

Effect of Time and Temperature on TPC Parameters in WIP Products Dry Marination Process of Chicken Fillet

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Abstract

Work in Process (WIP) dry-marinated chicken fillet is a semi-finished product that remains highly susceptible to microbial contamination before the cooking stage. Inadequate control of storage time and temperature during WIP handling may accelerate bacterial growth, thereby reducing product quality and compromising food safety. This study aimed to evaluate the effects of storage time and temperature on the Total Plate Count (TPC) of dry-marinated chicken fillet during the WIP stage. The study employed an experimental design by storing dry-marinated chicken fillets under different storage temperatures and holding times. Total Plate Count analysis was conducted using the standard pour plate method, and the obtained data were analyzed using analysis of variance (ANOVA) to determine the significance of treatment effects. The results demonstrated that both storage time and temperature significantly affected ($P < 0.05$) the TPC values. Increasing storage duration consistently increased bacterial populations, while higher storage temperatures accelerated microbial proliferation compared with refrigerated storage. The interaction between storage time and temperature indicated that improper WIP handling substantially increased the microbiological risk before the cooking process. Although dry marination may contribute to slowing bacterial growth through reduced water activity and antimicrobial effects of seasoning ingredients, these effects were insufficient to inhibit microbial proliferation during prolonged storage. Therefore, maintaining refrigerated storage and minimizing WIP holding time are essential to preserve microbiological quality and ensure compliance with food safety standards. These findings provide practical recommendations for optimizing WIP handling procedures and strengthening Hazard Analysis and Critical Control Point (HACCP)-based quality management in poultry processing industries.

1. Introduction

Marination is a term taken from the word marine which means ocean. The word originated as early as the 18th century when it was used by fishermen to preserve fish or other catches from the sea. In addition, another meaning of the word marinasi comes from the latin 'marinus' with the meaning soaked. The principle of marination has the concept of passive transport by osmosis, IE meat soaked will experience excess water in the cells and tissues so that the materials used will be mixed and homogenized in (Yusop et al, 2011).Marinated chicken product is a product of mixing marinades with additional spices and other food additives with additional absorption process by massaging or with the help of thumbing machine (P. Mithun Hari Raj,, et al 2023). This process will affect the degree of softness, water binding and product quality (Meltem Serdaroğlu, et al 2024).

The application of various kinds of marinating materials has been commonly used in both households and poultry meat processing industries for a long time. Meat and poultry meat processed products that have been treated with various kinds of marinating materials either singly or in combination with several marinating processes can improve the color, taste, and tenderness, as well as increase the shelf life of poultry meat through the mechanism of reducing the growth rate of pathogenic microorganisms and can also reduce the occurrence of fat oxidation processes in poultry meat. The application of various kinds of marinating materials shows the fact that it can improve the food safety of poultry meat, quality, and also the added value of poultry meat. This review can be information for the direction of efforts to develop various kinds of marinating materials that will be used in the poultry meat processing industry (U-chupaj, et.al, 2017).

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Seasoning is a raw material mixture consisting of raw powder seasoning, additional liquid seasoning in it with the most composition of salt, sugar, and MSG. Seasoning itself can cause a good taste as a complement to cooking spices. The dominant savory taste is not only obtained from MSG or a combination of basic ingredients but also from natural ingredients such as glutamic acid which can be taken from the hydrolysis of beef or chicken and also vegetable. (Otsuka, 1973). Palupi et al 2013. Dry marination is a method of marinating without the addition of water. In this study the method is done without the use of water, seasoning and chicken fillet mixed together manually without the help of tumbling and injection machines. Tumbling is a marination method that combines the process of stirring and homogenizing so that the taste of the marinade is optimally distributed into the meat.(Priyanto et al 2023).

TPC is a method of calculating the total value of bacteria using the Total Plate Count (TPC) method to calculate how many bacteria are present in the product. Done by isolating the product sample and see the growth of bacteria on the product. [4] according to SNI 7388:2009, the maximum amount of TPC content is 1×10^6 cfu/g. (Utari et al 2016). WIP is a Work in Progress / Process (WIP), which is a product that is still in the stages of the production process and has gone through one or several stages of processing, but has not yet become the final product. In the production process of dry marinated chicken fillet, WIP is a product that is still in raw condition (raw product) before entering the cooking process. The cooking stage is an important part in the application of Hazard Analysis and Critical Control Point (HACCP) because it is a Critical Control Point (CCP) that serves to eliminate or reduce biological hazards to acceptable limits (Codex Alimentarius Commission, 2022). In the poultry meat processing industry, the WIP storage stage is one of the phases that has a high risk of microbiological contamination. During the holding process before cooking, the product is still in raw condition so that microorganisms from raw materials, equipment, production environment, and operators still have the potential to develop if the storage time is too long or the temperature is not controlled properly. Chicken meat has a high water content, abundant protein content, and a pH that is close to neutral so that it becomes an ideal medium for the growth of various spoilage and pathogenic microorganisms (Soeparno, 2016). Therefore, controlling the storage time and temperature of WIP products is a very important factor to maintain food safety and maintain product quality.

The application of the Hazard Analysis and Critical Control Point (HACCP) system places temperature and storage time control as part of critical control measures in the food production chain. The control aims to prevent the number of microorganisms from increasing to levels that could harm consumers before the product enters the cooking stage. The cooking process is able to inactivate most pathogenic microorganisms, but if the number of microbes at the WIP stage has increased significantly due to uncontrolled storage, the risk of deterioration in quality, toxin formation by certain bacteria, and cross-contamination during the production process can still occur (Codex Alimentarius Commission, 2022; Jay et al., 2005). One of the most widely used microbiological parameters for evaluating the quality of food products during storage is the Total Plate Count (TPC). This Parameter describes the total number of live mesophilic aerobic bacteria present in the product and is a general indicator of the level of hygiene of the production process and the effectiveness of sanitary control. An increase in TPC values during storage indicates the activity and growth of microorganisms that are influenced by various factors, especially temperature and duration of storage. The higher the storage temperature and the longer the storage time, the rate of bacterial growth will be faster, potentially shortening the shelf life of the product and reducing the level of food safety (Jay et al., 2005).

Several previous studies have reported that the length of storage is a major factor that affects the increase in the number of microorganisms in chicken meat. Windyasmara and Sariri (2021) showed that the value of the Total Plate Count (TPC) increased markedly with increasing storage time in broiler chicken meat marinated using pineapple extract, although the marinated ingredients had antimicrobial activity. The study showed that TPC value increased gradually during storage, indicating that the effectiveness of antimicrobial compounds will decrease if the storage time is longer. The results of the study Pasha et al. (2025) also showed that long storage led to increased activity of microorganisms followed by changes in the quality characteristics of chicken meat. The longer the storage, the higher the activity of bacteria that cause changes in pH, deterioration in physical qualities, and an increased risk of spoilage of the product. These conditions confirm that the control of temperature and storage time is an important factor in maintaining the safety and quality of chicken meat products.

Based on these conditions, research on the effect of storage time and temperature on the parameters of the Total Plate Count (TPC) on the product work in Process (WIP) dry marination of chicken fillet becomes important to do. The results of this study are expected to provide scientific information about the

time limit and safe storage temperature during the production process so that it can be the basis for the preparation of Standard Operating Procedure (SOP), validation of the application of the HACCP system, as well as decision-making in quality control and food safety in the chicken fillet processing industry.

2. Method

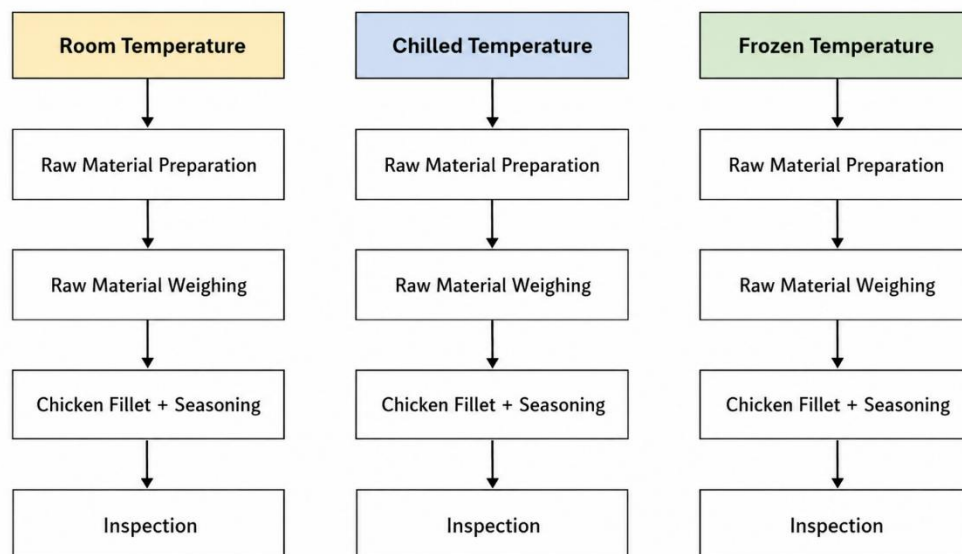
The research was conducted using sensory evaluation of product acceptance by 10 trained panelists. Trained panelists are panelists who have been trained from their experience because they have a background in food technology (Rosalia and kiki 2016). Where the determination of the stages of selection of the most qualified panelists is as follows :

2.1. Selection Stage

The selection stage consists of recruitment, filling out questionnaires, interviews and sensory selection tests.

2.2. Training and Test Phase

This analysis stage contains a description of the panelists of the sample. Description performed on absolute threshold test with five concentrations of sample solution. This test is repeated so that the panelists really remember and understand the true impression contained in the sample. Sugar-filled solution 0,1%, 0,3%, -5% 0,7%. A solution of salt, vinegar, boiled bitter melon and msg with the same percentage. Panelists must be able to answer questions by ranking the lowest and highest coefficients of materials in the solution. If there is a panelist who fails even if only 1 part, the panelist is declared not to be the best panelist. - Performance Language Panelists must know the texture that shows mucus. Karena this is the basic parameter for determining the initial and rapid amount of TPC. The SOP of this research is as follows: chicken fillet power meat is marinated at room temperature, chiller and frozen and then weighing and preparation of raw material. Then add seasoning. When the time showed already 1, 2, 3, 4 hours of observation and checking process WIP. Here is the SOP done :



Chicken fillet checking results :

	H	T 28C Room				T 6C Chiller				T -20C Frozen			
		TPC 1-2-3-4	SE		TPC 1-2-3-4	SE		TPC 1-2-3-4	SE		TPC 1-2-3-4	SE	
			Lendir	Bumbu meresap		Lendir	Bumbu meresap		Lendir	Bumbu meresap		Lendir	Bumbu meresap
Marinade	4	65.000.000	v	v	550.000	x	v	11.000	x	v			
	3	20.000.000	v	x	300.000	x	x	15.000	x	x			
	2	900.000	v	x	170.000	x	x	25.000	x	x			
	1	280.000	x	x	100.000	x	x	30.000	x	x			
TPC 0		10.000			10.000			10.000					

3. Result and Discussion

3.1. Effect of Storage Time and Temperature on Total Plate Count (TPC)

Total Plate Count (TPC) analysis was conducted to evaluate the microbiological quality of dry-marinated chicken fillet during Work in Process (WIP) storage under different storage temperatures and durations. TPC is one of the most important microbiological indicators used to determine the hygienic quality and shelf life of poultry products because it reflects the total viable aerobic microorganisms present in the sample. The experimental results demonstrated that storage time and storage temperature significantly influenced microbial growth ($P < 0.05$). An increase in storage duration consistently resulted in higher TPC values across all temperature treatments. Likewise, samples stored at higher temperatures exhibited faster microbial proliferation than those maintained under refrigerated conditions.

The interaction between storage time and temperature indicated that bacterial growth accelerated as storage conditions approached the optimum growth temperature for mesophilic bacteria. During refrigerated storage, microbial metabolism remained relatively slow, whereas storage at higher temperatures stimulated rapid bacterial multiplication, resulting in exponential increases in TPC values. This finding confirms that temperature control is one of the most critical factors in maintaining microbiological quality during WIP storage. The increase in TPC during storage is closely associated with the high moisture content, abundant nutrients, and nearly neutral pH of chicken meat, which provide favorable conditions for microbial development. During storage, microorganisms utilize proteins and carbohydrates as substrates, producing metabolites that gradually deteriorate meat quality. Consequently, prolonged storage without adequate temperature control accelerates spoilage and reduces product safety.

These findings are consistent with the study conducted by Pasya et al. (2025), which demonstrated that storage duration significantly increased bacterial populations in broiler chicken meat regardless of packaging treatment. Their study reported statistically significant increases in total bacterial counts as storage time increased, indicating that microbial growth is strongly influenced by storage duration. Similarly, Windyasmara and Sariri (2021) reported that Total Plate Count increased progressively during refrigerated storage of pineapple-marinated broiler chicken. Although pineapple extract exhibited antimicrobial activity through bromelain and phenolic compounds, bacterial populations continued to increase as storage time became longer, indicating that antimicrobial marinades delay but do not completely inhibit microbial growth.

The observed increase in microbial populations can be explained by bacterial growth kinetics. During the initial storage period, microorganisms enter the lag phase, where adaptation to the surrounding environment occurs with minimal cell multiplication. As storage continues, bacteria enter the exponential phase characterized by rapid cell division and accelerated colony formation. When storage temperature remains relatively high, the duration of the lag phase becomes shorter, resulting in earlier exponential growth and higher TPC values. This mechanism explains why temperature and storage duration simultaneously contribute to increased microbial loads.

In dry-marinated chicken fillet, the marination ingredients may initially reduce microbial activity by lowering water activity and introducing antimicrobial compounds from salt and seasonings. Nevertheless, these inhibitory effects gradually diminish during prolonged storage because surviving microorganisms adapt to environmental stress and continue multiplying. Therefore, dry marination alone cannot replace proper cold-chain management during WIP handling.

From an industrial perspective, these results emphasize that strict temperature control throughout WIP processing is essential for ensuring food safety. Refrigerated storage slows bacterial metabolism, extends shelf life, and minimizes the risk of microbial contamination before further processing. Conversely, temperature abuse during intermediate processing stages may rapidly increase microbial populations and compromise final product quality. Overall, the present findings demonstrate that storage temperature and storage duration are critical determinants of microbiological quality in dry-marinated chicken fillet. Maintaining low storage temperatures while minimizing WIP holding time represents the most effective strategy to suppress bacterial growth and ensure compliance with microbiological safety standards for poultry products.

4. Conclusion

This study demonstrated that storage time and storage temperature significantly affected the Total Plate Count (TPC) of Work in Process (WIP) dry-marinated chicken fillet. An increase in storage duration consistently resulted in higher microbial populations, while elevated storage temperatures accelerated bacterial growth compared with refrigerated conditions. These findings indicate that the interaction between time and temperature plays a crucial role in determining the microbiological quality and safety of dry-marinated chicken during intermediate processing stages. The results further suggest that although the dry marination process may contribute to suppressing microbial growth through reduced water activity and antimicrobial effects of seasoning ingredients, its protective effect is insufficient to prevent microbial proliferation during prolonged storage. Therefore, effective cold-chain management, including strict temperature control and minimization of WIP holding time, remains essential to maintain product quality and ensure compliance with microbiological safety standards. From an industrial perspective, this study provides practical evidence that optimizing storage temperature and processing time can improve food safety management, extend the microbiological shelf life of WIP products, and reduce the risk of spoilage before subsequent processing. Future studies are recommended to investigate the combined effects of modified atmosphere packaging, natural antimicrobial agents, and predictive microbiological modeling to develop more effective preservation strategies for marinated poultry products

Author Contributions

Dhita Sari Siregar: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Writing – Original Draft Preparation. **Yeni Kurniati:** Methodology, Investigation, Validation, Writing – Review & Editing. **Amelya Setyawati:** Investigation, Data Curation, Visualization. **Gita Mutiara Annisa Chaerani:** Investigation, Resources, Validation. **Tri Matya Ningrum:** Formal Analysis, Visualization, Writing – Review & Editing. **Palupi Purnhama Dewi:** Supervision, **Febby Barita Lumban Tobing:** Project Administration, Conceptualization, **Khoirunnisa Rahmah Shadrina:** Writing – Review & Editing. All authors have read and approved the final version of the manuscript and agree to be accountable for all aspects of the work. All authors have equal contributionsto the paper. All the authors have read and approved the final manuscript.

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Declaration of Conflicting Interests

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