DESIGN OF SALMON STORAGE PACKAGING TO MAINTAIN QUALITY USING THE QUALITY FUNCTION DEPLOYMENT (QFD) METHOD AND MORPHOLOGICAL CHART

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Abstract

Salmon is a high-value food commodity that is highly susceptible to quality deterioration due to lipid oxidation and microbial growth during storage. This issue is often caused by packaging designs that do not fully accommodate product characteristics and consumer requirements. This study aims to develop a salmon packaging design capable of maintaining product quality and extending shelf life by integrating the Quality Function Deployment (QFD) method and the Morphological Chart approach. The theoretical framework and literature review cover food packaging concepts, QFD, the House of Quality, and the Morphological Chart as a tool for generating design alternatives. This research employs a descriptive method with qualitative and quantitative approaches. Data were collected through literature studies and the identification of the voice of customer, which were subsequently analyzed using QFD to determine priority technical requirements. The results indicate that packaging methods (vacuum/MAP), oxygen permeability, and storage temperature are the most critical technical priorities. Furthermore, the Morphological Chart produced an optimal design combination consisting of MAP packaging with very low oxygen control, multilayer food-grade materials, high sealing strength, and storage temperatures ranging from −1 to 0 °C. In conclusion, the integration of QFD and the Morphological Chart is effective in generating a salmon packaging design that meets consumer needs and preserves product quality.

Keywords: salmon packaging, quality function deployment, morphological chart, shelf life, product quality

INTRODUCTION

Salmon is a high-value food product, but its quality can easily deteriorate if storage and transportation are not properly managed. Salmon can spoil quickly when temperature is unstable, packaging allows air infiltration, liquid exudes from the fish flesh, or excessive vibration occurs during transportation. The impact can be observed through dull color, fishy odor, soft texture, and increased microbial risk, as explained by Sone et al. [1]. This condition is further exacerbated by conventional packaging designs that do not fully consider the unique characteristics of salmon, as highlighted by Kaewprachu et al. [2]. There are three main issues in current salmon packaging: high oxygen permeability, difficulty in maintaining ideal temperature, and inadequate ergonomic design, according to Salvador et al. [3]. Industry surveys reveal that the majority of product damage is caused by a mismatch between storage requirements and packaging specifications, as reported by Chan et al. [4].

Quality Function Deployment (QFD) provides a systematic framework to translate customer needs into technical parameters in packaging design [5]. This method has been proven to increase consumer satisfaction by up to 30% in packaged food products. Meanwhile, the Morphological Chart enables in-depth exploration of various design alternatives by mapping combinations of materials, structures, and packaging technologies. This approach is particularly useful for identifying innovative solutions in active packaging. A literature review indicates that no previous research has specifically integrated QFD and Morphological Chart for salmon packaging. In fact, this combination has the potential to improve design efficiency by up to 40% compared to traditional methods. This research is highly relevant because it offers design solutions based on empirical data, reduces post-harvest losses by up to 25%, and establishes new standards in fisheries product packaging, in line with Sivertsvik et al. Practically, the implications include improving the competitiveness of the national fisheries industry and reducing food waste. Recent developments in active packaging technology show significant potential for application in salmon products. Recent studies identify that the use of oxygen scavengers and antimicrobial films can extend the shelf life of salmon by up to 40% compared to conventional packaging, according to Yam et al. However, the implementation of these technologies is still constrained by high production costs and design complexity. The integration of QFD and Morphological Chart enables a holistic approach that considers technical, economic, and environmental aspects. Case studies on other fisheries products indicate that this combined method can reduce the design cycle time by up to 35% while increasing consumer satisfaction. The main challenge lies in the need for comprehensive and accurate consumer data to properly construct the House of Quality. Therefore, it can be concluded that the main problem faced by companies is the decline in salmon quality during storage and transportation, while the required solution must be systematically designed starting from real field needs (through QFD) and then translated into several alternative packaging designs that can be selected and tested (through the Morphological Chart). By combining these two methods, the resulting packaging design is expected to be more effective. This is the reason why this study adopts the title "Design of Salmon Storage Packaging to Maintain Quality Using the Quality Function Deployment (QFD) Method and Morphological Chart."

LITERATURE REVIEW

1. Salmon Quality and Shelf Life

Salmon is a high-value fish product that is highly perishable due to its high moisture and unsaturated fat content. Quality deterioration is characterized by color fading, soft texture, off-odors, lipid oxidation, and microbial growth. Temperature instability during storage and transportation accelerates spoilage. Therefore, maintaining stable cold-chain conditions and proper packaging systems is essential to preserve product quality and extend shelf life.

2. Salmon Packaging

Packaging serves as a protective barrier against oxygen, moisture, contamination, and physical damage. Conventional plastic packaging often has limitations in oxygen permeability and temperature control. Advanced technologies such as oxygen scavengers, antimicrobial films, and modified atmosphere packaging (MAP) have been developed to extend shelf life. However, these solutions may increase production costs and design complexity.

3. Quality Function Deployment (QFD)

Quality Function Deployment (QFD) is a structured method used to translate customer needs into technical specifications through the House of Quality matrix. In packaging design, QFD helps identify and prioritize critical requirements such as temperature stability, oxygen resistance, safety, and ergonomics. This method ensures that the final design aligns with consumer expectations and technical feasibility.

4. Morphological Chart

The Morphological Chart is a systematic design tool used to generate and evaluate alternative solutions by identifying product functions and possible technical options for each function. In salmon packaging design, it allows exploration of various combinations of materials, structural systems, and preservation technologies to develop innovative and effective packaging concepts.

5. Product Quality

Product quality in salmon packaging is reflected in the ability to maintain freshness, safety, sensory attributes, and shelf life during storage and distribution. The integration of QFD and Morphological Chart supports a systematic and innovative approach to designing packaging that effectively preserves product quality.

METHOD

This study employs a descriptive research design using both qualitative and quantitative approaches to develop an optimal storage packaging design for salmon in order to maintain product quality and extend shelf life. The qualitative approach is used to identify the voice of customer through literature review and relevant food packaging standards. Meanwhile, the quantitative approach is applied using the Quality Function Deployment (QFD) method to determine technical priorities of the packaging design. The House of Quality (HoQ) matrix is utilized to translate customer requirements into measurable technical specifications. Furthermore, the Morphological Chart method is employed to generate and evaluate alternative packaging design concepts by combining different materials, structural systems, preservation technologies, and ergonomic aspects. The research was conducted at BG company in Medan during the period of January–December 2025. The object of this study includes salmon as the material object and the packaging design strategy developed using QFD and Morphological Chart as the methodological object. The overall research framework begins with identifying customer needs, translating them into technical parameters using QFD, and generating alternative packaging concepts through the Morphological Chart to produce an optimal, economically feasible, and environmentally sustainable salmon storage packaging design.

RESULTS AND DISCUSSION

Data Collection

Based on the research objective to develop a salmon storage packaging design with extended shelf life and improved food safety, data collection focuses on product characteristics, customer requirements, and the performance of commonly used packaging systems for fresh fish products.

The collected data include customer needs (Voice of Customer), technical packaging characteristics, and comparative information from previous studies regarding salmon shelf life under different packaging methods.

The sources of data in this study consist of:

1. Scientific literature on salmon packaging systems (vacuum packaging, modified atmosphere packaging (MAP), and active packaging).
2. Empirical data from previous studies related to salmon shelf life.
3. Heuristic assessment to determine the level of importance of customer requirements.

Voice of Customer (WHAT)

The Voice of Customer in this study was obtained through direct field observation at BG company in Medan. The observation covered the handling process of salmon from cold storage, package opening, preparation and serving stages, to the condition of salmon when displayed or ready for use.

During observation, key quality indicators frequently emphasized in operational practice were identified, including storage durability, food safety (microbiological aspects), fishy odor due to oxidation, changes in color and aroma, drip loss affecting product appearance, and seal strength to prevent leakage. Based on previous literature, fresh salmon stored under refrigeration without specialized packaging typically has a shelf life of approximately 5–7 days. Therefore, salmon storage packaging must meet specific functional and technical requirements to effectively maintain product quality and safety.

Table 1 Voice of Customer

No	Voice of Customer	Importance (1–5)
V1	Longer shelf life	5
V2	Microbiological safety	5
V3	Low oxidation / no fishy odor	4
V4	Fresh color and aroma retention	4
V5	Low drip loss and clean appearance	4
V6	Tight packaging (strong seal, leak-proof)	3

Technical Requirements (HOW)

The technical requirements in this QFD analysis are fully based on international standards for food packaging and fresh fish preservation. These technical parameters are designed to address the identified customer needs and ensure that the packaging system effectively maintains salmon quality, safety, and shelf life. The technical requirements include measurable parameters such as oxygen transmission rate (OTR), water vapor transmission rate (WVTR), storage temperature control capability, antimicrobial performance, sealing strength, and material safety compliance with food-grade standards. These requirements serve as the “HOW” component in the House of Quality (HoQ), translating customer expectations into specific, quantifiable packaging performance criteria.

Table 2 Technical Requirements

No	Technical Requirement (HOW)	Technical Indicator	Reference Standard
H1	Oxygen permeability (OTR)	cc/m²·24 hours	ISO 15105-2
H2	Water vapor permeability (WVTR)	g/m²·24 hours	ISO 15106-3
H3	Packaging method (Vacuum/MAP)	Type of method	ISO 14469
H4	Food-grade packaging material	Food contact safety compliance	ISO 22000 / Codex
H5	Seal strength	Seal strength value	ASTM F88
H6	Salmon storage temperature	°C	Codex CAC/RCP 52-2003

Relationship Matrix

In the QFD relationship matrix, each technical requirement (HOW) is evaluated against customer needs (WHAT) using a weighted scoring system. Oxygen permeability (H1) has a strong relationship with longer shelf life (V1), low oxidation (V3), and fresh color and aroma retention (V4), since oxygen is the primary factor accelerating lipid oxidation in salmon. Lower OTR values directly reduce rancidity, discoloration, and sensory quality degradation, making oxygen control a critical technical parameter in packaging design. Water vapor permeability (H2) is strongly related to low drip loss and clean appearance (V5). Controlling WVTR helps stabilize internal humidity conditions within the package, thereby minimizing liquid release from fish tissue. Its relationship with other customer requirements is relatively moderate compared to oxygen permeability.

The packaging method (H3), such as vacuum packaging or modified atmosphere packaging (MAP), has a very strong relationship with shelf life (V1), microbiological safety (V2), and oxidation control (V3). Oxygen reduction inside the package effectively suppresses microbial growth and oxidative reactions, particularly when combined with low-temperature storage. Food-grade packaging material (H4), seal strength (H5), and storage temperature (H6) function as supporting technical parameters. Food-grade materials ensure compliance with food safety regulations. Seal strength is essential to prevent leakage and maintain package integrity. Storage temperature has a strong influence on shelf life and microbiological safety while also supporting sensory quality preservation.
The relationship scores used in the matrix are defined as follows:

- 9 = Strong
- 3 = Moderate
- 1 = Weak
- 0 = No relationship

Table 3 Relationship Matrix

Voice of Customer (WHAT)	H1 OTR	H2 WVTR	H3 Vacuum/MAP	H4 Food-Grade Material	H5 Seal Strength	H6 Storage Temp
V1 Longer shelf life	9	3	9	1	3	9
V2 Microbiological safety	3	1	9	1	3	9
V3 Low oxidation / no fishy odor	9	1	9	1	1	3
V4 Fresh color & aroma retention	9	1	3	1	1	3
V5 Low drip loss & clean appearance	1	9	1	1	3	1
V6 Tight packaging (strong seal, leak-proof)	0	0	0	1	9	0

Evaluation Results

The total assessment is calculated by multiplying the importance value of each Voice of Customer (Table 3.1) by the corresponding relationship score (Table 3.3), and then summing the results for each technical requirement (H1–H6).

This calculation determines the technical priority level in the QFD analysis. The technical parameter with the highest total score is considered the most critical factor in designing salmon storage packaging, as it has the strongest combined impact on customer needs and product quality preservation. The final priority ranking provides the basis for selecting and developing packaging design alternatives using the Morphological Chart method.

Table 4 Weighted Scores

No	Technical Requirement (HOW)	Weighted Score Calculation	Total
H1	Oxygen permeability (OTR)	(5×9)+(5×3)+(4×9)+(4×9)+(4×1)+(3×0)	136
H2	Water vapor permeability (WVTR)	(5×3)+(5×1)+(4×1)+(4×1)+(4×9)+(3×0)	64
H3	Packaging method (Vacuum/MAP)	(5×9)+(5×9)+(4×9)+(4×3)+(4×1)+(3×0)	142
H4	Food-grade packaging material	(5×1)+(5×1)+(4×1)+(4×1)+(4×1)+(3×1)	25
H5	Seal strength	(5×3)+(5×3)+(4×1)+(4×1)+(4×3)+(3×9)	77
H6	Salmon storage temperature	(5×9)+(5×9)+(4×3)+(4×3)+(4×1)+(3×0)	118

Priority Analysis Results

Based on the weighted score calculation, the technical priorities are determined as follows:

Table 5 Priority Analysis

No	Technical Requirement (HOW)	Weighted Score	Percentage (%)	Priority Rank
H3	Packaging method (Vacuum/MAP)	142	25.27%	1
H1	Oxygen permeability (OTR)	136	24.20%	2
H6	Storage temperature	118	20.99%	3
H5	Seal strength	77	13.70%	4
H2	Water vapor permeability (WVTR)	64	11.39%	5
H4	Food-grade material	25	4.45%	6
Total		**562**	**100%**	

House of Quality (HoQ)

Thus, the results of the House of Quality (HoQ) analysis can be seen in the following figure. A larger and more detailed version of the HoQ matrix is also attached at the end of this research report.

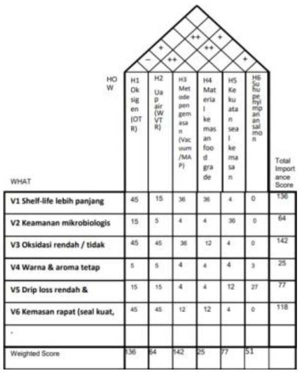

Figure 1. House of Quality (HoQ) Analysis Results

Morphological Chart

Based on the QFD results presented in Table 3.2 and Table 3.3, it is identified that the packaging method (H3), oxygen permeability (H1), and storage temperature (H6) are the primary technical priorities in designing salmon storage packaging. Therefore, the Morphological Chart is developed with a strong emphasis on these key technical parameters, while the remaining parameters serve as supporting factors in the overall packaging design process.

Table 6 Morphological Chart Analysis Results

Fungsi Teknis (HOW)	**Alternatif A**	**Alternatif B**	**Alternatif C (Terpilih)**
H3 Packaging method	Non-vacuum	Vacuum	MAP (CO_2/N_2)
H1 Oxygen permeability (OTR)			
H6 Storage temperature	4 °C (Less optimal)	0–2 °C (Optimal)	−1–0 °C (Highly optimal)
H5 Seal strength	Standard	Strong	Very strong
H2 Water vapor permeability (WVTR)	Poor	Poor	Very good (with absorbent pad)
H4 Food-grade packaging material	PE multilayer	PET/PE multilayer	PA/PE multilayer
Freshness retention performance	Low	Moderate	High
H3 Packaging method	4 °C (Less optimal)	0–2 °C (Optimal)	−1–0 °C (Highly optimal)

The Morphological Chart analysis resulted in three alternative design combinations that align with the technical priorities identified through QFD. Among these, the selected concept emphasizes Modified Atmosphere Packaging (MAP), very low oxygen control, and storage temperatures close to the freezing point, as these factors significantly contribute to extended shelf life and improved microbiological safety of salmon. Supporting parameters such as high seal strength ensure packaging system stability during storage and distribution. Thus, the Morphological Chart functions as a synthesis tool that translates QFD technical priorities into realistic and applicable packaging design alternatives within this research.

Proposed Packaging Design

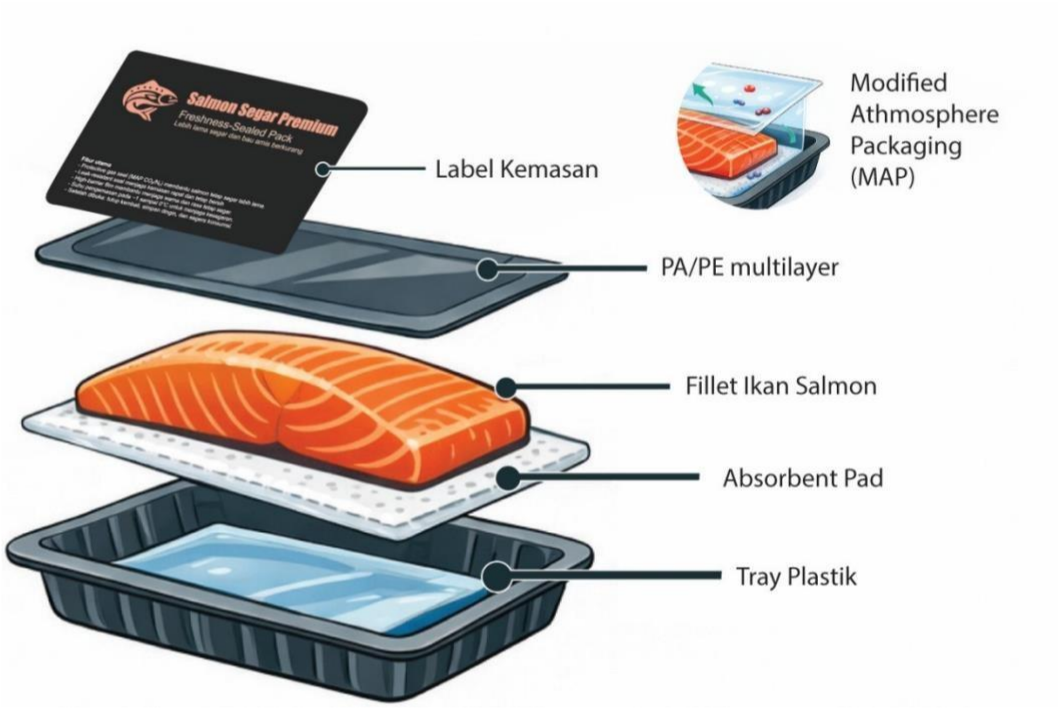

Figure 2 Proposed Packaging Design

Thus, this study proposes a plastic tray packaging design with a Modified Atmosphere Packaging (MAP) system**,** specifically developed to maintain the freshness of salmon during storage and transportation. The packaging design focuses on technical functionality, ensuring that each component directly contributes to product quality preservation. The packaging consists of **a** food-grade plastic tray serving as the primary container for salmon fillets. Inside the tray, an absorbent pad is placed to absorb drip loss during storage, helping to maintain a clean appearance and reduce excess moisture. The salmon fillet is then sealed using a high-barrier multilayer PA/PE film, which provides very low oxygen permeability. The film is tightly sealed along the edges of the tray to ensure package integrity and prevent leakage during distribution. The internal headspace of the package is filled with a MAP gas mixture (CO_2/N_2)**,** which functions to suppress oxidation and inhibit the growth of harmful microorganisms that may reduce freshness. Overall, this proposed packaging system integrates oxygen control, moisture management, strong sealing, and near-freezing storage conditions to effectively extend shelf life, improve microbiological safety, and maintain the sensory quality of salmon products.

CONCLUSION

Based on the results of this study, the conclusions are as follows:

1. This research produced a proposed material and storage packaging system for salmon focused on maintaining freshness and product quality through the integration of Modified Atmosphere Packaging (CO_2/N_2), high-barrier multilayer food-grade material (PA/PE), strong seal strength, and storage temperature support at −1 to 0 °C. This combination is expected to extend storage time compared to conventional packaging systems.
2. The proposed packaging design was developed as an optimal solution based on the integration of Quality Function Deployment (QFD) and the Morphological Chart method. This combined approach ensures that the design aligns with technical priorities and customer needs, aiming to achieve improved shelf-life performance compared to conventional packaging.

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