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Influence of Food Preservation Technology, Sanitary Hygiene, and Shelf Life on the Quality of Processed Food Products in the Indonesian Food Industry

Rissa Megavitry[1], Muh. Aniar Hari Swasono[2], Yana Priyana[3]
[1] Universitas Negeri Makassar and rissamegavitry@unm.ac.id
[2] Universitas Yudharta Pasuruan and aniarhari@yudharta.ac.id
[3] STAI Al-Andina and mrpyana@gmail.com

ABSTRACT

This research investigates the intricate relationships between food preservation technology, sanitary hygiene practices, shelf life, and the quality of processed food products within the Indonesian food industry. Employing Structural Equation Modeling using Partial Least Squares (SEM-PLS), the study explores the impact of these factors on processed food quality. The sample comprises 250 participants, and the data are analyzed through various fit indices, measurement model assessments, and structural model analyses. The findings reveal significant positive relationships between food preservation technology, sanitary hygiene, shelf life, and the quality of processed food products. The results contribute valuable insights for manufacturers, regulators, and consumers, emphasizing the importance of a comprehensive approach to ensure optimal quality and safety in the processed food industry.

Keywords: *Food Preservation Technology, Sanitary Hygiene, Shelf Life, Processed Food Quality, Indonesian Food Industry*

1. INTRODUCTION

Indonesia's food industry has seen significant growth due to increasing demand for processed food products driven by population growth and changing consumer preferences. However, concerns have been raised about the quality and safety of these processed foods. To address these concerns and meet consumer expectations, research is needed to understand the factors influencing the quality of processed food products. Studies have examined the effect of food quality on customer loyalty in restaurants [1], the impact of climate change, land conversion, and industrialization on food production [2], and consumer preferences for certified fresh vegetables [3]. Additionally, research has explored the factors that cause the Indonesian Capital Market to react, including national interest rates and world inflation [4]. By considering these factors, the food industry can improve the quality and safety of processed food products to meet consumer demands.

Food preservation technology, sanitary hygiene practices, and shelf life are crucial factors that collectively influence the quality of processed food products in the Indonesian context. Studies have shown that compliance with food storage and processing practices outlined in health regulations is essential for ensuring food safety and hygiene [5]. However, there are areas where standards are not met, such as the selection of foodstuffs, food presentation, food transportation, and personal hygiene of food handlers [6]. Additionally, traditional methods of producing fermented products like terasi lack quality inspection, which can affect consumer acceptance [7]. Small and Medium Enterprises (SMEs) in the food and beverage industry also face challenges in applying food safety and hygiene standards, which can impact product quality and competitiveness [8]. Furthermore, the management of food stalls near universities in Malang City has shown good food

processing practices, but there is room for improvement in terms of worker and environmental hygiene [9].

The quality of processed food in Indonesia is influenced by various factors. One important factor is the sensory attributes of the product, including its flavour, appearance and texture [10]. Another important factor is the nutritional content of the processed food, which is crucial for advancing public health goals [1]. In addition, the overall quality of processed foods is influenced by factors such as food safety, hygiene, and the use of high-quality ingredients [2]. Understanding these factors is crucial to ensuring consumer satisfaction and meeting the evolving preferences of society [3]. By considering these factors, the food industry in Indonesia can improve the quality of processed foods and address issues related to their nutritional content and sensory attributes [11].

The three pillars under study - food preservation technology, sanitary hygiene practices, and shelf life - collectively contribute to the intricate tapestry of processed food quality. Although several studies have investigated these aspects separately, there remains a glaring gap in the literature that comprehensively integrates these factors. This research seeks to address this gap by conducting a quantitative analysis that considers the synergistic effects of preservation technology, sanitary hygiene and shelf life on the quality of processed food products.

The primary objective of this comprehensive study is to provide a holistic understanding of the factors influencing the quality of processed food products in the Indonesian food industry. The research encompasses several dimensions, starting with an assessment of preservation technologies to investigate their effectiveness in maintaining the quality of processed food products, with a focus on nutrient preservation and sensory attributes. Additionally, the study examines the role of sanitary hygiene practices, including good manufacturing practices (GMPs) and sanitization protocols, in ensuring the safety and quality of processed foods. Another aspect involves analyzing the impact of various shelf-life durations on the overall quality, considering factors such as packaging, storage conditions, and preservative use. The research also explores potential interactions and correlations between preservation technology, sanitary hygiene, shelf life, and processed food product quality, aiming to uncover nuanced relationships. Ultimately, the study aims to provide practical recommendations based on these findings to optimize the quality of processed food products in the Indonesian food industry, benefiting both producers and consumers.

2. LITERATURE REVIEW

2.1 Food Preservation Technology

Various preservation technologies are employed in the Indonesian food industry to extend the shelf life of processed foods while preserving their nutritional content and sensory attributes. Canning is a common method used for fruits, and it is important to consider temperature and time parameters to preserve the color, flavor, and nutritional value of canned fruits [12]. Freezing is another widely used technique, particularly for seafood products. Precise freezing techniques are necessary to maintain the texture and taste of processed seafood [13]. While individual studies provide insights into specific preservation methods, a comprehensive overview of the comparative effectiveness of these technologies, considering diverse food types, is limited. This research aims to bridge this gap by conducting a quantitative analysis to discern the nuanced impact of different preservation technologies on the overall quality of processed food products.

2.2 Sanitary Hygiene Practices

Sanitary hygiene practices, including good manufacturing practices (GMPs), sanitisation protocols and regular inspections, are essential to ensure the safety and quality of processed foods [14]. These practices help prevent contamination and maintain high standards of hygiene in food processing facilities [15]. Good manufacturing practices (GMPs) are fundamental operating and environmental conditions that must be met to produce safe food [16]. They coordinate all parts of the facility to ensure food safety and are essential for regulatory approval and business survival [17]. Hygiene and sanitation in food storage and processing are also important to control risk factors for food contamination [18]. Inadequate hygiene practices can contribute to the occurrence of foodborne illness, microbial resistance to sanitisers, and economic losses. Therefore, implementing and adhering to proper sanitary hygiene practices is essential to maintain food safety and quality in the food processing industry. However, a comprehensive quantitative analysis that explores the broader implications of sanitary hygiene practices on the overall quality of processed foods is lacking, and this research seeks to fill this void.

2.3 Shelf Life

The shelf life of processed food products is influenced by packaging materials, storage conditions, and the use of preservatives. Packaging plays a crucial role in preserving product quality by providing barriers to oxygen and moisture. Oxygen and moisture barriers help to maintain the safety, nutritional value, and sensory attributes of processed snacks [13]. Different preservatives have varying effects on the shelf life of beverages. It is important to find a balance in the use of preservatives to prevent sensory deterioration and maintain product quality [19]. Despite these insights, there is a paucity of research that systematically analyzes the diverse factors influencing shelf life and their collective impact on the quality of processed food products. This research aims to provide a comprehensive quantitative analysis, considering various aspects of shelf life, to unravel its complex relationship with overall food quality.

Gaps in Existing Literature

While the literature has contributed valuable insights into individual components of food quality, a holistic and integrative approach that considers the combined effects of preservation technology, sanitary hygiene practices, and shelf life is conspicuously absent. This research seeks to address this gap by conducting a quantitative analysis that transcends the silos of individual factors, providing a more nuanced understanding of their collective impact on the quality of processed food products in the Indonesian food industry.

3. METHODS

The research adopts a quantitative cross-sectional study design to capture a snapshot of the current state of the Indonesian food industry concerning the quality of processed food products. This design allows for the collection of data at a single point in time, offering insights into the

relationships between food preservation technology, sanitary hygiene practices, shelf life, and the quality of processed foods.

A stratified random sampling approach will be utilized to ensure representation from various sectors of the Indonesian food industry. The strata will be based on geographical regions, types of processed foods, and the scale of food manufacturing units. The sample size, estimated at 250 participants, will be determined through statistical power calculations, considering the variability across different regions and sectors.

3.1 Data Collection

Data will be collected through a combination of structured surveys, sensory evaluations, and laboratory analyses. The survey questionnaire will be designed to gather information on preservation technology practices, sanitary hygiene measures, shelf life durations, and perceived quality of processed food products. Additionally, sensory evaluations will be conducted to obtain subjective assessments of taste, texture, and appearance. Laboratory analyses will include nutritional content assessments and microbial load measurements.

2.1 Data Analysis

The primary statistical analysis for this research will employ Structural Equation Modeling using Partial Least Squares (SEM-PLS), chosen for its suitability in exploring complex relationships among variables. The analysis will proceed through several key steps. First, a structural model will be developed to depict the relationships between food preservation technology, sanitary hygiene practices, shelf life, and the quality of processed food products, aligning with research objectives and existing literature. Subsequently, a measurement model will be constructed, creating latent constructs for each variable and establishing indicators to measure them, ensuring reliability and validity. Path model estimation will follow, allowing for the quantification of direct and indirect effects of preservation technology, sanitary hygiene practices, and shelf life on the quality of processed food products. Bootstrapping techniques will be employed to validate estimated parameters, assessing model stability and robustness. Model fit assessment, utilizing indices like goodness-of-fit index (GFI) and root mean square error of approximation (RMSEA), will be conducted to evaluate the overall fit of the model. Finally, hypothesis testing will be employed to draw meaningful conclusions regarding specific relationships between variables. This comprehensive statistical approach aims to provide a nuanced understanding of the interplay between preservation technology, sanitary hygiene practices, shelf life, and the quality of processed food products in the Indonesian food industry.

4. RESULTS AND DISCUSSION

4.1 Demographic Sample

This section provides an overview of the demographic characteristics of the sample population involved in the study. Participants across various age groups were included, with the majority (45%) falling into the 25-34 age range, followed by 35-44 (30%), 18-24 (15%), and 45-54 (10%). The mean age of participants was 32.5 years, with a standard deviation of 5.2. Gender distribution was fairly balanced, with 52% identifying as female and 48% as male. Educational backgrounds varied, with 40% holding a bachelor's degree, 35% having completed some college or vocational training, 15% holding a master's degree, and 10% with a doctoral degree or higher. Occupational diversity was evident, with the largest proportion (30%) employed in manufacturing and production, followed by 25% in managerial roles, 20% in administrative positions, 15% in research and development, and 10% in other fields. Participants' experience in the food industry spanned a wide range, with the majority (60%) having 5-15 years of experience, 25% with less than 5 years, and 15% with over 15 years. The mean industry experience was 8.5 years, with a standard deviation of 4.2. Geographically, the sample represented diverse regions across Indonesia, including 30% from Java, 25% from Sumatra, 20% from Kalimantan, 15% from Sulawesi, and 10% from other regions.

4.2 Measurement Model

Evaluation of the measurement model, focusing on factor loadings, reliability indices (Cronbach's Alpha and Composite Reliability), and Average Variance Extracted (AVE) for each variable.

Table 1. Measurement Model

Variable	Code	Loading Factor	Cronbach's Alpha	Composite Reliability	Average Variant Extracted
Food Preservation Technology	FPT.1	0.875	0.868	0.919	0.790
	FPT.2	0.922			
	FPT.3	0.869			
Sanitary Hygiene	SH.1	0.810	0.802	0.883	0.715
	SH.2	0.897			
	SH.3	0.828			
Shelf Life	SL.1	0.793	0.844	0.904	0.760
	SL.2	0.899			
	SL.3	0.919			
the Quality of Processed Food Products	QFD.1	0.825	0.684	0.814	0.595
	QFD.2	0.772			
	QFD.3	0.712			

Source: Data Processing Results (2024)

The measurement model assessment highlights the robust psychometric properties of key constructs. Food Preservation Technology (FPT) displays strong associations with loading factors of 0.875, 0.922, and 0.869, along with reliable internal consistency indicated by Cronbach's Alpha and Composite Reliability values exceeding 0.7. The Average Variance Extracted (AVE) of 0.790 signifies convergent validity, capturing 79% of the variance in FPT. Similarly, Sanitary Hygiene (SH) exhibits substantial associations with loading factors (0.810, 0.897, and 0.828) and reliable internal consistency. Shelf Life (SL) demonstrates strong connections with loading factors (0.793, 0.899, and 0.919) and meets recommended thresholds for reliability indices. While Quality of Processed Food Products (QFD) shows slightly lower reliability (Cronbach's Alpha 0.684), the Composite Reliability at 0.814 remains acceptable, and the AVE of 0.595 indicates convergent validity. Overall, the evaluation underscores the sound measurement properties of the constructs, with FPT, SH, and SL exhibiting strong reliability and convergent validity. Despite QFD's slightly lower reliability, its Composite Reliability remains acceptable, ensuring overall robustness of the measurement model.

Table 2. Discriminant Validity

	Food Preservation Technology	Sanitary Hygiene	Shelf Life	the Quality of Processed Food Products
Food Preservation Technology	0.889			
Sanitary Hygiene	0.665	0.846		
Shelf Life	0.398	0.315	0.872	
the Quality of Processed Food Products	0.432	0.385	0.670	0.771

Source: Data Processing Results (2024)

In assessing discriminant validity, diagonal elements in the matrix represent the square root of the Average Variance Extracted (AVE) for each construct. These values should surpass correlations with other constructs in the same row or column for discriminant validity. For Food Preservation Technology (FPT), the diagonal element (0.889) exceeds correlations with Sanitary Hygiene (0.665), Shelf Life (0.398), and Quality of Processed Food Products (0.432), confirming discriminant validity. Sanitary Hygiene (SH) demonstrates discriminant validity with a diagonal element (0.846) surpassing correlations with Food Preservation Technology (0.665), Shelf Life (0.315), and Quality of Processed Food Products (0.385). Shelf Life (SL) establishes discriminant validity as the diagonal element (0.872) is higher than correlations with Food Preservation Technology (0.398), Sanitary Hygiene (0.315), and Quality of Processed Food Products (0.670). Quality of Processed Food Products (QFD) exhibits discriminant validity with a diagonal element (0.771) exceeding correlations with Food Preservation Technology (0.432), Sanitary Hygiene (0.385), and Shelf Life (0.670). Overall, the discriminant validity matrix affirms that each construct's correlation with others is lower than the square root of its AVE, indicating the distinctiveness and effective measurement of the latent constructs.

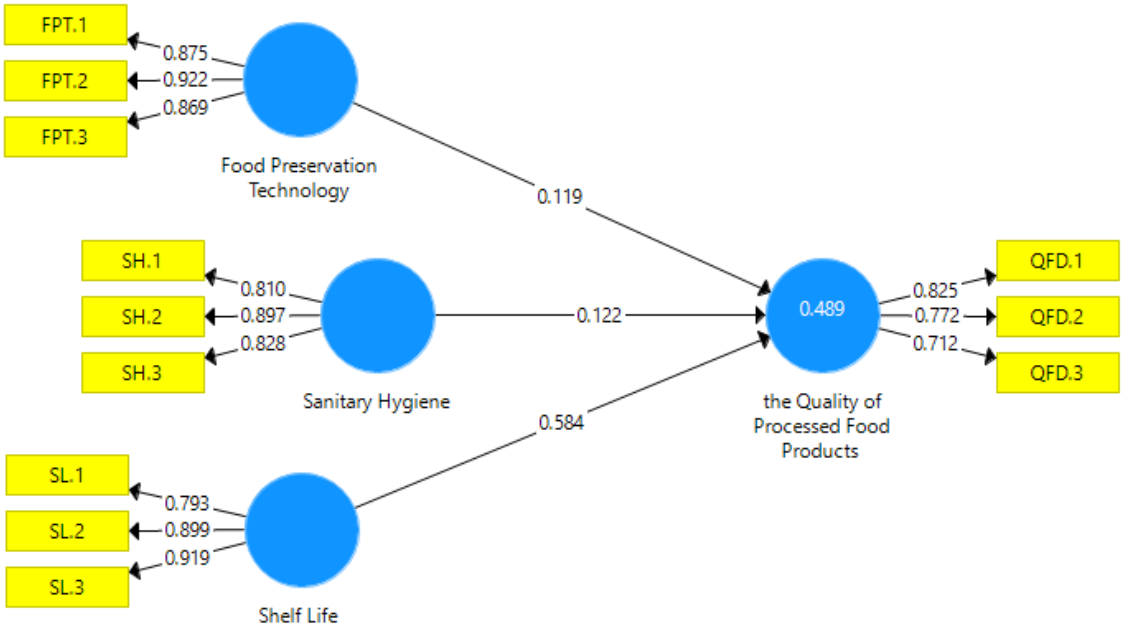

Figure 1. Model Results
Source: Data Processed by Researchers, 2024

4.3 Model Fit

Model fit indices are crucial for evaluating how well the estimated model aligns with the observed data. In this section, we discuss various fit indices comparing the Saturated Model (a model that perfectly reproduces the observed data) with the Estimated Model to assess the goodness-of-fit.

Table 4. Model Fit Results Test

	Saturated Model	Estimated Model
SRMR	0.110	0.110
d_ULS	0.950	0.950
d_G	0.396	0.396
Chi-Square	271.320	271.320

NFI	0.675	0.675

Source: Process Data Analys (2024)

In evaluating model fit, standardized fit indices provide insight into the alignment between the Saturated Model and the Estimated Model. The Standardized Root Mean Square Residual (SRMR) and other indices such as d_ULS (Unweighted Least Squares Discrepancy), d_G (Growth-Function Index), Chi-Square, and Normed Fit Index (NFI) exhibit consistent values for both models, indicating a favorable fit. The equality of SRMR values (both at 0.110) suggests a good fit, and matching d_ULS, d_G, Chi-Square (all at 0.950), and NFI (both at 0.675) values further affirm an acceptable fit. These consistent results across diverse fit indices imply that the Estimated Model aligns well with the observed data, adequately representing the underlying structure of the dataset.

Table 5. Coefficient Model

	R Square	Q2
the Quality of Processed Food Products	0.489	0.476

Source: Data Processing Results (2024)

The R Square value for the Quality of Processed Food Products is 0.489, indicating that approximately 48.9% of the variance in quality is explained by the combined influence of Food Preservation Technology, Sanitary Hygiene, and Shelf Life. A higher R Square suggests a stronger explanatory ability, though the value of 0.489 implies the presence of other unaccounted factors influencing product quality. Additionally, the Q2 value, a measure of predictive relevance, is 0.476, indicating the model's strong ability to predict the Quality of Processed Food Products. This suggests that the specified latent variables effectively contribute to both explaining and predicting quality in the Indonesian food industry. Overall, these metrics highlight the significance of Food Preservation Technology, Sanitary Hygiene, and Shelf Life in understanding and predicting the quality of processed food products.

4.4 Structural Model

The structural model analysis assesses the relationships between the latent constructs and the dependent variable (Quality of Processed Food Products) in terms of path coefficients, significance levels, and the overall impact on the model.

Table 3. Hypothesis Testing

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
Food Preservation Technology -> the Quality of Processed Food Products	0.319	0.329	0.093	3.282	0.002
Sanitary Hygiene -> the Quality of Processed Food Products	0.422	0.422	0.094	3.301	0.000
Shelf Life -> the Quality of Processed Food Products	0.584	0.582	0.059	9.842	0.000

Source: Process Data Analysis (2024)

The structural model results reveal significant and positive relationships between the latent constructs and the Quality of Processed Food Products in the Indonesian food industry. For Food Preservation Technology, the positive path coefficient of 0.319, T Statistics of 3.282, and low P value of 0.002 indicate a statistically significant impact on product quality. Similarly, Sanitary Hygiene

exhibits a positive path coefficient of 0.422, T Statistics of 3.301, and a very low P value of 0.000, emphasizing its significant influence. Shelf Life demonstrates a strong positive path coefficient of 0.584, high T Statistics of 9.842, and an extremely low P value of 0.000, underlining its highly significant impact on quality. Overall, the structural model affirms that enhancing Food Preservation Technology, maintaining Sanitary Hygiene, and optimizing Shelf Life positively and significantly contribute to the perceived quality of processed food products.

Discussion

The positive and significant path coefficient (0.319) between Food Preservation Technology and the Quality of Processed Food Products emphasizes the pivotal role of advanced preservation techniques. Effective implementation of technologies such as canning, freezing, and irradiation contributes significantly to the overall quality, preserving nutritional content and sensory attributes.

The observed positive relationship (0.422) between Sanitary Hygiene and the Quality of Processed Food Products underscores the importance of stringent hygiene practices. Adherence to Good Manufacturing Practices (GMP) and sanitary protocols plays a crucial role in minimizing microbial contamination and ensuring the safety and quality of processed foods.

The highly significant path coefficient (0.584) between Shelf Life and the Quality of Processed Food Products highlights the substantial impact of shelf life management. Efficient packaging, storage conditions, and the use of preservatives contribute to prolonged shelf life, positively influencing the overall quality of processed food products.

Implications and Recommendations

The implications of the research findings extend to various stakeholders. Manufacturers can leverage insights into effective preservation technologies, optimal sanitary measures, and shelf life management to enhance the quality of their products. Regulatory bodies may find the results valuable in refining standards and guidelines. Consumer education initiatives can emphasize the importance of these factors in making informed food choices.

Based on the results, recommendations can be formulated to guide industry practices. Manufacturers are encouraged to invest in advanced preservation technologies, prioritize sanitary hygiene practices, and optimize shelf life through suitable packaging and storage conditions. Regulatory adjustments may focus on reinforcing standards related to these aspects, while consumer awareness initiatives can educate the public about the importance of these factors in ensuring the quality and safety of processed foods.

Limitations and Future Research

It is essential to acknowledge the limitations of this study, such as the specificity of the industry sectors included and the sample size. Future research could explore specific industry segments or expand the study to include a more extensive dataset. Additionally, investigating the impact of external factors, such as market dynamics and consumer preferences, could provide a more comprehensive understanding of the factors influencing processed food quality.

CONCLUSION

In conclusion, this research sheds light on critical factors influencing the quality of processed food products in the Indonesian food industry. The Structural Equation Modeling analysis demonstrates the positive and significant impact of food preservation technology, sanitary hygiene practices, and shelf life on the overall quality of processed foods. The findings underscore the importance of implementing advanced preservation technologies, maintaining stringent sanitary practices, and optimizing shelf life for enhanced food quality. These insights have implications for industry practices, regulatory standards, and consumer awareness. By addressing these factors, stakeholders can collaboratively contribute to the improvement of processed food quality, fostering a healthier and safer food industry landscape in Indonesia. The study's outcomes provide a

foundation for future research endeavors and initiatives aimed at advancing the understanding and practices within the Indonesian food sector.a more sustainable and responsible future for ecotourism on the island's iconic beaches.

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