EFFECT OF PASTEURIZATION TEMPERATURE ON THE TEXTURAL AND COLOR PROPERTIES OF POMELO PEEL FERMENTED PRODUCT

● NGUYEN DUC TOAN[1] - GIANG KIEN QUOC[1]
[1]Post-Harvest Technology Center
Faculty of Agriculture and Aquaculture, Tra Vinh University

ABSTRACT:

This study evaluates the effects of pasteurization temperature on the texture and color characteristics of pomelo peel nem. Pasteurization within the range of 60 -80°C significantly influences product quality ($p < 0.05$). As temperature increases, textural properties improve, while color parameters (L*, a*, and b*) decline and total color difference (ΔE) increases, indicating a darker appearance relative to the control. Among the tested conditions, pasteurization at 70°C achieves the most favorable balance between enhanced structural integrity and acceptable color retention.

Keywords: lactic acid fermentation, pasteurization temperature, pomelo peel nem

1. Introduction

Pomelo peel nem (vegetarian nem) is a naturally fermented product in which pomelo albedo is used as the main ingredient, combined with spices to develop characteristic sensory properties (Thạnh et al., 2023). The fermentation process is governed by lactic acid bacteria, which contribute to the biosynthesis of organic acids and the establishment of an acidic environment typical of the product (Phan et al., 2017, Nguyen et al., 2010). In addition, due to its high pectin content, pomelo peel is capable of forming a gel structure, playing a crucial role in developing the elasticity and cohesiveness of the product after fermentation (Hung. et al., 2020).

However, under acidic conditions, the pectin structure may undergo degradation, leading to a reduction in structural integrity and adversely affecting the sensory quality of the product (Liu et al., 2020). Furthermore, the color of the product may change due to chemical reactions occurring during processing and storage, particularly under thermal conditions. These changes are critical factors influencing overall product quality and consumer acceptability.

Pasteurization is considered an effective approach to stabilize product quality by limiting ongoing biochemical changes after fermentation. However, thermal treatment may simultaneously affect the pectin gel structure and the color properties of the product (Liu et al., 2020). Increasing temperature can promote gelation, resulting in enhanced structural firmness, but may also induce non-enzymatic browning reactions, leading to color deterioration (Lund and Ray, 2017).

Therefore, selecting an appropriate pasteurization temperature is essential to simultaneously control the structural and color attributes of the product. This study was conducted to evaluate the effect of pasteurization temperature on the textural and color properties of pomelo peel fermented product, thereby proposing suitable thermal processing conditions to stabilize product quality.

2. Literature review

Previous studies have highlighted the important role of lactic acid bacteria (LAB) in determining the quality and safety of fermented products similar to nem chua. For instance, Nguyen et al. (2013) reported that LAB dominate the microbial community in traditional nem chua, contributing to acidification and inhibition of spoilage microorganisms. In addition, Nguyen et al. (2010) demonstrated that the selection of appropriate LAB strains can improve fermentation efficiency and product quality. Expanding to plant-based substrates, Phan et al. (2017) revealed a high diversity of LAB in both meat- and vegetable-based fermented foods in Vietnam, suggesting their applicability in plant-based fermented products. More specifically, Thạnh et al. (2023) confirmed the potential of pomelo peel as a suitable substrate for lactic fermentation. Furthermore, LAB are known to produce antimicrobial compounds such as bacteriocins, which enhance microbial stability and extend shelf life, as reported by Elyass et al. (2017).

Despite these advances, previous studies have mainly focused on fermentation and microbial aspects, with limited attention to the effects of post-fermentation heat treatment. In particular, the impact of pasteurization on key quality attributes such as color and texture of pomelo peel nem remains unclear. Thermal processing may induce changes in color parameters and alter the pectin-based gel structure, thereby affecting product quality. Therefore, it is necessary to investigate the effect of pasteurization conditions on the color and texture characteristics of pomelo peel nem.

3. Materials and methods

3.1. Raw materials

Pomelo peel fermented product was prepared from mature green pomelo fruits, with the outer flavedo removed, retaining only the inner albedo. The bitterness of the pomelo peel was reduced by repeated washing with clean water, followed by steaming at 100°C for 15 min to soften the material.

Auxiliary ingredients included shredded green papaya dried to approximately 50% moisture content, lime juice (to provide acidity and a favorable pH environment for lactic acid bacteria), beetroot juice (as a natural colorant), and roasted rice powder (as a nutrient source for lactic acid bacteria), along with spices such as pepper, garlic, and chili. These components were mixed according to the proportions presented in Table 1.

Table 1. Fixed proportions of ingredients used in pomelo peel nem

Ingredients	Percentage (%)
Pretreated pomelo peel	50
Pretreated shredded papaya	37
Lime juice	7
Beetroot juice	4
Ground black pepper	0,25
Minced garlic	0,25
Sliced chili pepper	0,25
Roasted rice powder	1,25

3.2. Custom-built pasteurization system

The pasteurization system used in this study operated based on a principle similar to that of an industrial forced - convection steam retort, utilizing saturated steam as the heat transfer medium combined with a fan to enhance convective heat transfer. The system consisted of a vertical cylindrical chamber (30 cm in diameter and 30 cm in height), equipped with a 2kW electric heater to boil water and generate steam.

Steam temperature was monitored using a K-type thermocouple and controlled via a PID feedback loop (Model TC4S - 14R, Autonics) to maintain the setpoint temperature. An electric fan (12×12 cm) was mounted on the chamber lid to promote forced convection of steam. The core temperature of the product was recorded using a data logger (Mastech MS6514). The configuration of the system is illustrated in Figure 1.

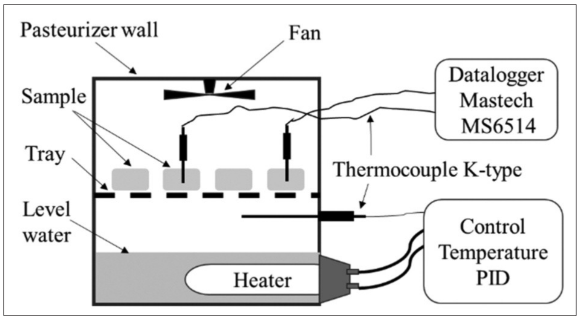
3.3. Experimental design

3.3.1. Formulation design

The experiment was conducted to determine the appropriate mixing ratios of additives to produce a vegetarian fermented product with the best sensory quality. A single-factor experimental design was applied, consisting of eight additive formulations. The experiment was replicated three times.

The base formulation of the product was kept constant as presented in Table 1. The investigated factor was the mixing ratio of additives (sugar, salt,

Figure 1. Configuration of the pasteurization system



seasoning powder, and monosodium glutamate) as shown in Table 2.

After mixing according to the predetermined ratios, the samples were packaged using PVC food wrap and subjected to lactic fermentation at a constant temperature of 37 °C (Chockchaisawasdee et al., 2010) for 48 h. Sensory evaluation was conducted with 30 students majoring in Food Technology using a 7-point Hedonic scale (1-7), where a score of 1 indicated unacceptable quality and a score of 7 indicated the highest level of acceptance.

Data were analyzed by ANOVA under a completely randomized design, followed by LSD test using SPSS.

3.3.2. Fermentation study

The fermentation experiment was designed as a single-factor study to determine the appropriate fermentation time (0-96 h). Samples were prepared using the optimal formulation, wrapped with PVC film, and incubated at 37 °C. Analyses were conducted every 24 h, including pH and lactic acid content.

The pH of the samples was measured using a digital pH meter (Hanna HI99163, Romania). Lactic acid content was determined by titration with 0.1N NaOH. All measurements were performed in triplicate.

3.3.3. Pasteurization treatment

Previous studies have shown that lactic acid bacteria exhibit limited heat resistance and are rapidly inactivated under pasteurization conditions such as 63°C for 30 min or 72°C for 15s. Based on this, temperatures of 60, 70, and 80°C were selected for the experiment (Zhao et al., 2024).

The core temperature was monitored and recorded every 2 s using a K-type thermocouple connected to a data logger (Mastech MS6514), while the system temperature was maintained at 82 ± 1°C (Figure 2). Samples were vacuum-sealed in heat-resistant plastic bags prior to pasteurization. Once the target core temperature was reached, samples were rapidly cooled in ice water to prevent further heating.

After processing, samples were stored at 20 ± 2°C for 5 days. Texture and color were evaluated before and after heat treatment. Texture was measured using a CTX100 texture analyzer (AMETEK Brookfield, USA) with a blade probe (60 mm width), at a cutting depth of 10 mm and a speed of 10 mm/s.

Color parameters were determined using a colorimeter based on the CIE Lab* system. The instrument was calibrated with a standard white tile. L* (lightness), a* (red-green), and b* (yellow-blue)

Table 2. Proportions of additive formulations in experimental treatments, calculated based on the initial material weight

Treatment	Sugar (%)	Salt (%)	Seasoning powder (%)	Monosodium glutamate (%)
A1	18.5	0.5	0.5	0.5
A2	18.0	1.0	0.5	0.5
A3	18.0	0.5	1.0	0.5
A4	18.0	0.5	0.5	1.0
A5	17.5	0.5	1.0	1.0
A6	17.5	1.0	0.5	1.0
A7	17.5	1.0	1.0	0.5
A8	17.0	1.0	1.0	1.0

values were recorded. Each sample was measured three times at three random positions, and mean values were used for analysis.

4. Results and discussion

4.1. Effect of additive formulations on sensory acceptability of pomelo peel nem

The sensory evaluation results of the formulations are presented in Table 3. One - way analysis of variance (ANOVA) showed that the mixing ratios of additives had a statistically significant effect on the overall acceptability of the vegetarian fermented product ($p < 0.05$), indicating that variations in the proportions of sugar, salt, seasoning powder, and monosodium glutamate significantly influenced the sensory attributes.

Table 3. Mean sensory scores of experimental treatments

Treatment	Sensory score
A4	7.87 ± 0.73^{a}
A3	7.00 ± 0.73^{b}
A2	6.80 ± 0.61^{b}
A5	6.70 ± 0.65^{b}
A1	6.53 ± 0.51^{b}
A6	6.17 ± 0.53^{c}
A7	5.80 ± 0.65^{d}
A8	5.57 ± 0.50^{d}

Different letters in the same column indicate significant differences ($p < 0.05$).

As shown in Table 3, formulation A4 exhibited the highest sensory score (7.87 ± 0.73) and was significantly different from the others. This indicates that its additive ratios provided an optimal balance of sweetness, saltiness, and umami, which are key determinants of consumer acceptability in fermented products.

Formulations A1, A2, A3, and A5 showed no significant differences ($p > 0.05$), suggesting that variations within this range did not markedly affect sensory perception. However, their lower scores compared to A4 indicate a less optimal flavor balance. Formulation A6 had a significantly lower score, while A7 and A8 showed the lowest acceptability, likely due to imbalanced flavor profiles.

Overall, the results highlight the importance of optimizing additive ratios to improve sensory quality, with balanced flavor components being critical for consumer acceptability.

4.2. Changes in pH during fermentation

The pH of the pomelo peel fermented product decreased continuously during fermentation, from 4.20 to 3.37 after 96 h (Table 4). The decline was more pronounced between 24 and 72 h, followed by a slower decrease as the microbial system gradually approached equilibrium. This trend is characteristic of lactic fermentation, in which lactic acid bacteria convert carbohydrates into organic acids, mainly lactic acid, resulting in environmental acidification (Elyass et al., 2017).

In traditional fermented products such as nem chua, Lactobacillus, Pediococcus, and Leuconostoc are dominant and play key roles in this process, contributing to pH reduction and product stabilization (Nguyen et al., 2013). The pH range obtained after 72-96 h is favorable for inhibiting spoilage microorganisms, thereby enhancing the microbiological safety of the product.

4.3. Changes in lactic acid content during fermentation

One-way ANOVA showed that fermentation time significantly affected lactic acid content ($p < 0.05$), and the LSD test confirmed differences among all sampling points (Table 4).

Table 4. Changes in pH and lactic acid content of pomelo peel nem during fermentation

Time (h)	pH	Titratable acidity (% lactic acid)
0	4.20 ± 0.00^{a}	-
24	4.07 ± 0.06^{b}	0.87 ± 0.06^{a}
48	3.87 ± 0.06^{c}	1.13 ± 0.03^{b}
72	3.57 ± 0.06^{d}	1.48 ± 0.03^{c}
96	3.37 ± 0.06^{e}	1.73 ± 0.03^{d}

Different letters in the same column indicate significant differences ($p < 0.05$).

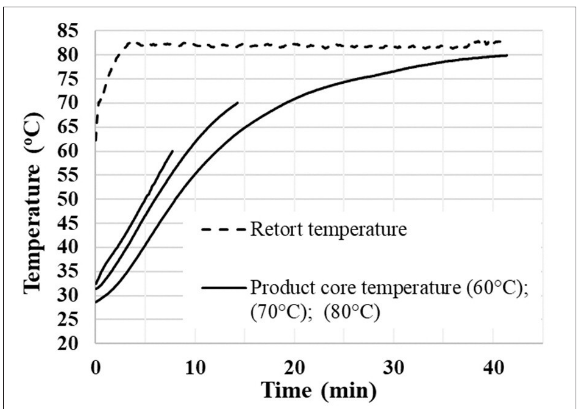
Lactic acid reached 1.13-1.73% after 48-96 h, within the typical range for fermented meat products such as nem chua. Previous studies have reported lactic acid levels of 1-2% after 2-4 days, contributing to microbial inhibition and sensory development (Lucke, 2000).

This similarity indicates that pomelo peel is a suitable substrate for lactic fermentation, producing biochemical changes comparable to traditional fermented foods. Therefore, a fermentation time of 72–96 h is considered appropriate.

4.4. Changes in structure and color as affected by pasteurization temperature

It should be noted that the pasteurization temperatures (60°C, 70°C, and 80°C) refer to the target temperatures measured at the product core. Results in Figure 2 show that higher processing temperatures resulted in longer times to reach thermal equilibrium. This may affect the physical structure and induce chemical reactions within the product.

Figure 2. Heating profiles of retort and product core temperatures during thermal processing at different target temperatures (60°C, 70°C, and 80°C)



4.4.1. Changes in the texture of pomelo peel nem at different pasteurization temperatures

The cutting force of the pomelo peel fermented product showed significant differences at different pasteurization temperatures ($p < 0.05$). Comparison of cutting force values before and after pasteurization indicated that the texture of the product was enhanced following thermal treatment (Table 5).

Thermal treatment can promote stronger interactions among polysaccharide chains, particularly pectin, leading to the formation of a denser and firmer gel network. In addition, the ability of polysaccharide chains to utilize water within the product for gelation may reduce the softening effect of water on the structure. This is advantageous for the sensory attributes, particularly in terms of texture and overall product state, of pomelo peel nem. Although higher temperatures improve structural firmness, excessive hardness may negatively affect sensory acceptability. Therefore, an optimal thermal condition should be considered to balance textural improvement and consumer preference.

Table 5. Effect of core pasteurization temperature on shear force of pomelo peel nem

Core temperature (°C)	Shear force (N)
Control	18.94 ± 0.81[a]
60°C	20.29 ± 0.45[b]
70°C	22.20 ± 0.62[c]
80°C	25.57 ± 0.68[d]

Different letters in the same column indicate significant differences (p < 0.05).

4.4.2. Changes in color of pomelo peel nem after thermal treatment

Color parameters (L*, a*, and b*) were significantly affected by pasteurization temperature ($p < 0.05$). Compared to the untreated sample, all thermally treated samples exhibited noticeably lower L* values, indicating a darker color after heat processing (Table 6), while a* and b* values slightly decreased, reflecting reductions in red and yellow components. These changes are consistent with non-enzymatic browning reactions, particularly the Maillard reaction, as well as thermal degradation of phenolic compounds present in pomelo peel (Lund & Ray, 2017).

To evaluate the overall color variation, the total color difference (ΔE) was calculated based on the CIELAB color space using the following equation:

$$\Delta E = \sqrt{(L^* - L^*_0)^2 + (a^* - a^*_0)^2 + (b^* - b^*_0)^2}$$

Where: L^*_0, a^*_0, và b^*_0 represent the color values of the untreated sample, while L*, a*, và b* correspond to those of the pasteurized samples. The color difference (ΔE) of pomelo peel nem at different pasteurization temperatures was markedly higher compared to the unpasteurized sample. As the pasteurization temperature increased, ΔE values also increased, indicating greater color deviation. In general, ΔE values greater than 3 are considered

Table 6. Changes in color parameters (L*, a*, b*) of pomelo peel nem as affected by core pasteurization temperature

Core temperature (°C)	L*	a*	b*	ΔE
Control	32.27 ± 0.13[a]	39.87 ± 0.76[a]	20.44 ± 0.71[a]	-
60	18.99 ± 0.85[b]	28.00 ± 1.33[b]	17.58 ± 1.00[b]	18.06 ± 0.88[a]
70	16.56 ± 0.17[c]	28.18 ± 0.62[b]	17.19 ± 0.66[b]	19.88 ± 0.79[b]
80	14.88 ± 0.53[d]	25.77 ± 0.41[c]	11.19 ± 0.93[c]	24.25 ± 0.94[c]

Different letters in the same column indicate significant differences ($p < 0.05$).

perceptible to the human eye, suggesting that thermal treatments caused significant changes in the color of pomelo peel nem (Pathare et al., 2013).

4.4.3. Relationship between structural and color changes of pomelo peel nem during pasteurization

Notably, the decrease in L* values occurred simultaneously with the increase in shear force, indicating that thermal treatment affected both the structural and color properties of the product. This relationship suggests that moisture loss and gelation during pasteurization not only reinforce the mechanical structure but also alter light scattering and promote chemical reactions within the product. These concurrent changes reflect the combined effects of physical and chemical processes during thermal treatment, in which water loss and compositional changes govern both mechanical properties and visual color attributes, in agreement with previous reports on thermally processed food systems (Singh and Ramaswamy, 2023).

From a practical perspective, increasing pasteurization temperature enhances the structural integrity of pomelo peel nem but negatively affects its color quality. Therefore, an optimal pasteurization condition should be selected to balance these effects. Based on the present results, a moderate temperature of approximately 70 °C provides an acceptable balance between textural properties and color quality.

5. Conclusion

Pasteurization temperature significantly affected the structural and color properties of pomelo peel nem ($p < 0.05$). Increasing the temperature from 60°C to 80°C led to an increase in shear force, indicating enhanced structural integrity, but resulted in a decline in color quality, as evidenced by decreases in L*, a*, and b* values and an increase in ΔE. An optimal temperature of approximately 70°C achieved a balance between improved texture and acceptable color, providing a basis for selecting appropriate thermal processing conditions to stabilize product quality ■

REFERENCES:

Chockchaisawasdee, S., Namjaidee, S., Pochana, S., & Stathopoulos, C. E. (2010). Development of Fermented Oyster-Mushroom Sausage. Asian Journal of Food and Agro-Industry, 3(01), 35-43.

Elyass, M. E., Shigidi, M. T., Attitalla, I. H., & Mahdi, A. A. (2017). Characterization and Optimization of Bacteriocin from Lactobacillus plantarum Isolated from Fermented Beef (Shermout). Open Journal of Applied Sciences, 07(03), 83-97. https://doi.org/10.4236/ojapps.2017.73008

Liu, J., Bi, J., McClements, D. J., et al. (2020). Impacts of thermal and non-thermal processing on structure and functionality of pectin in fruit- and vegetable- based products: A review. Carbohydrate Polymers, 250(2), 116890. https://doi.org/10.1016/j.carbpol.2020.116890

Lucke, F. K. (2000). Utilization of microbes to process and preserve meat. Meat Science, 56(2), 105-115.

Lund, M. N., & Ray, C. A. (2017). Control of Maillard Reactions in Foods: Strategies and Chemical Mechanisms. Journal of Agricultural and Food Chemistry, 65(23), 4537-4552.

Nguyen, D. T. L., Van Hoorde, K., Cnockaert, M., De Brandt, E., De Bruyne, K., Le, B. T., & Vandamme, P. (2013). A culture-dependent and -independent approach for the identification of lactic acid bacteria associated with the production of nem chua, a Vietnamese fermented meat product. Food Research International, 50(1), 232-240.

Nguyen, H. T. H., Elegado, F. B., Librojo-Basilio, N. T., Mabesa, R. C., & Dizon, E. I. (2010). Isolation and characterisation of selected lactic acid bacteria for improved processing of Nem chua, a traditional fermented meat from Vietnam. Beneficial Microbes, 1(1), 67-74.

Hung, P.P.V., Phi, N.T.L., Nam, T.H., & Tuan, N.D.P. (2020). Optimization of condition for pectin extraction from pomelo peel using response surface methodology. Can Tho University Journal of Science, 12(1), 50-57.

Pathare, P. B., Opara, U. L., & Al-Said, F. A. J. (2013). Colour Measurement and Analysis in Fresh and Processed Foods: A Review. Food and Bioprocess Technology, 6(1), 36-60.

Phan, Y. T. N., Tang, M. T., Tran, T. T. M., Nguyen, V. H., Nguyen, T. H., Tsuruta, T., & Nishino, N. (2017). Diversity of lactic acid bacteria in vegetable-based and meat-based fermented foods produced in the central region of Vietnam. AIMS Microbiology, 3(1), 61-70.

Singh, H., & Ramaswamy, H. S. (2023). Thermal Processing of Acidified Vegetables: Effect on Process Time-Temperature, Color and Texture. Processes, 11(4). https://doi.org/10.3390/pr11041272

Thanh, N. N., Thi, T., Huyen, N., Thi, N., Cam, M., Tan, L. C., Thien, T., Ai, N., Chau, L. M., Hoang, B., Long, D., Phong, H. X., Cong, V., & Dai, T. (2023). Isolation, Selection of Lactic Bacteria and Application in Fermentation of Pomelo Peel. 21(8), 1019-1027.

Zhao, J., Gong, J., Liang, W., & Zhang, S. (2024). Microbial diversity analysis and isolation of thermoresistant lactic acid bacteria in pasteurized milk. Scientific Reports, 14(1), 1-12.

Received date: March 5, 2026
Reviewed date: March 19, 2026
Accepted date: March 28, 2026

ẢNH HƯỞNG CỦA NHIỆT ĐỘ THANH TRÙNG ĐẾN ĐẶC TÍNH CẤU TRÚC VÀ MÀU SẮC CỦA NEM CHUA VỎ BƯỞI

● **NGUYỄN ĐỨC TOÀN**[1]
● **GIANG KIẾN QUỐC**[1]
[1] Trung tâm Công nghệ Sau thu hoạch
Khoa Nông nghiệp - Thủy sản, Đại học Trà Vinh

TÓM TẮT:

Nghiên cứu này đánh giá ảnh hưởng của nhiệt độ thanh trùng đến đặc tính cấu trúc và màu sắc của nem vỏ bưởi. Quá trình thanh trùng trong khoảng 60–80°C có tác động đáng kể đến chất lượng sản phẩm ($p < 0,05$). Khi nhiệt độ tăng, các đặc tính cấu trúc được cải thiện, trong khi các thông số màu (L*, a*, b*) giảm và độ sai khác màu tổng (ΔE) tăng, cho thấy sản phẩm có xu hướng sẫm màu hơn so với mẫu đối chứng. Trong các điều kiện khảo sát, mức nhiệt 70°C đạt được sự cân bằng tối ưu giữa việc cải thiện cấu trúc và duy trì màu sắc chấp nhận được.

Từ khóa: lên men lactic, nhiệt độ thanh trùng, nem chua vỏ bưởi.