	Manual peeling; time-consuming and labour-intensive	Introduction of automatic peelers to speed up the process
Blanching	Manual blanching; inconsistent timing and results	Standardized blanching process with automated timing controls
Blending & mixing	Manual or partially automated; inconsistent mixing	Fully automated blending and mixing for consistent results
Frying	Manual frying; variability in quality and timing	Automated frying with consistent temperature control
Inspection	Limited or manual inspection; prone to missed defects	Automated inspection systems with real-time feedback
Packaging	Manual packaging; inconsistent speed and quality	Automated packaging to ensure consistency and reduce labour costs
Time Management	No standardized time management; variability in production times	Lean time management principles and real-time monitoring systems
Workforce Allocation	High manual labour requirement; inefficient use of manpower	Optimized workforce allocation with cross-training for flexibility

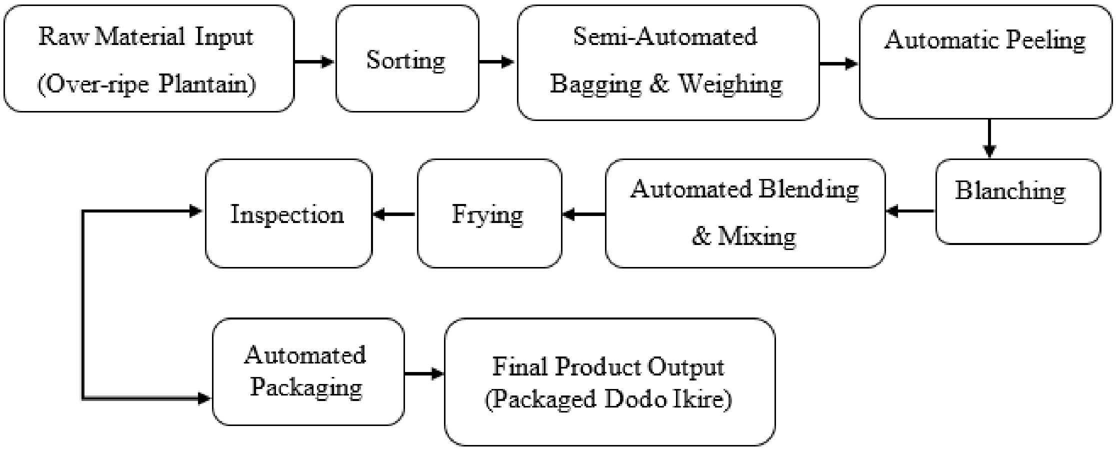

Figure 3: Proposed Production Flowchart

Table 7: Comparison with Existing Production Facilities

Parameter	Oja Ale Market	Total Station Market	Gbongan Garage Market	Oja Tuntun Market	New Production Facility
Total Production Time (Minutes/Day)	394	439	338	318	307
Total Output (Packs/Day)	388	410	367	367	460
Total Production/Unit (Daily)	2328	2371	2248	2216	2760
Plantain Usage (Daily)	480	474	449	443	394
Efficiency (%)	81%	78%	66%	69%	88%
Manpower Required	24	31	28	21	13
M/C or Manual	Mostly Manual	Mostly Manual	Mostly Manual	Mostly Manual	Mostly Automated

2.3.5. Evaluation of the Best Production Facility

Based on the analysis, Oja Ale Market emerges as the best production facility for several reasons:

i. Time Optimization: The facility maintains a balanced production time while achieving a high output, leading to a strong overall performance.

ii. Production Output: Oja Ale Market consistently produces the highest total output (12,018 units) with a favourable daily output (388 packs).

iii. Efficiency: With the highest efficiency of 81%, Oja Ale Market maximizes its resources to achieve the best results among all facilities.

iv. Resource Allocation: The facility uses a balanced amount of manpower and machinery, contributing to its superior performance.

The findings suggest that other facilities could improve their operations by adopting similar strategies used by Oja Ale Market, such as better time management practices and more strategic use of machinery in the production process.

3. Results and Discussion

3.1. Comparison of Existing and Proposed Methods

Below is a comparison of the existing methods and the proposed methods for the new production system. The table summarizes the key differences in approach to improve productivity, time optimization, and resource allocation across the production facilities.

3.2. New Production Flowchart

The new proposed production flowchart is designed to improve productivity, time optimization, and resource allocation. It integrates the proposed methods for each operation, streamlining the workflow and reducing bottlenecks.

This flowchart represents a more efficient production system where automation and standardization play key roles in enhancing productivity, reducing manual labour dependency, and optimizing time management.

3.3. Comparison with Existing Production Facilities

The following table compares the data of the new production facility with the other existing production facilities.

4. Implementation Plan

To implement the new production system, the following steps should be taken:

Procurement of Machinery: Invest in automated systems for sorting, peeling, blending, mixing, frying, inspection, and packaging.

Training and Development: Train workers on operating new machinery and maintaining standardized processes.

Pilot Testing: Implement the new system in a pilot phase to identify any issues and make necessary adjustments.

Full Implementation: Roll out the new system across all production facilities, with continuous monitoring and evaluation.

Continuous Improvement: Regularly review performance data to identify further opportunities for optimization.

By following this plan, the production facilities will experience significant improvements in productivity, time efficiency, and resource utilization, leading to enhanced overall performance and competitiveness.

5. Conclusion

The analysis reveals that the proposed new production facility, with its automated processes and optimized resource allocation, outperforms the existing facilities in terms of productivity, efficiency, and resource utilization. The significant reduction in manpower and plantain usage further underscores the effectiveness of the proposed methods. This new system is not only more productive but also more cost-effective and efficient, setting a new standard for production processes.

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