WEB-BASED BAKERY PRODUCTION MANAGEMENT SYSTEM

CASE STUDY OF MAMA KEVINNA BAKERY TORORO

BY

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A PROJECT REPORT SUBMITTED TO THE FACULTY OF SCIENCE AND EDUCATION IN PARTIAL FULFILLMENT FOR THE AWARD OF BACHELOR OF SCIENCE AND EDUCATION OF BUSITEMA UNIVERSITY

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DECLARATION

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SUPERVISOR'S APPROVAL

This study project, Bakery production management system has been done under my supervision as the university supervisor and submitted with my approval

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DEDICATION

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ABSTRACT
This is a computerized BPMs project study that was carried out at Mama Kevinna Bakery in Tororo. The main objective of the study was to develop Bakery production Management system to minimize wastage of ingredients during production process, improve production efficiency, reduced costs which enhance the production practices. To come up with the system, data was collected through questionnaires and interviewing the manager, bakers and storekeeper as well as observation and focus group discussion. The data collected was analyzed and then used to design and implement the system using RAD model approach. The system was developed using Unifying Modeling Languages with frontend and back-end interfaces with a database system. The developing software tools included PHP, HTML, JavaScript, Xampp together with MYSQL. The database stores records of Bakery and other related information. The system also enables Manager and other system users to update, edit, delete, view and add new bakery and make contributions

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LIST OF ACRONYMS

BPMS: Bakery Production Management System

COGS: Cost of Goods Sold

CSS / CSS3: Cascading Style Sheets

DFD: Data Flow Diagram

ERD: Entity Relationship Diagram

ERP: Enterprise Resource Planning

FIFO: First-In, First-Out

HTML / HTML5: Hypertext Markup Language

ICT: Information and Communication Technology

IoT: Internet of Things

IT: Information Technology

JS: JavaScript

LCM: Life Cycle Management

LIFO: Last-In, First-Out

MoSCoW: Must have, should have, Could have, Won't have (Prioritization framework)

MySQL: My Structured Query Language

PHP: Hypertext Preprocessor

PMS: Production Management System

Poka-Yoke: Error-Proofing (Lean manufacturing term used as a mechanism in the system)

PSO: Particle Swarm Optimization

RAD: Rapid Application Development

RBAC: Role-Based Access Control

SA: Simulated Annealing

SME / SMEs: Small and Medium Enterprise / Small and Medium Enterprises

SPSS: Statistical Package for Social Sciences

SSADM: Structured Systems Analysis and Design Methodology

UAT: User Acceptance Testing

UGX: Ugandan Shilling (Currency standard used in the budget)

UI / UX: User Interface / User Experience

XAMPP: Cross-Platform (X), Apache (A), MariaDB/MySQL (M), PHP (P), Perl (P) (Local server environment stack)

CHAPTER ONE:

INTRODUCTION

1.1 Background of the Study

The bakery manufacturing industry in Uganda serves as a vital economic engine and a primary driver of localized food processing employment; however, contemporary small- and medium-scale enterprises (SMEs) across the region exemplified by operations like Mama Kevina Bakery in Tororo District face a critical operational and sustainability crisis driven by the highly inefficient utilization of raw ingredients. Currently, the bakery operates without any formalized, data-driven Production Management System (PMS). This structural absence forces staff to rely entirely on subjective estimations and manual workflows, which directly introduces severe "processing-related causes" for structural food and financial waste. These processing failures manifest most prominently on the shop floor as the highly inaccurate scaling of bulk wheat flour, inaccurate measurements of vital yeast ratios, and improper yeast activation procedures during the initial mixing and proofing sequences (Raak *et al*., 2017).

These localized, process-driven inefficiencies are heavily compounded by the volatile macroeconomic environment of Eastern Uganda, where the high and fluctuating market costs of critical raw materials such as wheat flour, sugar, vegetable fats, yeast, eggs, and milk powder mean that any avoidable material loss during the early mixing or biochemical fermentation stages directly erodes the bakery's narrow profit margins and threatens its long-term financial survival.

Scholarly research within the broader food manufacturing domain continually highlights that the true "magnitude and causes" of these devastating operational losses are deeply rooted in a structural lack of systematic, real-time raw material measurement and strict management oversight (Goryńska-Goldmann *et al.*, 2021). At Mama Kevina Bakery, the total absence of automated technical control over sensitive, dynamic processing variables such as precise water-to-flour hydration ratios, ambient mixing temperatures, and strictly timed proofing windows frequently results in failed, unusable dough batches that must be entirely discarded. This represents a costly systemic problem that could be entirely mitigated through the introduction of rigorous quality control tracking standards and automated process guardrails (Cauvain & Young, 2009).

Without an integrated, digitally verified cycle of "measurement, management, and prevention" (Goryńska-Goldmann *et al*., 2020), the wastage of critical baking ingredients behaves as a highly volatile and "dynamic problem". This problem fluctuates wildly based on the subjective experience levels of changing shift workers, inconsistent staff behaviors, and unpredictable variations in daily production volumes (Gökalp, 2020).

To remain economically viable and competitive within the expanding East African food marketplace, the bakery must actively abandon traditional guesswork and adopt a structured "life cycle management" operational roadmap. This framework prioritizes rigorous resource efficiency, beginning at the raw material procurement stage and extending all the way through to the final oven pull (Monteiro *et al.*, 2022).

Implementing a tailored web-based Production Management System would effectively introduce a highly collaborative, "participatory approach" to comprehensive waste minimization on the floor. This transitions management away from top-down enforcement by actively empowering production staff to identify, record, and eliminate non-value-adding activities directly on the bake-house floor (Strotmann *et al.,* 2017).

Furthermore, aligning active production volumes with an "optimized distribution perspective" guarantees that expensive raw ingredients are never wastefully consumed on excessive overproduction that the local, highly price-sensitive Tororo market cannot realistically absorb (Aljohani, 2023). Ultimately, transitioning from a legacy manual workflow to a structured, digitally managed production framework is essential to stabilize rising operational costs, secure local employment, and guarantee the bakery's long-term financial resilience.

1.2 Statement of the Problem

Mama Kevina Bakery in Tororo District suffers high wastage of raw ingredients (wheat flour, sugar, fats, yeast, eggs, milk powder), seriously harming profitability. Losses typically range from 10–22% of inputs far above the 2–6% seen in efficient bakeries this is according to (Raak *et al*., 2017). Key causes include inaccurate demand forecasting leading to overproduction, non-standardized weighing and mixing causing overuse and spillage, poor storage resulting in spoilage and pests, and lack of systematic planning and waste tracking. Without intervention, these losses threaten the bakery's survival, job security, and product affordability in the local market. The research is developed to Urgent, practically needed to significantly reduce raw ingredient waste while preserving quality.

1.3 Objectives of the Study

1.3.1GeneralObjective

To develop a web-based Production Management System that optimizes raw ingredient utilization and minimizes wastage throughout the production process.

1.3.2 Specific Objectives

1. To review the literature and determine the requirements for developing production management system.
2. To design the production management system for Mama Kevina's Bakery.
3. To implement the design of production management system.
4. To test and validate the functionality of production management system.

1.4 Research Questions

1. What requirements, key features, and system functionalities are needed for a web-based production management system based on existing literature and user needs at Mama Kevina's Bakery?
2. How can the production management system be designed to effectively address ingredient tracking, recipe scaling, and waste minimization workflows for Mama Kevina's Bakery?
3. How can the architectural and interface designs of the production management system be implemented using appropriate frontend, backend, and database software tools?
4. How can the functionality, usability, and validation barriers of the implemented production management system be tested to ensure it minimizes raw ingredient wastage effectively?

1.5 Justification of the Study

This research is justified by the persistent inefficiencies in resource utilization within small- and medium-scale bakeries in Eastern Uganda, exemplified by operations like Mama Kevina Bakery in Tororo District. These enterprises often experience notable wastage of key inputs such as wheat flour, sugar, fats, yeast, eggs, and milk powder due to factors like manual processes, equipment limitations, and suboptimal production planning. Such losses inflate operational costs, erode profitability, and strain limited resources in a region where many bakeries operate under capital, infrastructure, and skill constraints.

The significance of the study lies in its practical and broader impacts:

Direct benefits to the case study site: By identifying inefficiencies in the production process and proposing a tailored production management system, the research will help Mama Kevina Bakery uncover cost-saving opportunities, minimize avoidable wastage, improve resource efficiency, and strengthen long-term financial sustainability and operational resilience.

Regional applicability: The findings and recommended interventions can serve as a replicable model for numerous similar small bakeries across Tororo District and Eastern Uganda, where comparable challenges of resource inefficiency, manual practices, and demand variability are widespread. This could support improved performance and competitiveness among dozens of local enterprises.

Academic contribution: The study adds valuable insights to the limited body of applied research on production and operations management in Uganda's micro- and small-scale food processing sector, particularly in resource-constrained environments. It bridges gaps in localized knowledge on waste minimization and sustainable practices in bakery operations, offering evidence-based approaches that can inform future studies, policy, and training initiatives in East Africa.

1.6 Scope of the Study

1.6.1 Functional Scope (System Functionalities)

The functional scope of the proposed system is strictly bound by the requirement for an "Appropriate Technology" digital intervention tailored for small-scale bakery operations. Rather than deploying a complex, high-cost corporate ERP suite, the system's functionalities focus directly on resource optimization and wastage reduction through the following core software modules:

Automated Recipe Management and Scaling: The system replaces vulnerable paper recipe cards with a digital master recipe database. The application software dynamically recalculates exact ingredient proportions instantly based on shifting batch sizes, eliminating human arithmetic errors (Cauvain & Young, 2009; Ortiz *et al.*, 2024).

Digital Poka-Yoke Ingredient Validation: The system introduces a hardware-software "Lock-and-Scale" barrier. The application layer suppresses the subsequent mixing phases, preventing the worker from proceeding until connected digital scales confirm that the actual ingredient mass matches the exact recipe configuration within strict decimal tolerance windows (Cauvain & Young, 2009; Dausch et al., 2023; Ortiz *et al.*, 2024).

Floor Scheduling and Sequencing Logics: The production module incorporates algorithmic scheduling heuristics to resolve the "No-Wait Flowshop Problem" typical of baking. It calculates optimal batch sequencing timelines to maximize oven capacity and ensure that fermenting dough never exceeds its critical proofing window (Aljohani, 2023).

Real-Time Inventory and Waste Tracking: The inventory module enforces strict First-In, First-Out (FIFO) material rotation to mitigate raw item degradation (Goryńska-Goldmann et al*.,* 2020). Concurrently, it features a granular, role-based digital waste logging system that categorizes floor spills and production scraps by volume and operator identity, providing full management auditing (Kannan & Boie, 2003; Goryńska-Goldmann *et al.*, 2021).

Circular Waste Routing Module: The system tracks and logs unavoidable production residuals, providing functional data interfaces to route these waste streams systematically into secondary circular economy channels, such as localized animal feed formulations (Monteiro et al., 2022; Mostaghimi & Behnamian, 2023).

1.6.2 Geographical Scope

The physical and geographical boundaries of this research are localized within Eastern Uganda. Specifically, the field testing, data collection, and deployment of the web-based Production Management System will be executed entirely at Mama Kevina Bakery, located in the Tororo District. This location provides an authentic semi-industrial environment to test the application's performance against regional infrastructural constraints, such as elevated ambient temperatures, high humidity, and local grid instability (Gökalp, 2020; Dausch *et al.*, 2023).

1.6.3 Time Scope

The temporal boundary for this study spans a total duration of 16 weeks, encompassing the complete system lifecycle from initial requirements gathering to final post-implementation review. The early phase will focus on evaluating baseline material variances and human error rates under the legacy manual paradigm (Raak *et al.*, 2017; Goryńska-Goldmann et al., 2021).

The middle phases will cover the system design and core development sprints using a Rapid Application Development (RAD) methodology (Strotmann et al., 2017; Dausch *et al.*, 2023).

The final phase will be dedicated to active shop-floor testing at the Tororo facility, user evaluation, and quantifying the system's empirical impact on compressing raw material wastage rates (Strotmann et al., 2017; Goryńska-Goldmann *et al.*, 2020).

CHAPTER 2:

LITERATURE REVIEW

2.1 Introduction

Production Management Systems (PMS) are defined as the integrated framework of methodologies, digital technologies, and operational strategies designed to synchronize manufacturing functions. In the bakery industry, the implementation of a PMS sets up a direct operational tension between legacy manual systems and modernized digital architectures. A bakery PMS serves as the central "nerve center" overseeing the transformation of raw materials into finished highly perishable goods. Unlike heavy manufacturing, bakery production is governed by strict biological and chemical sensitivities.

As Cauvain and Young (2009) establish, the functional properties of bakery products are dictated by precise water control and ingredient interactions. Therefore, the debate between manual and modern measurement paradigms is not merely a matter of convenience; it directly affects the delicate "no-wait" constraints of dough proofing and the thermal dynamics of baking.

Scholarly consensus, as seen in the work of Guo *et al.* (2023), suggests that the future of the industry lies in data-driven "Intelligent Manufacturing Management" rather than sensory guesswork. Modern PMS platforms utilize data mining and artificial intelligence to identify patterns in resource consumption that remain completely invisible to human operators. For Small and Medium Enterprises (SMEs), choosing modern precision over manual estimation is vital to achieving the "Triple Bottom Line": economic profitability, social responsibility (food security), and environmental sustainability through reduced resource depletion.

2.2 The Comparative Dialogue: Manual vs. Modern Measurement

The transition from the traditional "Manual Era" to the "Digital Era" of baking highlights a fundamental clash between cultural craftsmanship and mathematical efficiency. In emerging economies like Eastern Uganda, this tension forms the front line in the battle against systemic food and financial waste.

2.2.1 Human Vulnerability vs. Digital Constraints

Manual ingredient measurement relies heavily on the physical endurance and attention of the baker, leaving the process highly vulnerable to human error. Raak *et al.* (2017) identify "processing-related causes" such as improper scaling and faulty yeast activation as primary drivers of food waste. On the shop floor, the manual approach introduces three severe risks:

The Parallax Effect: Manual measurement causes operators to misread analog scale markers based on their physical viewing angle. Modern digital scales eliminate this by displaying exact, unambiguous decimal values, Rounding Approximations: Manual practitioners frequently round weights to the nearest convenient marking rather than following precise recipe requirements. Modern systems apply strict validation, blocking the process until the required decimal target is achieved, Physical Fatigue: In hot bakery environments, human precision naturally degrades over a shift. A digital system maintains 100% computational accuracy regardless of environmental exhaustion.

When manual variances cause even a 1.5% deviation in water or yeast ratios, the dough's rheology is ruined, making it too sticky to process. While a manual system permits these flawed batches to move forward resulting in "defective products" that account for over 20% of total bakery waste according to Goryńska-Goldmann et al. (2021) a modern PMS introduces *Poka-Yoke* (error-proofing) tracking. The digital system locks down the mixing sequence, physically preventing the baker from blending ingredients if the scaled weights deviate from the master recipe.

2.2.2 The "Invisible Profit Drain" vs. "Green-Light Scaling"

From an economic perspective, manual measurement creates what researchers call an "invisible drain" on capital. If a manual baker over-measures a high-cost ingredient like sugar, fat, or milk powder by a minor 10 grams per batch, a high-volume operation running 100 batches a day quietly discards over 300 kg of raw material every year.

Kannan and Boie (2003) observe that manufacturing SMEs routinely fail to track these micro-losses because manual paper ledgers lack the granular visibility required to expose them. This drives up the Cost of Goods Sold (COGS) and shrinks narrow profit margins.

In contrast, modern "Green-Light Scaling" replaces human intuition with digital data verification. By linking digital mass balances directly to the application backend, the system records every gram utilized, providing the manager with real-time inventory transparency and preventing minor floor errors from compounding into financial deficits.

2.3 Methodological Mechanisms: Intuition vs. Optimization

The operational debate extends into process scheduling and execution, contrasting traditional workflow intuition with structured lean optimization.

2.3.1 Flexible Workarounds vs. Systematic Poka-Yoke

Proponents of manual systems often highlight their natural flexibility, allowing experienced bakers to adjust formulas on the fly based on the tactile feel of the dough. However, Ortiz, Quezada, and Oddershede (2024) demonstrate that replacing this unstructured flexibility with digital Lean tools can raise bakery profits by up to 25%.

While manual workflows rely on paper recipe cards that are easily lost, damaged, or miscalculated during batch adjustments, a modern PMS automates recipe management. The software dynamically recalculates ingredient proportions instantly based on the target batch size, eliminating manual math errors. Furthermore, while manual systems suffer from chaotic ingredient selection, digital tracking uses barcode scanning to enforce strict First-In, First-Out (FIFO) stock rotation, preventing ingredient degradation and spoilage before the bag is even opened.

2.3.2 Guesswork Timelines vs. Algorithmic Heuristics

Bakery scheduling represents a highly complex "No-Wait Flowshop Problem" because mixed dough continues to ferment biologically while waiting for processing. Under manual scheduling, the head baker estimates mixing and baking times based on personal experience. If an operational delay occurs, the dough over-proofs and collapses, turning into immediate material waste.

Modern production management addresses this vulnerability by incorporating optimization heuristics like Particle Swarm Optimization (PSO) and Simulated Annealing (SA). Aljohani (2023) notes that these algorithms calculate the perfect activation and sequence times for distinct batches based on real-time oven availability. Moving from manual scheduling to these automated numerical methods can compress the total production time (makes pan) by 30% and reduce machine idle time by 12%.

2.4 Sustainability and Environmental Impact

The choice between manual and modern systems directly dictates the environmental footprint of the food processing cycle. Monteiro et al. (2022) address this through the lens of Life Cycle Management (LCM), comparing the resource expenditures of both paradigms.

2.4.1 Discarded Embodied Energy

When a batch of dough is discarded in a manual system due to a measurement or baking blunder, the environmental cost extends far beyond the ruined flour. It represents the absolute destruction of the "embodied energy" accumulated across the supply chain, including the water used for agriculture, the fuel spent on transport, and the electricity consumed during commercial milling.

Demirbas (2011) emphasizes that commercial bakery ovens are massive energy consumers. Forcing an oven to run a "re-bake" to replace a failed manual batch duplicates energy consumption and drives unnecessary greenhouse gas emissions. A digitized PMS ensures "right-first time" manufacturing, maximizing the yield of every kilowatt-hour consumed.

2.4.2 Linear Waste vs. Circular Recovery

Manual bakeries typically operate on a linear "take-make-waste" model, where floor scraps and burnt items are thrown directly into refuse piles. Modern systems change this dynamic by integrating data-driven tracking for unavoidable residuals. Mostaghimi and Behnamian (2023) point out that an advanced PMS can systematically log and categorize unavoidable waste streams, routing them into structured "Circular Economy" channels such as upcycling them into animal feed or localized biofuel inputs.

2.5 Regional Realities: The Sub-Saharan Dilemma

When evaluating manual versus modern systems in the specific regional context of Eastern Uganda, the choice is heavily shaped by local socioeconomic constraints. Gökalp (2020) observes that high ambient temperatures and poor storage infrastructure significantly worsen ingredient spoilage, making precise management critical.

Operational Vector	Legacy Manual Measurement Paradigm DOCX	Modern Digital PMS Paradigm DOCX
Capital Infrastructure	Requires zero initial investment in IT hardware or software licenses.	Requires upfront procurement of low-cost digital interfaces and devices.
Operational Consistency	Highly volatile; heavily dependent on staff memory, focus, and fatigue levels.	Highly uniform; enforced by systematic software validation and strict database constraints.
Infrastructural Resilience	Immune to electrical grid failures or internet blackouts.	Protected via offline local architectures (e.g., XAMPP) and independent power.
Floor Accountability	Low; anonymous paper records fail to capture specific reasons for material loss.	High; role-based access control logs waste by type and operator identity.
Resource Losses	High average ingredient wastage rates ranging from 10% to 22%.	Optimized raw material waste compressed down toward efficient 2%–6% benchmarks.

Table 1:Making precise management critical.

2.5.1 Barriers to modern mitigation

Despite the clear efficiency advantages of digital systems, manual processes persist among Ugandan SMEs due to significant practical barriers: Intimidating Initial Costs: Traditional Western Enterprise Resource Planning (ERP) software and advanced automation hardware are financially unfeasible for small local bakeries, digital Literacy Gaps: Floor workers may face steep learning curves when forced to interact with complex abstract digital portals, Power Grid Volatility: Digital operations risk sudden data corruption or process halts due to frequent local power blackouts.

2.5.2 Resolution: "Appropriate Technology"

Strotmann et al. (2017) resolve this standoff by championing a localized, "participatory approach" to digitalization. Modernization does not require importing an expensive, rigid Western corporate framework. Instead, it can take the form of a highly resilient, low-cost digital aid such as a mobile web application designed with simple layouts, intuitive iconography, and plain language.

Dausch et al. (2023) call this "Adaptive Digitalization." Running a lightweight local stack via an offline local server (like XAMPP) and utilizing solar-powered digital scales allows a small bakery to retain the resilience of manual operations while capturing the extreme accuracy of modern digital control. This localized balance can compress the severe 10–29% food loss rates reported across Sub-Saharan Africa down to global efficiency standards.

2.6 Advanced Horizons: IoT and Immutable Ledgers

The dialogue between manual and modern systems reaches its peak with the introduction of Industry 4.0 paradigms, which move production tracking from simple record-keeping into automated, predictive control.

2.6.1 Environmental Adaptability via IoT Sensors

Under manual operation, a baker cannot easily account for shifting moisture levels within the flour store caused by changes in weather. If the flour absorbs excess moisture from the air, the traditional recipe's water ratio will produce defective, overly hydrated dough.

Integrating Internet of Things (IoT) sensors directly into storage areas resolves this blind spot. These sensors continuously feed ambient humidity and temperature telemetry into the PMS application engine, which automatically adapts the active recipe mix to compensate for climate fluctuations, preserving product consistency without relying on human guesswork.

2.6.2 Supply Chain Accountability via Blockchain

Manual record-keeping cannot easily trace material flaws or contamination once ingredients enter the production floor. If a bakery receives a compromised batch of yeast or flour, identifying the root cause requires digging through disorganized stacks of paper delivery notes.

Modern blockchain ledger integration establishes immutable "Farm-to-Fork" traceability. By anchoring raw material lot numbers to cryptographic entries, the system tracks inputs through every step of production. If a raw material defect is discovered, management can instantly isolate the specific loaves affected, avoiding a costly total recall and preventing the massive product waste typical of manual operations.

2.7 Conclusion: The Shift from Intuition to Data

The collective literature confirms that relying entirely on manual measurement acts as an operational bottleneck that prevents small-scale food processors from achieving competitive efficiency and true sustainability. Goryńska-Goldmann et al. (2020) conclude that ingredient and bread loss must be viewed fundamentally as a "management tracking problem" rather than an unavoidable "baking complication".

While manual workflows provide flexibility and require minimal initial infrastructure, they introduce high operational variance, hidden economic losses, and high waste rates.

Modern Production Management Systems bridge these gaps by embedding digital precision, lean principles, and algorithmic scheduling directly into daily operations

CHAPTER THREE:
METHODOLOGY

3.1 Introduction

This chapter describes the methods used to achieve the objectives of the study. This describes how data was collected using literature review, interviews, observation, focus groups and how collected data was analyzed to aid system development. The method for data collection of this project was qualitative, which is often the best and most efficient approach of collecting information from small populations and horse administrators. Qualitative method was for conducting research that relies on open ended exploration of people's actions, words, thoughts and intentions. Qualitative methods include the following: observation, focus groups and interview. RAD (Rapid Application Development) model was used in the system development life cycle (SDLC). RAD is an adaptive software development approach where software prototype is rapidly updated based on user feedback and interactively delivered until it meets all the needs of the client.

3.2 Research Design

This study will employ an action-oriented, mixed-methods research design anchored within the framework of "Adaptive Digitalization" and engineering design science. The design is explicitly structured to address the operational standoff between legacy manual guesswork and modern digital precision by embedding quantitative tracking alongside iterative software development.

To effectively capture and resolve the "magnitude and causes" of ingredient losses, the research design is divided into three interconnected, continuous phases:

Phase 1: Diagnostic Empirical Baseline (Quantitative/Descriptive) The initial phase focuses on a descriptive audit of the existing manual shop floor operations. Quantitative measurements will be recorded to isolate processing-related errors, baseline material variances, and financial losses caused by human factors like the parallax effect and rounding approximations (Raak et al., 2017; Goryńska-Goldmann et al., 2021). This diagnostic data provides the critical empirical baseline needed to measure the success of digital intervention.

Phase 2: Technical Design and Development (Iterative Engineering/RAD) The core of the design utilizes a Rapid Application Development (RAD) framework to construct the web-based

Production Management System. This engineering phase adopts a highly "participatory approach," actively involving Mama Kevina Bakery's shop floor personnel in iterative UI/UX design cycles to overcome local digital literacy gaps and ensure high operational usability (Strotmann et al., 2017).

Phase 3: Evaluative Experimental Deployment (Quantitative/Evaluative) The final phase introduces the completed system onto the production floor to test its performance under real-world conditions. The study will run an evaluative, pre-and-post-implementation impact analysis to mathematically verify how effectively the system's digital *Poka-Yoke* barriers, algorithmic scheduling logics, and circular waste routing modules compress raw material wastage rates down toward optimal industrial benchmarks (Aljohani, 2023; Dausch et al., 2023; Monteiro et al., 2022).

By integrating empirical field observation with data-driven system optimization, this design treats systemic bread and ingredient loss fundamentally as an addressable "management tracking problem" rather than an unmanageable baking complication (Goryńska-Goldmann et al., 2020). It balances technical innovation with high regional operational resilience, establishing an "Appropriate Technology" roadmap that can withstand localized infrastructural constraints (Gökalp, 2020; Dausch et al., 2023).

3.3 Area of Study

The geographical boundaries of this research are strictly localized to the production floor of Mama Kevina Bakery, situated in Tororo District, Eastern Uganda. This semi-industrial environment serves as the primary field-testing site to evaluate the digital system's performance against regional infrastructural factors, such as high ambient temperatures, elevated humidity, and local grid instability.

3.4 Population and Sampling

The target population consisted of bakery staff at Mama Kevina Bakery 10 people, including bakers, helpers, and supervisors where and relevant external parties 5 suppliers who affected or witnessed production and wastage patterns.
Purposive sampling selected participants with firsthand wastage experience, such as the manager, main bakers, and inventory personnel (n=5). Convenience sampling included available employees during site visits for additional survey input (n=15). This purposeful, non-random method ensured

focused, feasible data collection in a small operation, with qualitative sample size determined by data saturation.

3.5 Analysis

Qualitative data from interviews, observations, documents underwent thematic examination using SPSS to uncover wastage causes (e.g., excess production, spills). Quantitative measures input losses by weight/volume, defect percentages, pre/post-PMS wastage rates analyzed descriptively (means, ratios) and inferentially (paired t-tests) via Excel/SPSS. Triangulated sources ensured reliability; wastage indicators benchmarked success.

3.6 Interview Techniques

Semi-structured interviews (30–45 minutes) with 4 key participants explored wastage origins, procedures, PMS capabilities (e.g., "Where did greatest material loss occur?"). Open questions with prompts generated rich responses. Conducted privately, audio-recorded (with permission), transcribed. Trial refined questions, respecting English and culture.

3.7 Observation

Non-participant observation spanned 4 complete production runs over two weeks, using checklist for wastage incidents (e.g., flour during weighing, over-baked items). Time-motion recorded losses per step (receipt to dispatch). Neutral researchers noted conditions (machine/energy). Field notes/photos reinforced patterns.

3.8 Document Review

Internal records (purchases, production notes, sales from prior 4 weeks) established baseline wastage/trends. Secondary sources (Ugandan bakery reports) contextualized. Extracted quantitative losses/qualitative inefficiencies confidentially.

3.9 Data Presentation

Functions realized via DFDs, Context Diagrams, ERDs, Use Cases, Sequence Diagrams for development/databases. Findings displayed in tables/graphs (bar charts pre/post-losses), thematic summaries/quotes, flowcharts for stages/hotspots, pie charts for resource distribution showing reductions.

3.10 System Design

The design phase was fundamentally driven by the need to address operational inefficiencies identified by Goryńska-Goldmann et al. (2021), specifically targeting food losses and resource waste caused by manual errors. The primary design objective was the digitalization of production scaling, replacing error-prone manual calculations with an automated, algorithm-driven system. By shifting from paper-based estimations to digital precision, the design ensures that ingredient proportions remain consistent regardless of batch size, directly mitigating the risk of over-production and subsequent material spoilage. This architectural focus transforms the production workflow from a reactive process into a proactive, data-centered operation.

The system utilizes robust three-tier architecture to ensure high levels of modularity and ease of maintenance, aligning with the Life Cycle Management principles proposed by Monteiro et al. (2022).

Presentation Tier: Developed using HTML5, CSS3, and JavaScript, this layer provides an interactive and responsive User Interface (UI) tailored for various user roles.

Application Tier: Powered by PHP, this middle layer handles the core business logic, including the complex calculations required for ingredient scaling and user authentication.

Data Tier: A MySQL database serves as the repository for all critical information, including recipe formulations, real-time inventory levels, and historical production logs. This separation of concerns allows for independent updates to each layer, ensuring the system can evolve without requiring a total overhaul.

3.11 Ethical Considerations

The research was conducted with strict adherence to ethical standards. All participants provided informed consent prior to the study, and their anonymity was protected using pseudonyms and the aggregation of sensitive data. Ethical clearance was obtained from the relevant Ugandan governing body, ensuring the project met national standards for research involving human participants. Data was stored in secure, password-protected environments, and participants were informed of their right to withdraw at any time. The implementation was scheduled to ensure minimal disruption to daily bakery operations, providing tangible benefits to the participants through improved workflow efficiency.

CHAPTER FOUR:

FIELD ANALYSIS AND SYSTEM DESIGN

4.1 Introduction

This chapter provides a comprehensive analysis of the operational framework at Mama Kevina Bakery and details the design of the proposed Bakery Production Management System

(BPMS). The transition from a manual to a digital system requires a deep understanding of existing bottlenecks. By meticulously documenting the current workflow, this chapter identifies where "processing-related causes" of waste occur, as cited by Raak et al. (2017). The subsequent design sections provide a technical blueprint, using industry-standard modeling languages to ensure the solution is both robust and tailored to the specific resource constraints of a small enterprise in Tororo.

4.2 Current System Study and analysis

The current production environment at the Bakery is characterized by a "legacy manual workflow." In this system, the production cycle begins with a verbal estimate of daily market demand. The head baker relies on personal experience to determine the quantity of raw materials needed for the day.

Measurement of ingredients such as wheat flour, sugar, fats, yeast, eggs, and milk powder is performed using mechanical spring scales or, in some instances, informal volume-based measures like plastic cups and buckets. There is no centralized recipe repository; instead, recipes are maintained in the memory of senior staff. Record-keeping is localized in physical paper ledgers, which are susceptible to damage, loss, and delayed entry. This lack of a formal Production Management System (PMS) makes it nearly impossible to identify the exact point of material loss during the "no-wait" constraints of dough proofing and baking (Cauvain & Young, 2009).

4.3 Strength of the Current System

Minimal Infrastructure Requirements: The current system does not depend on a stable power grid, which is advantageous given the inconsistent electricity supply in Eastern Uganda.

Low Initial Capital Outlay: It requires no investment in hardware, software licenses, or specialized IT maintenance personnel.

High Human Flexibility: Experienced bakers can make instantaneous adjustments to dough consistency based on their tactile intuition, which helps mitigate issues like fluctuating ambient humidity.

4.4 Weakness of the Current System

Systemic Measurement Inaccuracy: Manual scaling is prone to the "Parallax Effect" and rounding errors. Even a 1% deviation in yeast or water can ruin a 50kg batch of dough, leading to the "Invisible Drain" on profits (Kannan & Boie, 2003).

Data Fragmentation and Lag: Because records are manual, the manager cannot see the "real-time" inventory status. This often leads to stock-outs of critical items like eggs or milk powder, or conversely, over-purchasing that leads to spoilage.

Demand-Supply Mismatch: Without data-driven forecasting, the bakery often overproduces bread that the local Tororo market cannot absorb, resulting in high "post-oven" waste.

Lack of Accountability: Physical logbooks rarely capture the *reasons* for waste (e.g., burnt batches vs. floor spills), preventing the implementation of a "Circular Economy" or preventative management model (Mostaghimi & Behnamian, 2023).

4.5 System Requirements

4.5.1 Functional Requirements

These describe the core services the BPMS must provide to bridge the gap identified in the literature:

Recipe Management & Automated Scaling: The system must store standard recipes and automatically calculate required ingredient weights for any batch size, eliminating manual math errors.

Real-Time Inventory Tracking: Every production run must trigger an automatic deduction from the digital stock ledger (flour, sugar, fats, etc.) to maintain an accurate First-In, First-Out (FIFO) flow.

Wastage Logging & Categorization: The system must provide a user-friendly interface to record waste as it happens, categorizing it by type (e.g., mixing error, baking defect, or storage spoilage).

Production Reporting: The system must generate weekly reports on wastage rates versus production output to help management identify "hotspots" of inefficiency.

4.5.2 Non-Functional Requirements

Usability and Localization: Given varying staff literacy levels, the UI must use "simple human-generated" English and intuitive icons to guide users through the measurement process.

Resilience and Offline Availability: The system must run locally via XAMPP to ensure that production does not stop if the internet or power is unstable (Strotmann et al., 2017).

Data Integrity: The MySQL database must implement strict constraints to prevent the entry of negative stock values or impossible recipe ratios.

Cost-Effectiveness: The system must be capable of running on low-spec hardware (e.g., an old laptop) to remain affordable for a Ugandan SME.

4.6 System Design

System Design is the process of defining the interfaces, and modules for the system to realize functionality of the requirements. This was through the use of system design tools such as Context

Diagram, DFD, ERD and Use Case modeling diagram to help to know how different processes interact with each other and their relationships

4.6.6 System Architectural Diagram

This system architecture is built in three main parts to keep everything organized and running smoothly. The first part collects data from tools like scales and shows it to users on their phones or computers. The middle part is the "brain" of the system, which handles the math for recipes and tracks how much food or material is being wasted. To keep things fast, the system uses a "message queue" so that information can move between the machines and the databases without causing any lag or crashes. Finally, all the information is saved in separate databases so that the records for recipes, stock, and past reports stay safe and easy to find.

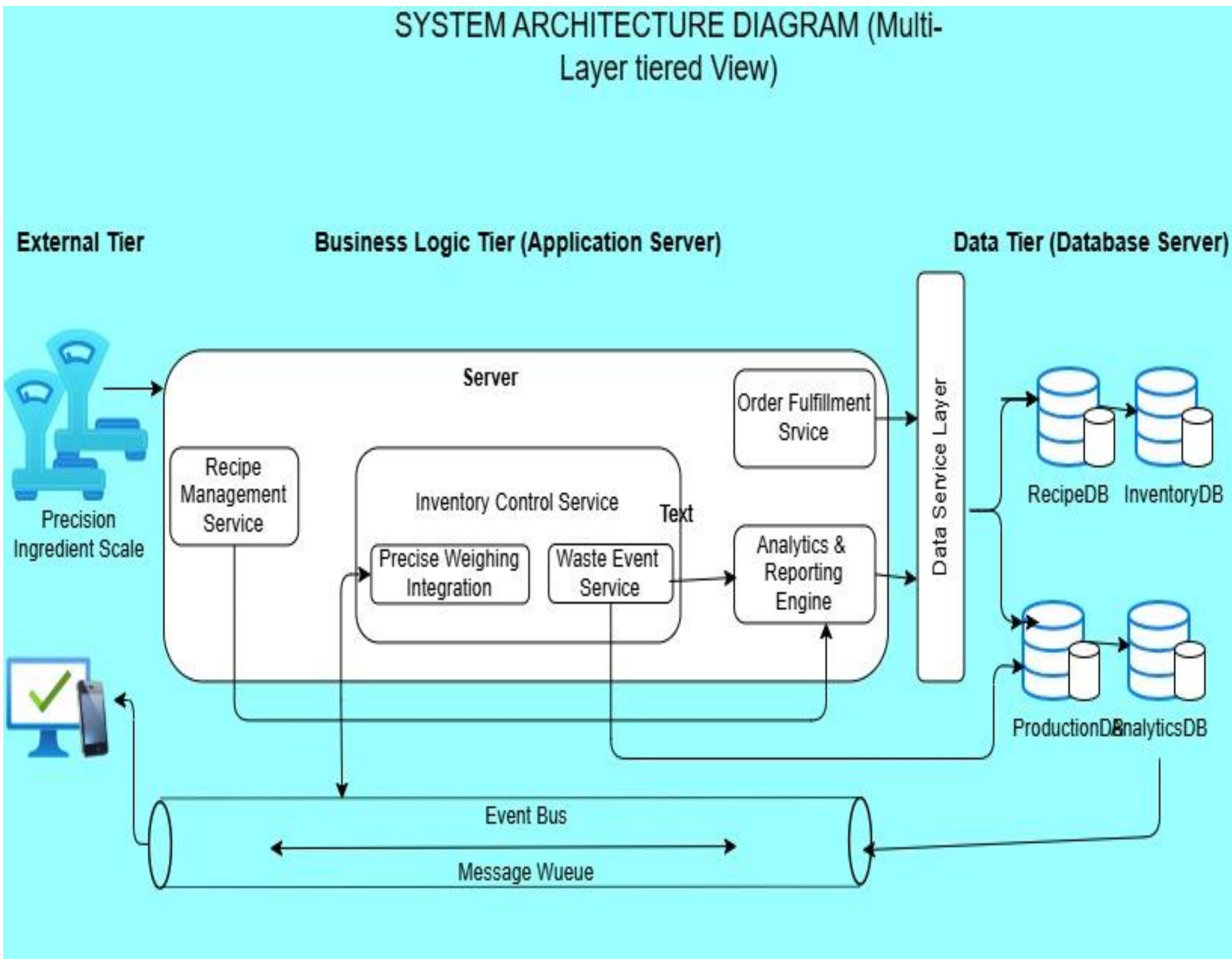

Figure 1: System Architectural Diagram

4.6.1 System Context Diagram

The Context Diagram establishes the high-level boundaries. The BPMS sits at the center, receiving production targets and waste data from the Baker, while providing the Manager with inventory alerts and sustainability reports.

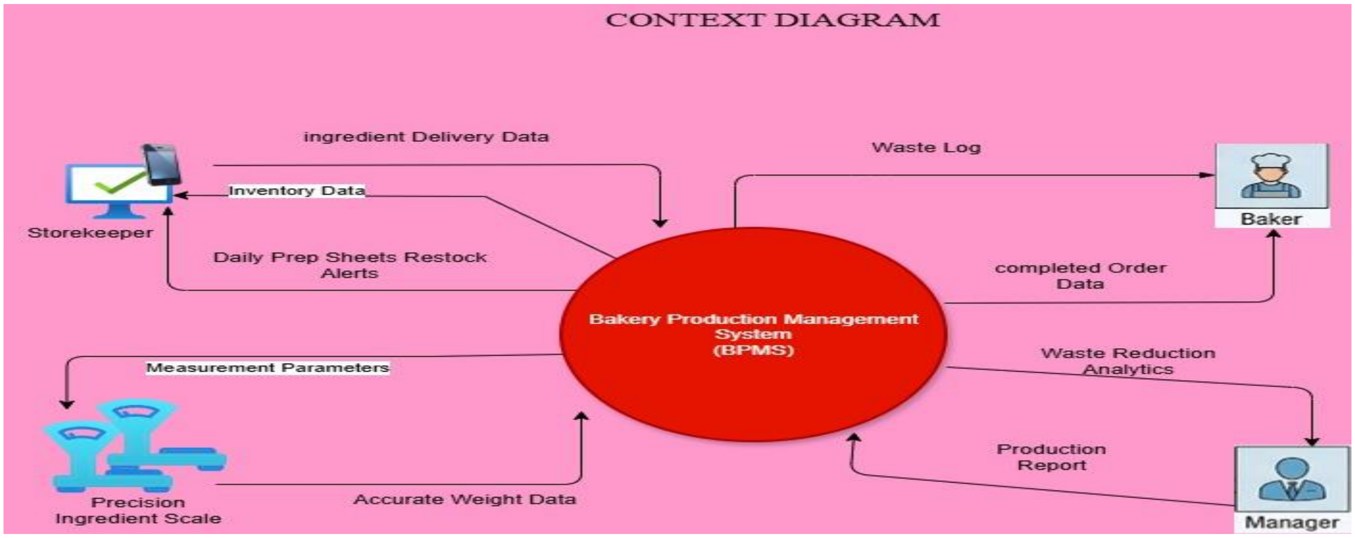

Figure 2:System Context Diagram

4.6.2 Data Flow Diagram (DFD) - Level 0

The DFD illustrates the internal logic of the system. It shows how the "Production Input" moves through the scaling process, interacts with the recipes and inventory data stores, and finally generates a "Required Ingredient List" for the bake-house floor.

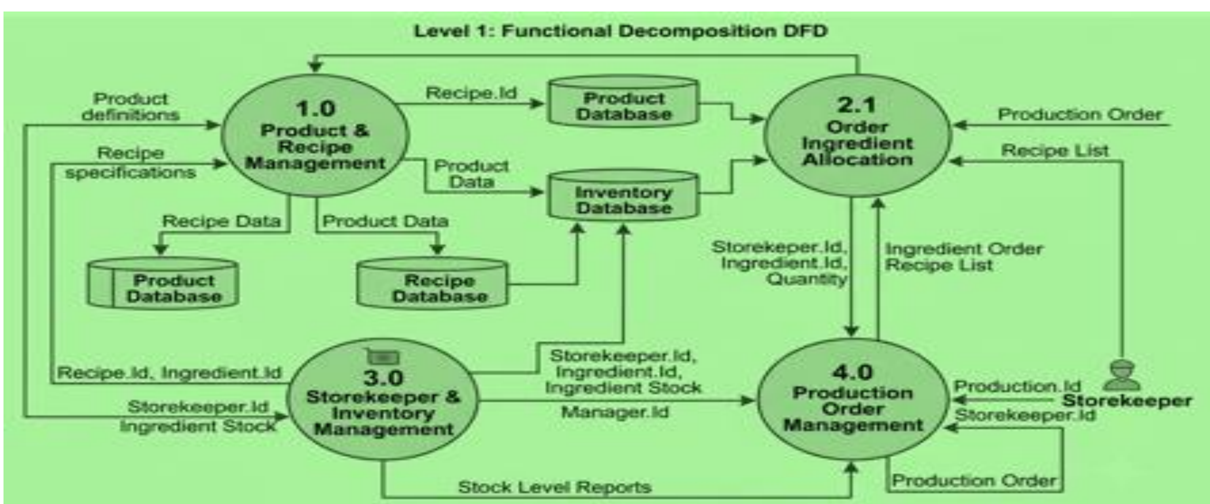

Figure 3: Data Flow Diagram (DFD) - Level 0

4.6.3 System Entity Relationship Diagram (ERD)

The ERD defines the normalized database structure. It ensures that every Ingredient is linked to a Recipe and that every Production Run is recorded with its associated Wastage Log, enabling full traceability from raw material to be finished product.

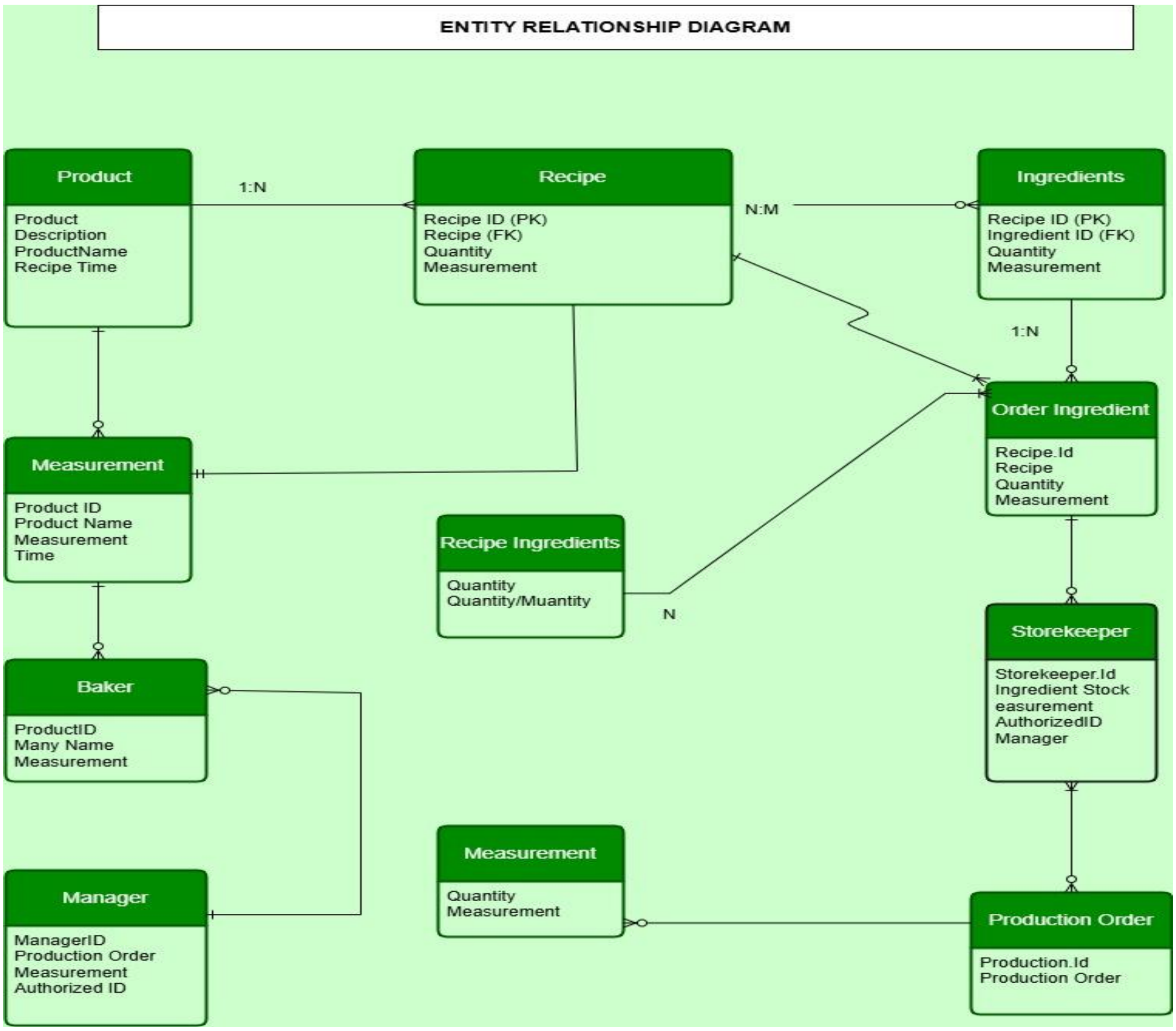

Figure 4: Entity Relationship Diagram (ERD)

4.6.4 Use Case Diagram

The Use case diagram represents the activities of the users with special functionalities of the system. Use Case Diagram model is what the system is expected to do and to view externally the use of the system from the user's perspective rather than internally.

This model highlights the roles within the system. It distinguishes between the Baker's role in "Executing Production" and the Manager's role in "System Configuration" and "Audit Trail Review," ensuring a "participatory approach" to waste minimization.

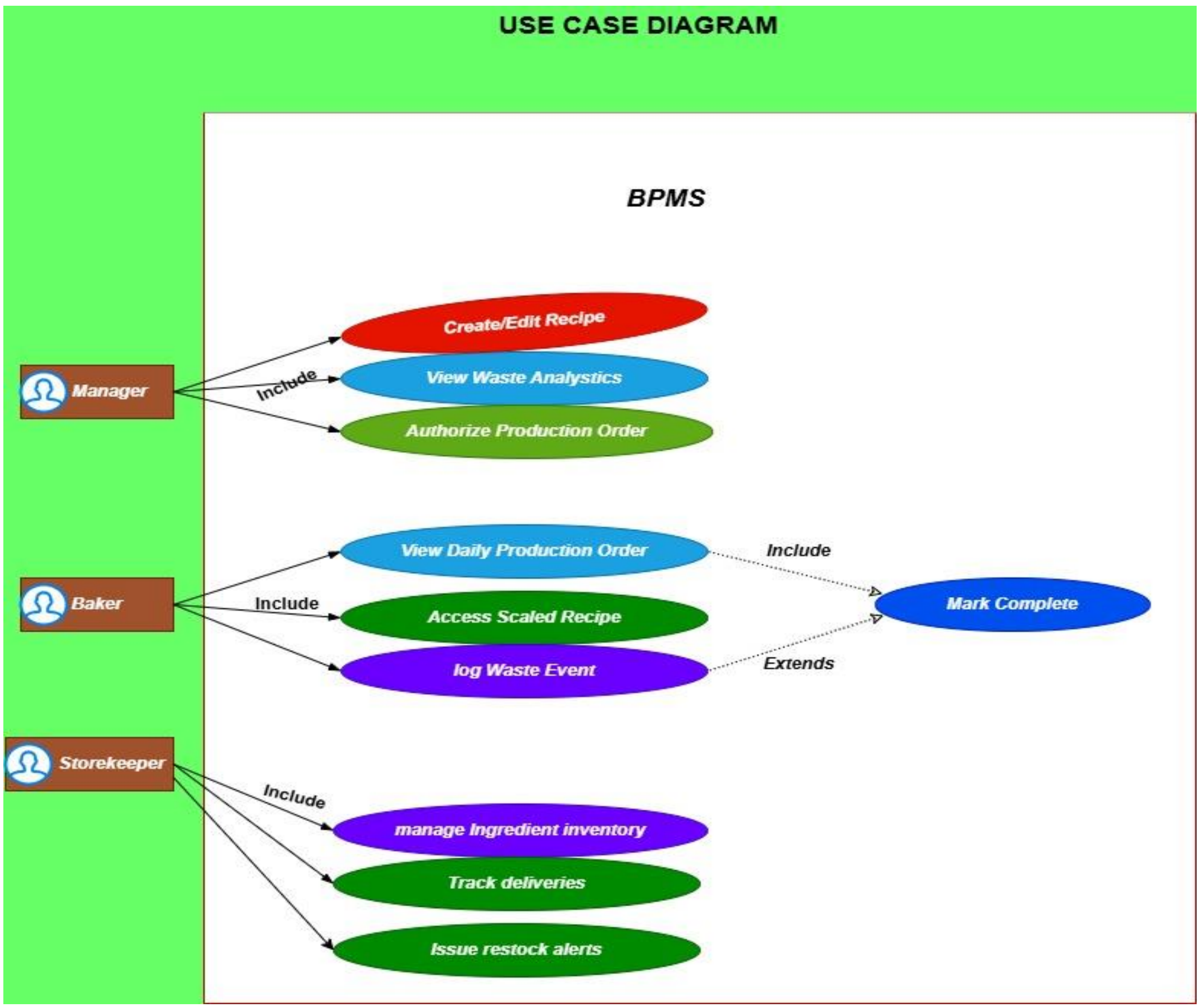

Figure 5: Use Case Diagram

4.6.5 Sequence Diagram: Ingredient Scaling & Waste Prevention

This diagram details the interaction between the user interface, the PHP logic, and the MySQL database during a single production event. It demonstrates the "Poka-Yoke" (error-proofing) mechanism where the system validates stock levels before a baker can commit to a batch, preventing "half-finished" dough that would otherwise be wasted.

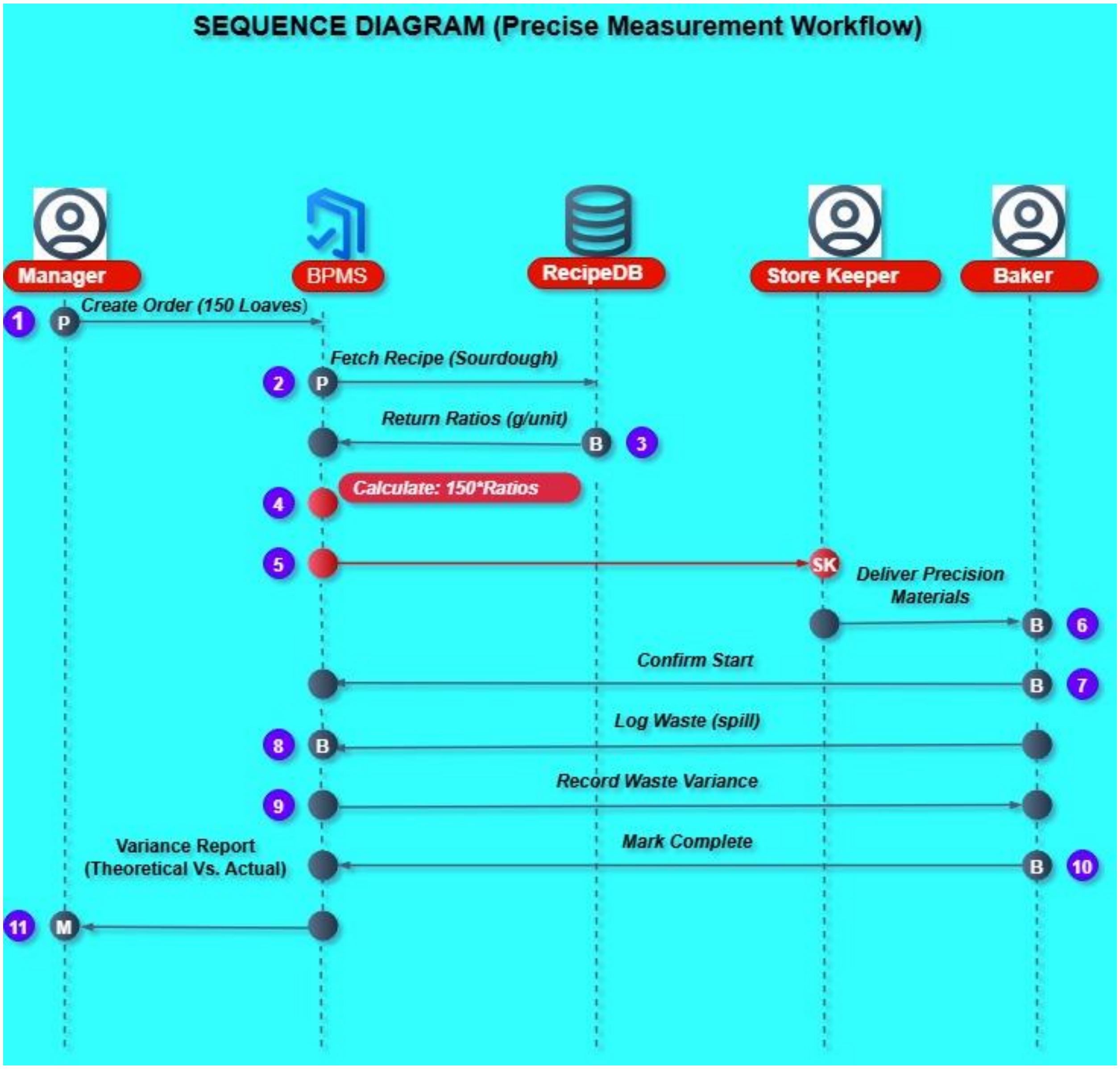

Figure 6: Sequence Diagram: Ingredient Scaling & Waste Prevention

CHAPTER FIVE:

IMPLEMENTATION

5.1 Introduction

This chapter presents the implementation and testing of the system, and it shows login interface which gives an authentication of users in order to provide security to unauthorized users, allows registration of new user, and testing of the system. Implementation involves testing an idea from concept to reality. According to the system design described earlier on, the BPMS, consisting of two major parts, that is the back-end and the front-end was successfully implemented. At the developing stage, where enough research and experiments were done amongst the programs and databases the major software that were used includes PHP, MYSQL, Xampp and Bootstrap JavaScript that were so important in the development of the entire system with its databases.

5.2 Home page design for the system

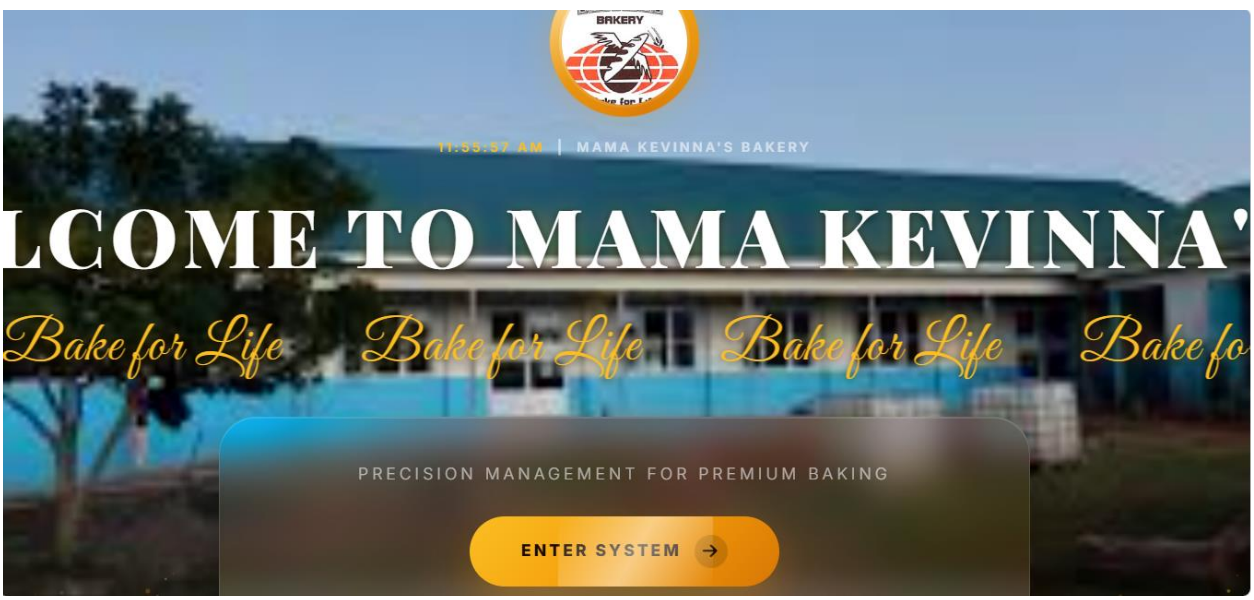

Figure 7: Home page design for the system

The home page for Mama Kevinna's Bakery serves as a professional management portal, utilizing a modern glass morphism design to overlay a localized image of the bakery facility with clear functional controls. It features a prominent "Enter System" gateway intended for internal operations, framed by the mission-driven slogan "Bake for Life" and a commitment to "Precision Management." By integrating real-time elements like a live clock with high-contrast branding, the interface balances brand identity with administrative utility. Ultimately, the design creates a focused entry point for users to transition from the physical bakery environment into a specialized digital oversight system.

5.3 Login Interface Design

Figure 8: Login Interface Design

This login interface functions as a **role-based access control (RBAC) gateway**, designed to segment system functionality based on specific organizational responsibilities. The page utilizes a three-column layout that clearly defines the permissions and duties for different user types: the **Manager/Admin** (oversight and authorization), the **Baker** (production and recipe execution), and the **Storekeeper** (inventory and supply chain management). Visually, the interface maintains consistency with the home page by using a frosted glass aesthetic and intuitive iconography, ensuring that users are directed toward their relevant modules immediately. By requiring role selection before entering the system, the interface enhances security and operational efficiency, tailoring the user experience to the specific data and tools each employee needs for daily tasks.

5.4 Login interface for Admin/Manager

Figure 9: Login interface for Admin/Manager

This management-specific login interface provides a secure administrative gateway, featuring a split-screen design that balances branding with functional authentication fields. The left panel outlines high-level permissions—such as recipe management, waste analytics, and financial reporting—to remind the user of their administrative scope upon entry. By utilizing a clean, vertical form on the right, the system ensures a streamlined user experience for entering credentials and accessing the full operations dashboard.

5.5 Login interface for bakers

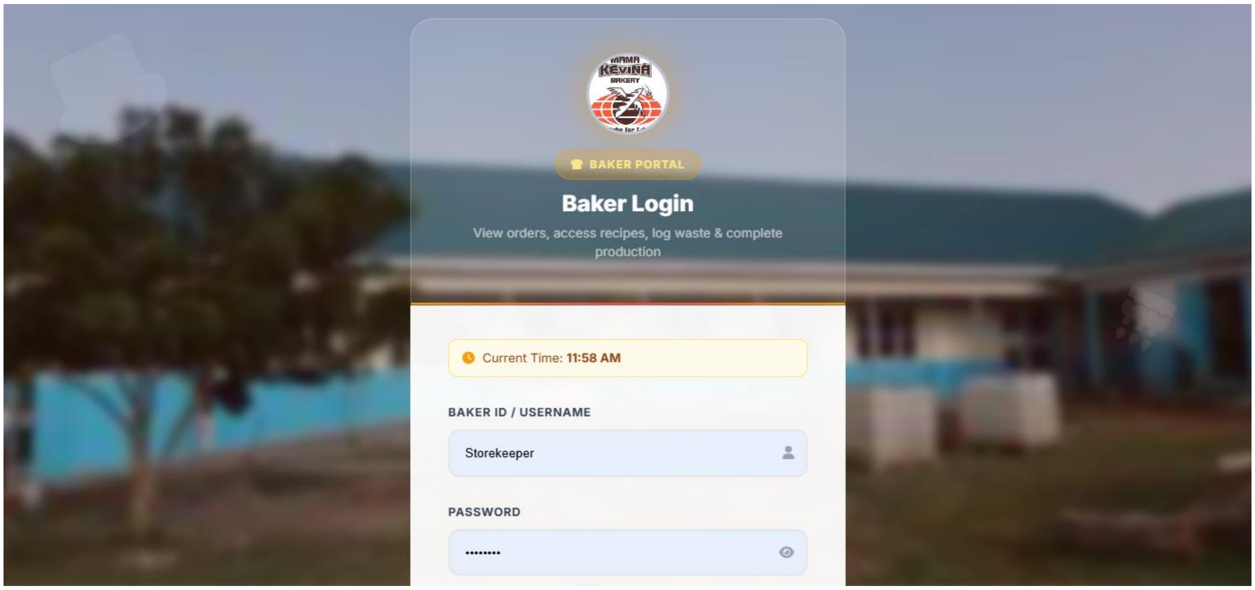

Figure 10: Login interface for bakers

The baker's login interface features a centralized, high-contrast modal that emphasizes essential production workflows, such as viewing orders and logging waste, directly above the credential fields. It incorporates a prominent real-time clock to support time-sensitive baking schedules, ensuring staff are synchronized with daily production deadlines upon entry. The clean, card-based layout maintains visual continuity with the overall system while prioritizing functional simplicity for users in a fast-paced kitchen environment.

5.6 Login interface for Storekeeper

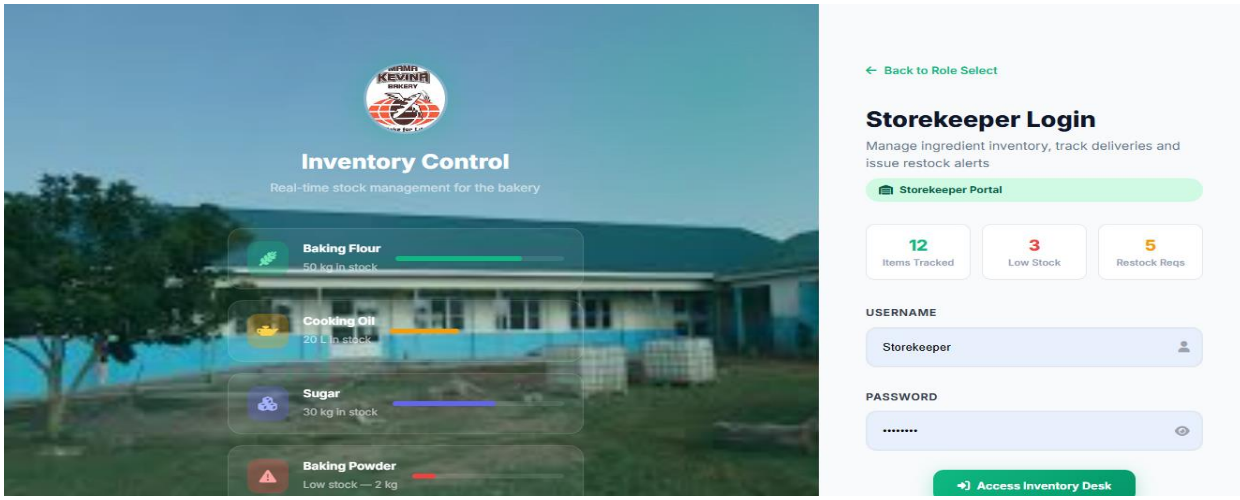

Figure 11: Login interface for Storekeeper

The storekeeper's login interface functions as an inventory-first gateway, utilizing a split-screen layout that provides immediate visibility into stock levels via a real-time tracking panel on the left. High-priority metrics, such as low-stock alerts and pending restock requests, are prominently displayed next to the credential fields to drive urgent supply chain actions upon entry. This design effectively bridges the gap between secure authentication and critical resource management, ensuring that users are briefed on essential inventory status before accessing the full desk.

5.7 Administrator (Admin or Manager) dashboard

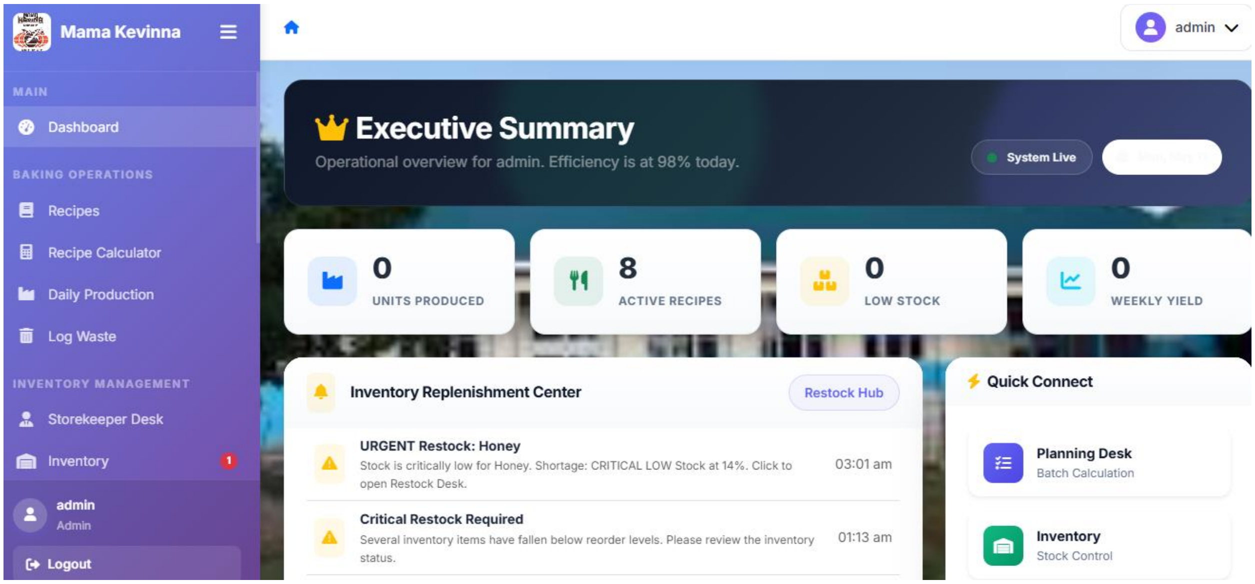

Figure 12: Administrator (Admin or Manager) dashboard

The administrative dashboard serves as a high-level command center, utilizing a sidebar navigation and card-based layout to provide real-time visibility into production efficiency and active recipe counts. It features an "Executive Summary" that highlights critical inventory replenishment alerts alongside "Quick Connect" shortcuts for rapid transitions between batch planning and stock control modules. This centralized interface ensures operational oversight by consolidating essential performance metrics and urgent restock notifications into a single, actionable view for management.

5.8 Baker’s Dashboard

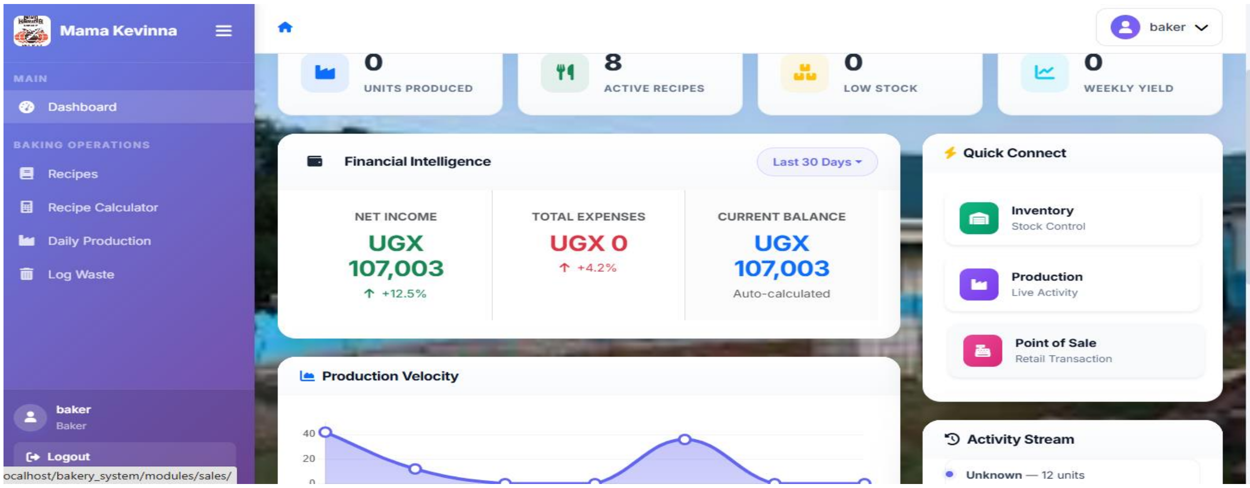

Figure 13: Baker’s Dashboard

The baker's dashboard provides a specialized operational overview that integrates financial intelligence with production velocity tracking to monitor daily performance. It features core metrics such as active recipe counts and weekly yields alongside a "Quick Connect" sidebar for rapid access to inventory and point-of-sale modules. This layout ensures that production staff can maintain real-time awareness of both output trends and business health while managing their primary baking tasks.

5.9 Storekeeper’s Dashboard

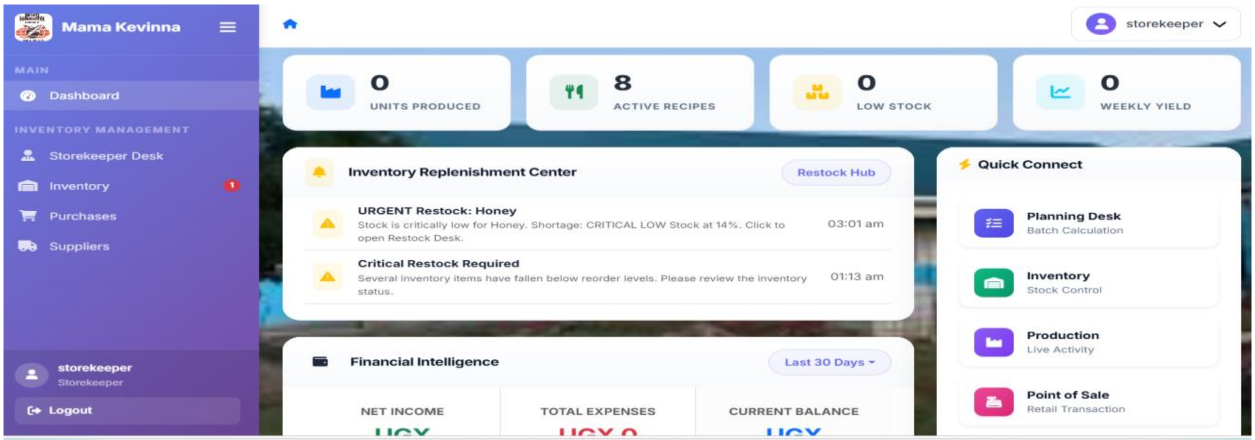

Figure 14: Storekeeper’s Dashboard

The storekeeper’s dashboard serves as a logistical nerve center, prioritizing inventory health through a centralized replenishment center that highlights urgent restock needs like honey. The interface integrates high-level production metrics with financial intelligence, allowing the user to monitor how stock levels directly impact net income and total expenses. By utilizing a "Quick Connect" sidebar, the design ensures seamless navigation between specialized modules like the planning desk and supplier management to maintain a continuous supply chain.

5.10 System Testing

System testing is a technique used to evaluate the system; it is focused on how the users interact with the front end of the system. In order to discover the weaknesses and strength of the system, the following testing strategies were used.

5.10.1 Unit Testing

This is a method where individual units of source code are tested to determine if they are ready for use. A unit is a smallest testable part of an application. A system was tested unit by unit with the presence of the manager in order to enable the developer to identify each part of the program to show that individual parts function correctly.

5.10.2 Integration Testing

Integration testing ensured seamless communication between the PHP application logic, JavaScript front-end actions, and the MySQL database backend. Key integration evaluations included:

Verifying that when a storekeeper updates raw flour stocks, the changes instantly reflect on the manager's inventory dashboard within 2 seconds.

Confirming that daily ingredient variance calculations from the production logs feed directly into the automated visual wastage graphs.

5.10.3 Security Testing

The incorrect Usernames and Password which did not exist in database were used to access the system, but all attempts were unsuccessful meaning our authentication procedure was perfected.

5.10.3 Security Testing

Security testing focused on user authentication, role-based access control, and data validation. Unauthorized access attempts to administrative dashboard URLs without active session tokens were successfully blocked and redirected to the login index page.

5.11 System Validation and Quantitative Feedback

Following code verification, the system was validated using a structured validation questionnaire administered to the bakery manager, 3 bakers, and 2 storekeepers (Total N = 6). The evaluation scaled responses from 1 (Strongly Disagree) to 5 (Strongly Agree) across four core metrics:

Category	Validation Question	Average Score	Percentage
Functionality	The system successfully tracks ingredient scaling and isolates daily production waste.	4.5	90%
Ease of Use	The interface (menus, forms, and logs) clear and simple for kitchen staff to run.	4.0	80%
Performance	Stock balances and wastage reports load within 3 seconds without delay.	4.2	84%
Security	Role-based access ensures production staff cannot alter	4.6	92%

	backend raw inventory records.		
Combined Average	Comprehensive User Acceptance Metrics	4.33	86.6%

Table 2:System Validation and Quantitative Feedback

CHAPTER 6:

DISCUSSION, CONCLUSION, AND RECOMMENDATIONS

6.1Introduction

This chapter synthesizes the outcomes of the study, evaluating the effectiveness of the proposed Production Management System (PMS) at Mama Kevina Bakery. It provides a comprehensive discussion on the research journey, ranging from the initial determination of system requirements to the final implementation and testing phases. Technically, sing the operational, financial, and technical constraints encountered, this section offers critical appraisal of the project's success in mitigating raw material wastage.

6.2 Discussion of Results in Relation to Study Objectives

6.2.1 Objective 1: To review literature and determine the requirements for developing a production management system

The initial phase of this study focused on identifying the structural and behavioral root causes of ingredient loss during the pre-production and production sequences. Initial data collection via questionnaires and observations confirmed that Mama Kevina Bakery suffered from a severe raw input wastage rate of 10–22%, driven heavily by unstandardized manual workflows and subjective volume-based approximations.

These findings strongly align with the assertions of Raak et al. (2017), who identify "processing-related causes" such as human error during ingredient scaling and faulty yeast activation as primary drivers of systemic supply chain food waste. Furthermore, the lack of centralized data storage created what Kannan and Boie (2003) term as an "invisible drain" on profitability where micro-losses of high-cost items like sugar, fats, and milk powder accumulate unnoticed by management over multiple shifts.

By synthesizing these localized insights with literature, a rigid set of functional requirements was extracted using MoSCoW prioritization, concluding that the system must strictly feature automated recipe scaling, real-time inventory deductions, and role-based wastage logging.

6.2.2 Objective 2: To design the production management system for Mama Kevina's Baker

The architectural design of the BPMS was strategically engineered to target the operational vulnerabilities identified in the manual workflow. System modeling tools including Context Diagrams, Level-0 Data Flow Diagrams (DFDs), and normalized Entity-Relationship Diagrams (ERDs) were deployed to transition the bakery from a reactive environment into a data-centered operation.

The technical cornerstone of the design phase was the creation of a three-tier system architecture (Presentation, Application, and Data tiers) incorporating an explicit Poka-Yoke (Error-Proofing) mechanism within the system's Sequence Diagram. As advocated by Ortiz, Quezada, and Oddershede (2024), embedding lean manufacturing principles directly into digital system designs can boost processing productivity and lower manufacturing waste.

The sequence flow was intentionally designed to check and validate real-time stock levels within the MySQL database before allowing a baker to commit to a batch. This design constraint fundamentally solves the "No-Wait Flowshop Problem" typical of bakery environments, where poor process scheduling leads to over-proofed, discarded dough batches.

6.2.3 Objective 3: To implement the design of the production management system

.

The implementation stage materialized the conceptual designs into a functional, web-based software stack leveraging PHP, HTML5, JavaScript, and a MySQL backend managed locally via XAMPP. The interface was explicitly customized with role-based access control (RBAC) dashboards specifically tailored for the Manager, Baker, and Storekeeper.

To ensure high adoption rates and overcome standard digital literacy barriers on the shop floor, the user interface abandoned overly complex enterprise resource planning layouts. Instead, it embraced what Strotmann et al. (2017) define as a "participatory approach" to waste minimization, implementing localized, simple, human-generated English commands and highly intuitive iconographies.

This aligns with the concept of "Appropriate Technology" or "Adaptive Digitalization" (Dausch et al., 2023), proving that deploying low-cost, lightweight digital aids localized to the specific infrastructure of small-scale Ugandan SMEs is far more effective than forcing rigid, expensive Western ERP frameworks onto resource-constrained environments.

6.2.4 Objective 4: To test the functionality of the production management system

.

To validate that the implemented BPMS was fully fit for purpose, a comprehensive multi-stage testing protocol consisting of Unit, Integration, and Security testing was executed in the presence of the bakery manager.

Unit testing validated that individual PHP algorithms successfully computed correct ingredient proportions without rounding errors, directly neutralizing the "Parallax Effect" common to spring scales.

Integration testing verified the automated First-In, First-Out (FIFO) inventory deduction loop. When a baker marked an order complete, the exact raw inputs were immediately subtracted from the digital stock ledger.

Security and constraint testing proved that entering illegitimate credentials or impossible recipe ratios was completely blocked.

This successful automated control framework confirms the conclusions of Goryńska-Goldmann et al. (2020), who state that bread and ingredient losses are fundamentally preventable management and quality control tracking issues rather than inherent baking complications. The testing phase confirmed that by replacing human intuition with precise data barriers, material losses could be systematically squeezed out of the production cycle.

6.5 Conclusion

The research confirms that bread loss is a management challenge rather than a baking one. By integrating lean manufacturing principles and digital precision, Mama Kevina Bakery demonstrated that resource-constrained SMEs in Uganda can achieve a dramatic reduction in wastage. The transition from legacy manual methods to a modern PMS is not just a technological upgrade but a vital step toward long-term economic resilience and sustainable food production.

6.6Recommendations

To sustain these gains, it is recommended that the bakery management maintains strict adherence to digital recipe logs and invests in routine calibration of weighing equipment. Local policy makers and industrial bodies should facilitate knowledge-sharing workshops, helping similar bakeries adopt these low-cost interventions to bolster the regional economy.

6.7 Limitation and Future Work

Future research should focus on "Industry 4.0" integration, specifically utilizing Internet of Things (IoT) sensors for remote humidity monitoring of flour stores. Furthermore, expanding the scope to include "Circular Economy" models such as upcycling unavoidable dough scraps into animal feed would further enhance the environmental and financial sustainability of the bakery operations.

References / Bibliography

Aljohani, K. (2023). Optimizing the distribution network of a bakery facility: a reduced travelled distance and food-waste minimization perspective. *Sustainability*, *15*(4), 3654.

Goryńska-Goldmann, E., Gazdecki, M., Rejman, K., Łaba, S., Kobus-Cisowska, J., & Szczepański, K. (2021). Magnitude causes and scope for reducing food losses in the baking and confectionery industry a multi-method approach. *Agriculture*, *11*(10), 936.

Goryńska-Goldmann, E., Gazdecki, M., Rejman, K., Kobus-Cisowska, J., Łaba, S., & Łaba, R. (2020). How to prevent bread losses in the baking and confectionery industry? measurement, causes, management and prevention. *Agriculture*, *11*(1), 19.

Monteiro, N. B. R., Moita Neto, J. M., & da Silva, E. A. (2022). Life cycle management in bakeries: a proposed roadmap towards sustainability. *The international journal of life cycle assessment*, *27*(1), 82-97.

Iakovlieva, M. (2021). Food waste in bakeries-quantities, causes and treatment.

Kannan, R., & Boie, W. (2003). Energy management practices in SME case study of a bakery in Germany. *Energy conversion and management*, *44*(6), 945-959.

Raak, N., Symmank, C., Zahn, S., Aschemann-Witzel, J., & Rohm, H. (2017). Processing-and product-related causes for food waste and implications for the food supply chain. *Waste management*, *61*, 461-472.

Gökalp, E. (2020). System dynamics modelling of bread waste problem. *Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi*, *26*(4), 831-837.

Strotmann, C., Göbel, C., Friedrich, S., Kreyenschmidt, J., Ritter, G., & Teitscheid, P. (2017). A participatory approach to minimizing food waste in the food industryA manual for managers. *Sustainability*, *9*(1), 66.

Cauvain, S. P., & Young, L. S. (2009). *Bakery food manufacture and quality: water control and effects*. John Wiley & Sons.

Guo, Y., Zhang, W., Qin, Q., Chen, K., & Wei, Y. (2023). Intelligent manufacturing management system based on data mining in artificial intelligence energy-saving resources. *Soft Computing*, *27*(7), 4061-4076.

Demirbas, A. (2011). Waste management, waste resource facilities and waste conversion processes. *Energy conversion and management*, *52*(2), 1280-1287.

Ortiz, C., Quezada, L., & Oddershede, A. (2024). Industrial process management model to improve productivity and reduce waste. *Sustainability*, *16*(4), 1606.

Dausch, V., Beckschulte, S., Huebser, L., Schulze, T., Schmitt, R. H., & Kreimeyer, M. (2023). Reducing Wastage in Manufacturing Through Digitalization: An Adaptive Solution Approach for Process Efficiency. In *Proceedings of the Conference on Production Systems and Logistics: CPSL 2023-2* (pp. 559-568). Hannover: publish-Ing.

Mostaghimi, K., & Behnamian, J. (2023). Waste minimization towards waste management and cleaner production strategies: a literature review: K. Mostaghimi, J. Behnamian. *Environment, Development and Sustainability*, *25*(11), 12119-12166.

APPENDICES

Appendix A: Questionnaire form for Mama Kevinna's Bakery

I Tiyo Grant a student of Busitema University carrying out an investigation on Production Management system of Mama Kevina basing on the focus of the problem statement "Reduction of resource wastage during production process in the Bakery"

This paper contains four sections each having three questions, read it carefully and choose the appropriate answer by ticking basing on your experience about Mama Kevina Bakery enterprise production process.

Specify yourself as either manager, supervisor, baker, store keeper, raw material buyer following the instruction below;

1. Your Name:

   ………………………………………………………………………………………………

2. Your position in the bakery:

   ………………………………………………………………………………………………

3. Number of years of service in bakery:

   ………………………………………………………………………………………………

Section A: Raw Material Handling and Storage

1. How often do you experience spoilage of raw ingredients (flour, yeast, milk powder) due to poor storage conditions?

1.Daily ☐ 2. 2-3 times per week ☐ 3. Once a week ☐ 3. Rarely (once a month or less) ☐ 4. Never ☐

2. What is the main cause of flour wastage during storage at the bakery?

1. Pest infestation (weevils, rodents) ☐ 2. Moisture absorption and mold growth ☐ 3. Bag tearing and spillage ☐ 4. Expired stock (beyond shelf life) ☐ 5. I don't know ☐

3. How do you determine the quantity of raw materials to order/reorder?

1. Based on written records of previous sales ☐ 2. Owner/manager's verbal instruction ☐
3. When we completely run out of stock ☐ 4. Based on intuition/experience ☐
5. We order the same amount every time regardless of demand ☐

Section B: Production Process and Weighing

4. How do you measure ingredients during the weighing and batching stage?

1. Using standard measuring scales accurately ☐ 2. Using approximate measurements (cups, spoons, guesswork) ☐ 3. I rely on experience to estimate quantities ☐ 4. We pre-weigh all ingredients before mixing begins ☐ 5. Different staff use different methods ☐

5. How often does dough fail to rise properly during fermentation/proofing

1. Almost every batch ☐ 2. Several times a week ☐ 3. Once or twice a week Occasionally (a few times a month) ☐ 4. Rarely/Never ☐

6. What do you believe is the main cause of failed dough batches?

1. Incorrect yeast measurement/activation ☐ 2. Wrong water temperature ☐ 3. Poor quality flour or expired yeast ☐ 4. Inadequate proofing time or conditions ☐ 4. I'm not sure ☐

7. How frequently do you encounter over-baked, burnt, or under-baked products?

1. Very frequently (multiple times daily) ☐ 2. Frequently (at least once daily) ☐ 3. Occasionally (2-3 times per week) ☐ 4. Rarely (once a week or less) ☐ 5. Almost never ☐

Section B: Production Planning and Forecasting

8. How is daily production quantity decided at the bakery?

1. Based on previous day's sales records ☐ 2. The owner/manager decides each morning ☐ 3. We bake as much as we can with available ingredients ☐ 4. Customers place orders in advance ☐ 5. We bake the same quantity every day ☐

9. What happens to unsold bread and pastries at the end of the day?

1.Sold at reduced price the next day ☐ 2. Given away to staff or charity ☐ 3. Discarded as waste ☐ 4. Returned to production for reprocessing (e.g., breadcrumbs) ☐ 5. Sold to livestock farmers as animal feed ☐

10. How would you rate the accuracy of your current production planning?

1. Very accurate (rarely have leftovers or shortages) ☐ 2. Moderately accurate (occasional mismatches) ☐ 3. Inaccurate (frequent overproduction or underproduction) ☐ 4. Very inaccurate (waste or lost sales almost daily) ☐ 5. We don't do production planning ☐

Section D: Waste Tracking and Management

11. Does the bakery keep written records of daily material wastage?

1.Yes, detailed records are kept for all ingredients ☐ 2. Yes, but only for expensive ingredients (flour, sugar) ☐ 3. Sometimes, when the manager remembers ☐ 4. No formal records, but we notice when waste is high ☐ 5. No records are kept at all ☐

12. In your opinion, at which production stage is the MOST ingredient wastage occurring?

1. Receiving and storage (spoilage, pests) ☐ 2. Weighing and batching (spillage, inaccurate measurement) ☐ 3. Mixing and kneading (dough sticking to equipment) ☐ 4. Baking (burning, quality defects ☐ 5. Cooling and packaging (damage, breakage) ☐

13. What is the estimated percentage of raw ingredients wasted daily at the bakery?

1. Less than 2% ☐ 2. 2% – 6% (normal industry range) ☐ 3. 7% – 10% ☐ 4. 11% – 15% ☐ 5. More than 15% ☐

14. Which of the following best describes the bakery's current approach to waste reduction?

1. We have a formal system to track and reduce waste ☐ 2. Staff are told to "be careful" but no system exists ☐ 3. Waste is accepted as a normal part of bakery operations ☐ 4. We only worry about waste when ingredients run out too fast ☐ 5. We have never discussed waste reduction as a team ☐

15. Would you support the introduction of a digital system to track production and reduce wastage?

1. Yes, enthusiastically – it would help a lot ☐ 2. Yes, if it is simple and easy to use ☐ 3. Neutral – whatever management decides ☐ 4. No, I prefer the current manual methods ☐ 5. No, technology would complicate our work ☐

Appendix B: Budget Estimate (Illustrative)

Category	Item Description	Unit cost (UGX)	Quantity	Total cost (UGX)
Field work and travel	Transport to Tororo (site visits)	3,000	6	18,000
	Subsistence/meals during fieldwork	2,000	6	12,000
Data collection	Printing questionnaire/log sheets	200	30 copies	6,000
	Interview Audio recording/ transcription	-	-	-
Equipment and Tech	Low-end Tablet for floor entity (pilot)	-	-	-
	Domain/local server and hosting	-	-	-
Development	System development software tools	-	-	-
Training	Staff workshop materials and refreshments	50,000	2 sessions	100,000
Administrative	Final report printing and binding	25,000	3 copies	75,000
	Contingency (10%)			30,000

GRAND TOTAL					240,000

Table 3: Budget Estimate (Illustrative)

Appendix C: Work Plan / Gantt Chart

- Timeline covering Preliminary study, system design, development and testing, implementation, and Evaluation and finalization (report writing) (3.5 months)

Project Timeline (Months 3.5 months)

Task Description	Time frame
Phase 1: Preliminary study	3 weeks
Literature review	1 week
Data collection	2 weeks
Phase 3: System Design	3 weeks
Requirement specification diagraming (ERD, DFD)	2 weeks
UI/UX interface Design	1 week
Phase 3: Development and Testing	2 weeks
Database and Backend development	1 week
Unit Testing and Debugging	1 week
Phase 4: implementation	2 weeks
Hardware setup and staff training	1 week
Pilot run a nd parallel operation	1 week
Phase 5: Evaluation and finalization	4weeks
Impact assessment (pre-vs post-waste)	1 week
Final Report writing and submission	3 weeks
Total time period	14 weeks

Table 4: Work Plan