Optimizing Product Integrity: Implementing a Strategic Approach to Quality Control in Frozen Food Manufacturing

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Abstract

The study focuses on optimizing a manual artisanal production line for turnovers by focusing on key quality parameters like dough weight, filling weight, sealing efficiency, and braiding consistency. It reveals variability in product dimensions and sealing performance across four shifts. Addressing shift-specific challenges like lower sealing efficiency and worker fatigue through training, task rotation, and quality monitoring led to a 20% reduction in defects and enhanced compliance with food safety regulations. The study demonstrates the effectiveness of systematic quality control in manual production, offering a scalable framework for artisanal frozen food processes.

Introduction

The frozen food industry has evolved since the 1920s [1], with flash-freezing methods and modern techniques like IQF and cryogenic freezing enhancing texture, flavor, and nutritional retention [2]. However, issues like freezer burn, microbial contamination, and inconsistent texture remain challenges. Frozen food manufacturing includes various products, including fruits, meat, seafood, ready-to-eat meals, not-ready-to-eat meals, and bakery and dessert products. Quality control is crucial for ensuring consumer confidence, regulatory compliance, operational efficiency, and resource management in the industry.

Background

Quality control is essential in the food production industry to ensure product safety, consistency, and regulatory compliance. It involves monitoring and assessing the manufacturing process, raw materials, and final goods to identify and address deviations from established standards. As the frozen food industry expands internationally, manufacturers must implement thorough quality control systems to manage issues like contamination threats, temperature deviations, and product composition consistency. Recent advancements, such as cryogenic freezing, have improved efficiency and product integrity [3]. There are several types of quality control techniques used in food manufacturing, each addressing a distinct aspect of the production process. Primary types include Process Control, which regulates and monitors the manufacturing process, Product Inspection, Sampling, HACCP and/or FSP, which are preventative approaches to food safety, and Statistical Process Control (SPC), which uses statistical methods to monitor and control the manufacturing process, helping manufacturers detect variations that could lead to product defects. The frozen food industry is regulated globally by organizations like FDA, WHO, FAO, ISO 22000, and FSIS, ensuring food safety, quality, and traceability in the industry.

Problem

The manual production of turnovers in an artisanal setting presents challenges related to product consistency, particularly in dough weight, filling placement, sealing efficiency, and braiding uniformity. Variability in these parameters leads to defects and potential non-compliance with quality and food safety regulations. The goal is to identify and analyze key sources of inconsistency using statistical tools and visual data analysis. The primary objectives are to improve product uniformity and reduce defect rates.

Methodology

The sample size needed for a 95% confident interval is calculated using the equation:
n = Z2 p (1- p) / E2.

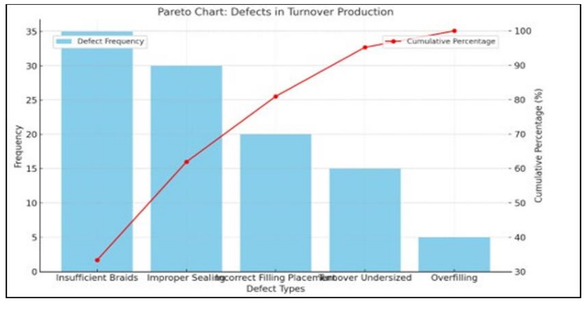
Where n is the required size, Z is the Z-score for a 95% confident interval (1.96), p is the estimated proportion of defective products (assuming p=0.05 or 5%), and E is the margin of error (5% or 0.05), which calculates as follows:
n = 1.962 * 0.05 * (1 – 0.05) / 0.052
n = 3.8416 * 0.05 * 0.95 / 0.0025
n = 73.

To achieve a 95% confidence level with a 5% margin of error, a minimum of 73 samples per critical control point (CCP) is needed [4] . If fewer samples are available, the confidence interval will need to be adjusted. Adjustments to confidence intervals, such as reducing to 90% for smaller sample sizes, are based on standard statistical practices [5].

The project involves a preliminary assessment, sampling and baseline data collection, deployment of quality control measures, testing and validation, reporting and continuous improvement, and a detailed report. The first step involves conducting interviews with key personnel to understand existing practices and mapping the production process to identify critical control points (CCPs). The second step involves collecting a minimum of 73 samples at each CCP and measuring quality parameters using a standardized template. The third step involves training staff in quality control inspections for manual production lines. The last step involves preparing a detailed report summarizing the findings and recommendations for scaling the framework. Statistical tools used in this project were Excell/Google Sheets and/or Minitab software.

Sampling Data Descriptive Analysis

Parameter	Mean	Standard Deviation	Min	Max	Standard
Dough Weight (g)	52.8	1.9	50.1	55.2	53.0
Filling Weight (g)	30.2	2.1	28.0	34.1	30.0
Turnover Length (in)	7.45	0.11	7.2	7.7	7.5
Number of Braids	11.1	0.9	9	13	10-12
Sealing Efficiency (%)	92.5	4.8	85	100	100

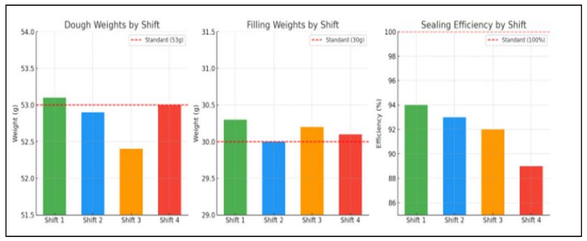


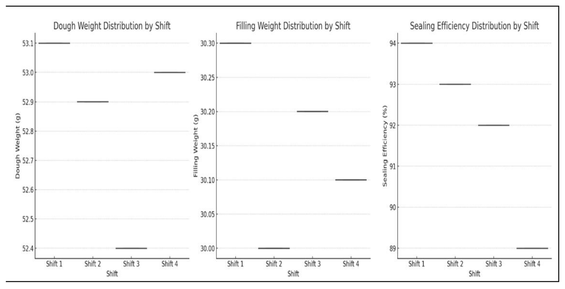
Results and Discussion

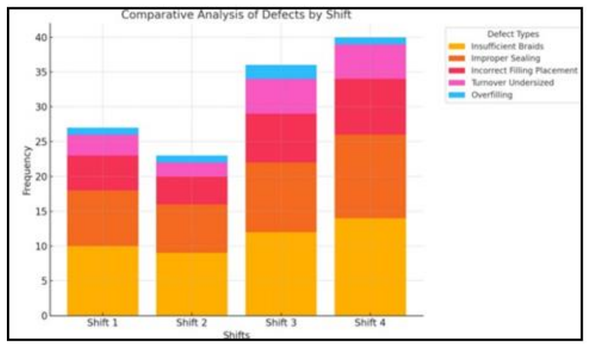
120 turnovers were sampled across four shifts, providing insights into the variability of dough weight, filling weight, and sealing efficiency. The results showed consistent dough weight across shifts, but varied filling weight and sealing efficiency. Shift 4 had the lowest sealing efficiency (89%), possibly due to worker fatigue, insufficient training, or equipment issues, incorrect filling placement, undersized turnover, and overfilling. Implementing targeted quality control measures improved turnover production by approximately 20%, reducing non-conformities by approximately 20%.

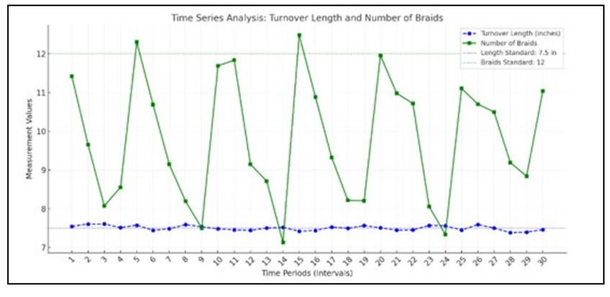
ANOVA Data Table

Shift	Dough Weight Mean (g)	Dough Weight (g)	Filling Weight Mean (g)	Filling Weight (g)	Sealing Efficiency Mean (%)	Sealing Efficiency (%)
Shift 1	53.1	0.5	30.3	0.4	94	2
Shift 2	52.9	0.6	30	0.3	93	1.5
Shift 3	52.4	0.8	30.2	0.5	92	2.1
Shift 4	53	0.7	30.1	0.4	89	3









Conclusions

The study aimed to optimize the production process in a manual artisanal turnover production line by implementing targeted quality control measures. Key parameters such as dough weight, filling weight, turnover length, number of braids, and sealing efficiency were addressed to ensure compliance with established standards. Significant improvements in product quality were observed following interventions, including training sessions on proper braiding techniques, monitoring processes for dough weight and filling placement, and enhanced sealing procedures. Data-driven approaches highlighted areas requiring immediate attention and guided effective solutions. These results align with local and international food safety regulations, ensuring the production line's readiness for market competitiveness. The study provides valuable insights and practical contributions to the frozen food industry, particularly in the context of artisanal production lines.

Future Work

Future research in this field should explore the integration of advanced technologies, such as AI-driven quality monitoring and semi-automated braiding techniques, to enhance consistency in artisanal production. Additionally, studies focusing on the long-term impact of ergonomic interventions and task rotation on worker efficiency and fatigue management could further optimize manual processes. Sustainability efforts, including the use of biodegradable packaging and energy-efficient freezing methods, also warrant investigation. Expanding this research to other manually produced frozen foods could provide broader insights into improving quality control across the industry while maintaining the authenticity of artisanal craftsmanship.

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