THE EFFECT OF THERMAL PROCESSING ON TEXTURE PROFILE ANALYSIS OF EGG WHITE NOODLES

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ARTICLE HISTORY

Received: 2 June 2023 **Revised:** 21 June 2023 **Published:** 3 July 2023

ABSTRACT

Egg whites are frequently utilized in various food products due to their excellent functional properties and being a rich source of protein. In recent years, there have been advancements in the development of egg white-based noodles, where encapsulation techniques are employed to eliminate the unpleasant odor associated with egg whites, making them more appealing to consumers. However, egg white noodles (EWN) still have a short shelf life and are sensitive to heat. Thermal processing techniques can affect the physiochemical and textural properties of EWN. Therefore, suitable thermal processing is crucial for the production of high-quality EWN. This study aimed to evaluate the effects of different thermal processing methods, namely pre-boiled (PB), boiled (B), pasteurized (P), and retorted (R) on the physiochemical properties, texture profile analysis, sensory acceptability, and the texture profile of P-EWN and R-EWN under various cooking methods. The findings revealed that thermal processing increased lightness, reduced yellowness, and improved the sizing of EWN. However, no significant differences in color and diameter of cooked EWN were observed. Moreover, pasteurization resulted in higher processed cooking yield compared to retort processing. The texture properties of EWN, including hardness, adhesiveness, tensile strength, elasticity, and firmness decreased with increased thermal processing. Across all the cooking methods, hardness, adhesiveness, and firmness of the noodles declined. Interestingly, there were no significant difference in sensory acceptability scores among the various thermal processing methods. These results have significant implications for the development of high-quality egg white-based food products with desirable sensory and textural characteristics.

Keywords: Egg white, Egg white noodles, Thermal processing, Texture profile analysis, Sensory evaluation

CITATION INFORMATION: Kerdjaiboon, P., Ngamukote, S., & Suantawee, T. (2023). The Effect of Thermal Processing on Texture Profile Analysis of Egg White Noodles. *Procedia of Multidisciplinary Research, 1*(7), 32.

INTRODUCTION

Non-communicable diseases (NCDs), including cardiovascular diseases (CVDs), diabetes, cancers, and chronic respiratory diseases, are the primary causes of morbidity and mortality worldwide. According to the World Health Organization (WHO), NCDs account for 71% of global deaths (World Health Organization, 2021). The rise of NCDs has been driven by four potential modifiable risk factors: tobacco use, physical inactivity, the harmful use of alcohol, and unhealthy diets (Schwartz et al., 2021). Improving diets is crucial for preventing NCDs, as unhealthy diets are typically high in refined carbohydrates, fat, sugar, sodium, and calories but low in essential nutrients such as proteins, vitamins, minerals, and antioxidants. Modifying diets to reduce fat and refined carbohydrates whiles increasing protein in the optimal proportion enhances public health and prevents chronic diseases.

In Asia, rice and noodles are the most important staple foods, and they are widely consumed in Thailand. In addition to rice, noodles can be made from various flours such as rice flour, mung bean flour, tapioca flour, and wheat flour. However, these flours are primarily high in carbohydrates and low in protein. This, combined with high-fat side dishes, leads to high-carbohydrate and high-fat meals. To address this, there has been a shift towards high protein noodles as an alternative to high carbohydrate noodles. Egg white has emerged as the source for producing high protein noodles with low levels of carbohydrates, fat, and calories.

Egg whites are high in protein, which is a complete protein. Several studies reported that high consumption of protein diets was found to reduce prospective food consumption, increase satiety, lower fasting insulin, and decrease body weight and body fat mass (Du et al., 2018; Matsuoka et al., 2017; Santesso et al., 2012). Apart from its health benefits, their strong odor can lead to undesired product characteristics. Processing egg whites through heat treatment, acidification, and mechanical processing can change their structure, functional properties, and bioactivity, resulting in a loss of quality. For this reason, encapsulation techniques are a well-established process known for its ability to mask odors and preserve the stability of bioactive compound, both during processing and in final products (Su et al., 2019). Sodium alginate is dissolved in an aqueous system, then undergoes gelation by the addition of divalent cations, especially Ca^{2+} from $CaCl_2$. The cross-linking of alginate with Ca^{2+} resulted in the formation of a hydrogel with improved swelling capacity, in vitro protein adsorption and thermal stability (Chantakun & Benjakul, 2020). Therefore, encapsulation techniques play a pivotal role in the development of egg white noodles, ensuring their success by effectively eliminating any unpleasant odor and enhancing the overall quality and stability of the product. In addition, thermal processing methods like pasteurization and sterilization are commonly employed for food preservation to prolong shelf-life and ensure safety. However, it is important to note that these various thermal processing methods can have an impact on the physiochemical properties, texture properties, and shelf-life of the final product.

The objective of this study was to investigate the effect of thermal processing, specifically pasteurization and sterilization (retort), on the physiochemical properties, texture profile analysis, and sensory acceptability of egg white noodles (EWN). Furthermore, the investigation included analyzing the texture profile of pasteurized and retorted EWN prepared using various cooking methods. This analysis aimed to explore the potential benefits of utilizing egg white into the development of healthier noodles that meet the highest nutritional values and consumer acceptance while maintaining good quality.

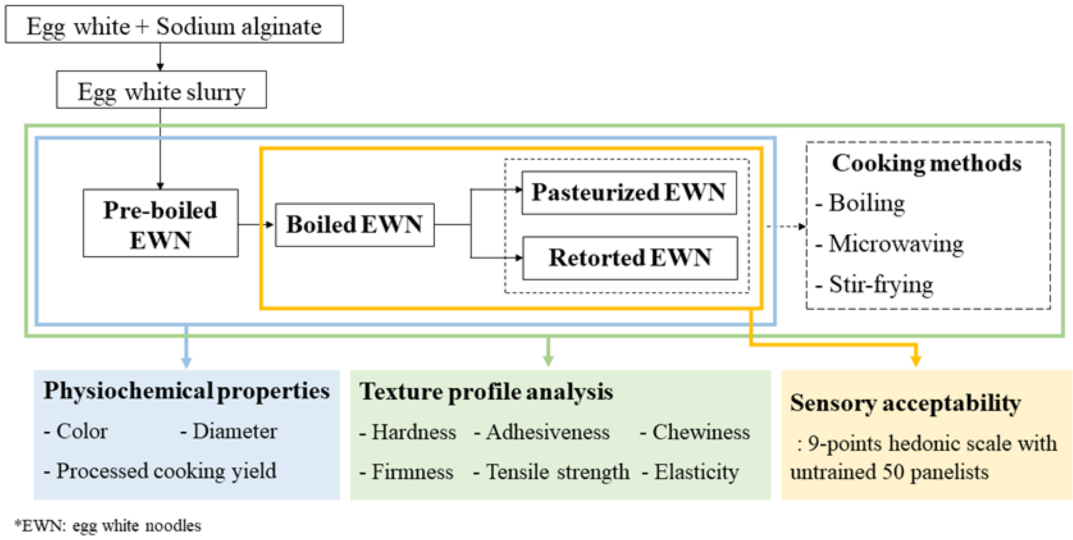

Figure 1 Conceptual Framework

RESEARCH METHODOLOGY

Preparation of materials

1) Preparation of EWN

The sample of EWN which includes pre-boiled (PB), boiled (B), pasteurized (P), and retorted (R)-EWN. All of samples were prepared from Thandee Innofood Co., Ltd., except P-EWN. B-EWN was produced by boiling PB-EWN at 100°C for 2 minutes. P-EWN was prepared by heating B-EWN at 80°C for 10 minutes. R-EWN was performed by retort at 121°C for 30 minutes.

2) Cooking methods of EWN

P-EWN and R-EWN underwent additional cooking methods including boiling, microwaving, and stir-frying. Boiling involved cooking the noodles in water until they reached a boiling point. Microwaving entailed cooking the noodles in water using a microwave oven set at 900 W (sample: water = 1:2 w/v). Stir-frying involved cooking the noodles with rice ban oil and seasoning sauce. Each cooking methods were cooked for 2 minutes. Following the cooking process, all samples were used for further measurement of texture profile analysis. For more details, the conceptual framework can be drawn as shown in Figure 1.

3) Physiochemical properties

3.1) Color

The color profile of EWN was determined using a colorimeter (Color flex, Hunter Associates laboratory, Inc., VA, United States) according to a previous study with minor modifications (Wongpattananukul et al., 2022). The noodles (15 g) were placed in transparent sample glass above the port insert. The results were expressed as the CIE L* (lightness), a* (redness), and b* (yellowness) color values. The measurement was performed in triplicate.

3.2) Diameter

The diameter of EWN was measured using a digital caliper. The midpoint of 20 individual strands of noodle was taken randomly and expressed as mm of EWN.

3.3) Cooking quality during thermal processing

The processed cooking yield of EWN was determined according to a previous study (Tan et al., 2016). After processing, the noodles were separated from the water and weighed. The weight of cooked noodles was measured after cooling. The processed cooking yield was calculated using the following equation:

$$\text{Processed cooking yield (\%)} = \frac{\text{the weight of noodles after processing (g)}}{\text{the weight of boiled EWN (g)}} \times 100$$

4) Texture profile analysis of EWN
The texture profile of EWN was performed by the Texture Analyzer, TA. XT2 Plus (Stable Micro Systems, Surrey, UK) with a 50 kg load cell according to a previous study with minor modifications (Petitot et al., 2010). All EWN and both P and R-EWN under various cooking methods were measured. Briefly, a set of three strands were cut to a 5-cm length and compressed by a cylindrical probe of 75 mm diameter (P/75). The EWN were axially compressed twice to 75% of the initial noodle thickness. The settings were used at 1, 5, and 5 mm/s for pre-test, test, and post-test speeds, respectively. The trigger type is auto with a trigger force of 0.5 g. The values of hardness (g), adhesiveness (g·sec), and chewiness (g) were measured. Tensile strength analysis was conducted by the Spaghetti/Noodle Rig (A/SPR) probe. One EWN strand with 40-cm length was fixed on the probe and pulled with a hook until breakage. The settings were used at 1, 3, 10 mm/s and 70 mm for pre-test, test, post-test, and distance, respectively. Firmness was used an Asian noodle rig (HDP/ANR) with three strands of 3-cm length following the Wheat Marketing Center method. Each experiment was tested in 15 replicates and analyzed using Exponent software.
5) Sensory acceptability
The process adopted for the sensory acceptability of EWN was approved by the Research Ethics Review Committee for Research Involving Human Research Participants, Group 1, Chulalongkorn University (COA No. 228/65). Written informed consent was obtained from all participants prior to involving them in the evaluation. The sensory acceptability and preference of B-EWN, P-EWN, and R- EWN were carried out by 50 untrained panelists at the sensory evaluation laboratories according to a previous study with minor modifications (Jayasena et al., 2010; Watts et al., 1989). The panelists were given approximately 10 g of each EWN without soup in a clear plastic cup with a lid at ambient temperature. The attributes of noodles such as appearance, color, odor, taste, firmness, springiness, and overall acceptability were evaluated by using a 9-point hedonic scale. Subsequently, preference ranking test was conducted according to a previous study (Koh et al., 2022). The panelists were asked to rank the three samples based on their preference using a score sheet with “1” as the most preferred and “3” as the least preferred.
6) Statistical Analysis
All data were expressed as mean of values ± standard error of the mean (S.E.M) ($n = 3$). One-way analysis of variance (ANOVA) followed by Tukey HSD test was used to analyze the means among multiple groups. T-test was used to analyze the means between pasteurized and retorted EWN under same cooking method. The non-parametric Friedman test followed by Fisher’s Least Significant Difference (LSD) test was used to analyze the significant differences among the ranking data (sensory evaluation). The significance different test was used for mean comparison and $p\text{-value} < 0.05$ was considered as statistically significant. The statistical analysis was carried out using IBM SPSS Statistics version 28.0 (SPSS Inc., USA).

RESEARCH RESULTS

Thermal processing on Physiochemical properties of EWN

The physiochemical properties of noodles refer to the characteristics including color, diameter, and processed cooking yield as shown in Table 1. The color (L*, a*, and b* values) is a crucial attribute that significantly affects consumer perception of food quality and overall satisfaction. The results showed that B-EWN significantly increased lightness (L*) by 1.28-fold, decreased yellowness (b*) by 2.15-fold, and extended diameter by 1.35-fold compared to PB-EWN. No significant differences were observed in color and diameter during thermal processing. However, pasteurization and retort had an impact on processed cooking yield. Cooking yield is considered to be a critical quality parameter of noodles in terms of cooking quality. It was observed that R-EWN significantly reduced percentage of processed cooking yield compared to P-EWN, accounting for 9%. These results indicate that boiling influences color and diameter, while pasteurization and retort affect the processed cooking yield.

Table 1 Physiochemical properties of EWN

	PB-EWN	B-EWN	P-EWN	R-EWN
Appearance				
Color				
L*	66.51±2.46^{a}	85.30±0.32^{b}	85.93±0.21^{b}	82.31±0.09^{b}
a*	-3.65±0.10^{a}	-3.07±0.26^{a}	-3.34±0.13^{a}	-1.56±0.08^{b}
b*	20.05±0.87^{a}	9.32±0.37^{b}	8.89±0.63^{b}	9.81±0.55^{b}
Diameter (mm)	2.24±0.02^{a}	3.04±0.04^{b}	2.99±0.06^{b}	2.86±0.05^{b}
Processed cooking yield (%)	nd	nd	106.48±1.05^{a}	97.82±1.90^{b}

The values are expressed as mean ± S.E.M. (n=3). Means values with different superscript letter in same row are significantly different ($P<0.05$). EWN: egg white noodles, PB-EWN: pre-boiled egg white noodles, B-EWN: boiled egg white noodles, P-EWN: pasteurized egg white noodles, R-EWN: retorted egg white noodles, and nd: not detected.

Thermal processing on Texture profile analysis of EWN

Texture is an important quality attribute that greatly affects consumer acceptance of noodles. In this study, the texture of noodles was evaluated using compressive and tensile tests. The changes in texture profile analysis parameter (hardness, adhesiveness, chewiness, firmness, tensile, and elasticity) during thermal processing are shown in Table 2. The results showed that B-EWN significantly increased hardness (56%), chewiness (13%), and firmness (50%) compared to PB-EWN. However, no significant differences were observed in the tensile strength and elasticity between B-EWN and PB-EWN. Additionally, P-EWN exhibited significantly lower tensile strength and elasticity compared to B-EWN, but significantly higher values compared to R-EWN. These results suggest that thermal processing of noodles at higher temperatures leads to a reduction in tensile strength, elasticity, and firmness.

The texture properties of P-EWN and R-EWN were also evaluated under various cooking methods, including boiling, microwaving, and stir-frying as shown in Table 3. The results demonstrated a significant decrease in hardness with all cooking methods, exhibiting 5-20% reduction of P-EWN and R-EWN, compared to the non-cooking state. However, no significant differences were observed in chewiness, tensile strength, and elasticity among cooking methods. Furthermore, among cooking methods, all the texture properties of R-EWN significantly decreased compared to P-EWN. These findings suggest that boiling, microwaving, and stir-frying contribute to the softening of noodles.

Table 2 Texture profile analysis of EWN during thermal processing

	PB-EWN	B-EWN	P-EWN	R-EWN
Texture properties				
Hardness (g)	6,361.51±42.17^{a}	9,916.30±62.93^{c}	11,236.36±13.03^{d}	7,414.53±79.80^{b}
Adhesiveness (g.sec)	-12.81±0.08^{a}	-9.05±0.05^{c}	-10.27±0.26^{b}	-11.18±0.18^{b}
Chewiness (g)	4.19±0.03^{a}	10.99±0.18^{c}	12.44±0.4^{c}	5.79±0.49^{b}
Tensile strength (g)	49.33±0.37^{a}	49.50±0.61^{a}	41.76±0.61^{b}	25.78±0.41^{c}
Elasticity (mm)	31.01±0.34^{a}	32.32±1.59^{a}	24.52±0.96^{b}	20.25±0.68^{c}
Firmness (g)	1,162.48±6.71^{a}	1,748.88±12.35^{b}	1,519.84±10.00^{c}	931.36±5.48^{d}

The values are expressed as mean ± S.E.M. (n=3). Means values with different superscript letter in same row are significantly different (P<0.05). EWN: egg white noodles, PB-EWN: pre-boiled egg white noodles, B-EWN: boiled egg white noodles, P-EWN: pasteurized egg white noodles, and R-EWN: retorted egg white noodles.

Table 3 Texture profile analysis of EWN under various cooking methods

Texture properties	EWN	Cooking methods			
		No cooking	Boiling	Microwaving	Stir-frying
Hardness (g)	P	11,236.86±12.03^{aA}	9,893.98±57.53^{cA}	10,577.67±58.99^{bA}	8,926.73±45.69^{dA}
	R	7,414.53±79.80^{aB}	6,678.44±22.71^{bB}	6,971.52±56.02^{cB}	6,488.73±22.06^{dB}
Adhesiveness	P	-10.27±0.26^{abA}	-9.54±0.15^{bA}	-11.04±0.12^{aA}	-7.84±0.31^{cA}
(g.sec)	R	-11.18±0.18^{abA}	-13.34±0.38^{aB}	-13.85±0.13^{bB}	-10.71±0.04^{cB}
Chewiness (g)	P	12.44±0.41^{aA}	12.26±0.40^{bA}	10.99±0.32^{abA}	11.84±0.35^{abA}
	R	5.79±0.49^{aA}	4.15±0.13^{bB}	5.34±0.69^{abB}	4.85±0.25^{abB}
Tensile strength (g)	P	41.76±0.61^{aA}	40.51±0.49^{aA}	38.37±0.51^{aA}	nd
	R	25.78±0.41^{aA}	25.54±0.52^{aB}	26.71±0.66^{aB}	nd
Elasticity (mm)	P	24.52±0.96^{aA}	29.30±1.84^{aA}	23.03±0.61^{bA}	nd
	R	20.25±0.68^{aA}	18.00±0.64^{aB}	19.95±0.69^{bB}	nd
Firmness (g)	P	1,519.84±10.00^{abA}	1,587.26±3.90^{aA}	1,460.29±6.46^{bA}	1,704.43±8.73^{cA}
	R	931.30±5.48^{abA}	827.75±10.27^{aB}	869.57±7.04^{bB}	837.77±8.19^{cB}

The values are expressed as mean ± S.E.M. (n=3). The texture properties were repeated 15 times for each sample. Means of processed EWN (a-b; cooking method effect) with different superscript letter in same row are significantly different (P<0.05). Means of EWN (A-B; thermal processing effect) with different superscript letter in same row are significantly different (P<0.05). EWN: egg white noodles, P-EWN: pasteurized egg white noodles, R-EWN: retorted egg white noodles, and nd: not detected.

Thermal processing on Sensory acceptability of EWN

Sensory acceptability is a direct method which can reflect the quality and acceptance of EWN. Sensory parameters of B-EWN, P-EWN, and R-EWN were carried out for appearance, color, odor, taste, softness, springiness, and overall acceptability, and the results of the hedonic test are shown in Table 4. The scores above 6 on a 9-point scale indicate positive consumers' acceptance (Morais Ferreira et al., 2017). The results showed that thermal processing was no significant effect on the sensory attributes of EWN, except for R-EWN which showed a significant increase in color score. All EWN received scores above 6 for appearance, color, springiness, and overall acceptability, indicating positive sensory attributes. According to ranking test, the most preferred EWN was B-EWN (mean rank score: 1.70), followed by P-EWN (1.78), and the least preferred was R-EWN (2.52). Thus, the best sensory acceptability was B-EWN.

Table 4 Sensory acceptability of EWN

	B-EWN	**P-EWN**	**R-EWN**
Sensory acceptability			
Appearance	6.80±0.23^{a}	6.56±0.22^{a}	6.52±0.22^{a}
Color	6.68±0.23^{ab}	6.30±0.22^{a}	7.18±0.18^{b}
Odor	5.00±0.28^{a}	5.14±0.28^{a}	4.50±0.22^{a}
Taste	5.96±0.24^{a}	5.90±0.22^{a}	5.80±0.19^{a}
Softness	5.96±0.25^{a}	5.74±0.28^{a}	5.88±0.22^{a}
Springiness	6.24±0.26^{a}	6.46±0.25^{a}	6.08±0.20^{a}
Overall acceptability	6.30±0.24^{a}	6.16±0.24^{a}	6.16±0.17^{a}

The values are expressed as mean ± S.E.M. (n=50). Means of EWN with different superscript letter in each column are significantly different (P<0.05). EWN: egg white noodles, B-EWN: boiled egg white noodles, P-EWN: pasteurized egg white noodles, and R-EWN: retorted egg white noodles.

DISCUSSION & CONCLUSION

Thermal processing affects the color, diameter, processed cooking yield, and texture analysis of EWN. Our findings reveal that heat treatment induces changes in EWN. Specifically, when egg white is heated to 70°C, the protein undergoes denaturation, causing the transition from a clear liquid to an opaque white state (Payawal et al., 1946). Consequently, heat treatment of egg white leads to the formation of edible gels, adding to its usefulness as a widely consumed food. In product development, encapsulation techniques effectively mask odors and preserve the stability of bioactive compounds throughout processing and in final products. However, previous studies have shown that the temperature which alginate bead gel (ABG) are heated plays a crucial role in their size and weight reduction (Kim et al., 2019; Saqib et al., 2022). The reduction in size of ABG beads is primarily attributed to water loss, leading to the development of a denser porous structure within the beads. Moreover, heat treatment induces a decrease in weight, thereby causing a decrease in the processed cooking yield as the temperature rises. Consequently, the overall yield of the cooked EWN decreases with increasing thermal processing temperatures. This weight reduction can be attributed to the moisture loss that occurs during the heat treatment process. Additionally, thermal processing exerts a significant influence on the texture of EWN. The application of heat alters the texture characteristics, resulting in variations such as firmness, chewiness, and elasticity. These changes in texture can impact the overall sensory experience and acceptability of the EWN. A previous study revealed that the hardness of alginate-guar gels mixed with pimiento pulp substantially increases with thermal treatment at 80°C for 15 minutes. This increase in hardness and loss of elasticity may be attributed to gel shrinkage, which leads to a more compact structure during heat treatment (Moosavi et al., 2018). Another study by Leo et al. (1990) showed that the gel strength, as defined by critical compression force, reaches its peak at 90°C and sharply declines as the temperature rises to 120°C. Beyond 120°C, alginate gels undergo depolymerization. The depolymerized chains lead to a more open structure of the gel, increased particle size, and enhanced gel. Consequently, as the temperature increases, alginate gels tend to exhibit less rigidity. A previous study also found that heated gels tended to be softer and less brittle while still maintaining gel structural integrity (Roopa & Bhattacharya, 2010). Syneresis, resulting in the shrinkage of the gel particles, was also observed in steam treated gels. As alginate gels are not thermoreversible, the gel deformation was maintained after heat was removed. The thermal processing, such as retort, can lead to the gelation of alginate, resulting in the formation of a more delicate and softer gel structure. Sterilization at 121°C has been shown to significantly deteriorate gel strength, resulting in softened noodles (Leo et al., 1990). Apart from thermal processing, the cooking method also impacts the texture of noodles. Boiling or microwaving noodles, which exposes them to water, results in moisture absorption, leading to hydration and a softer texture (Moosavi et al., 2018). When EWN are stir-fried with a small amount of oil, various ingredients, and liquid or sauce, they absorb the flavors and moisture, leading to a decrease in hardness and firmness. In addition, the high heat and constant stirring of the EWN during the cooking process ensure even heat distribution and facilitate moisture absorption. As the EWN are exposed to the heat, they gradually soften and become more pliable.

For sensory evaluation among thermal processing, all parameters were not significantly different, except for the odor in R-EWN. This high-heat treatment can lead to the breakdown of certain compounds, including sulfur-containing amino acids like cysteine and methionine, present in egg white proteins. The breakdown of these amino acids can lead to the release of volatile sulfur compounds, such as hydrogen sulfide, which is associated with an unpleasant odor (Germs, 1973). In contrast, pasteurization, which involves heating at a lower temperature for a shorter period compared to sterilization, is less likely to generate involatile sulfur compounds since the conditions are not sufficient to break down sulfur-containing amino acids.

Our study revealed that the application of thermal processing to EWN has a significant impact on their color, diameter, processed cooking yield, and texture. Increasing the intensity of thermal processing results in a reduced processed cooking yield and softer noodles. Among the thermal processing methods, pasteurization emerges as a more favorable approach for EWN, exhibiting better results in terms of texture profile analysis and sensory acceptability compared to retort processing. To improve the texture profile of R-EWN, it is recommended to focus on improving parameters such as hardness, chewiness, tensile strength, elasticity, and firmness. Furthermore, our observations indicate that different cooking methods exert distinct effects on the texture characteristics of EWN. The findings of our study provide valuable insights into the impact of thermal processing on EWN, facilitating the development of enhanced processing techniques that yield desirable texture and sensory properties in EWN. These advancements are essential in meeting consumer preferences and ultimately improving the overall quality of EWN.

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Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Conflicts of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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