

Production of squid sausage from purpleback flying squid (*Sthenoteuthis oualaniensis*)

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ABSTRACT

In recent years, the production of purpleback flying squid (*Sthenoteuthis oualaniensis*) has increased and plays an important role in Vietnam’s fisheries. This squid species is widely distributed in Vietnamese waters. Although its production is high, the cooked squid is generally considered less palatable than other squid species. When stored for an extended period, it develops an acrid taste, and dried squid often turns black, reducing the product’s commercial value. Therefore, utilizing purpleback flying squid for the production of value-added products, such as squid sausage, is desirable to enhance its utilization and market value. In this study, the effects of different concentrations of NaCl (0.5, 1, 1.5, and 2%) and seaweed (0.5, 1, and 2%) on the color, drip loss, protein solubility, texture, seasoning ratio, and gel strength of squid sausage were investigated. The results showed that the addition of salt and seaweed improved the texture of squid sausage compared to samples prepared without these ingredients. The best texture was observed in sausages formulated with 2% salt. The highest sensory score was achieved with a seasoning formulation consisting of 2% salt, 4% sugar, 0.5% monosodium glutamate (MSG), 0.7% garlic powder, 1% seaweed, 0.5% chili powder, and 1% chili sauce. These findings demonstrate that purpleback flying squid has strong potential for developing value-added products, and the optimized squid sausage formulation provides a promising application to enhance its commercial value and industrial utilization.

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1. Introduction

Processed seafood products are valuable sources of essential nutrients for humans. The purpleback flying squid (*Sthenoteuthis oualaniensis*) is a cephalopod mollusk belonging to the phylum Mollusca and is widely distributed

in tropical and subtropical seas and oceans. *Sthenoteuthis* is found extensively in Vietnamese waters. In recent years, the annual production of purpleback flying squid in Vietnam has been high, estimated at around 1,000 tons. Although *Sthenoteuthis* has higher nutritional value

compared to other squid species (Tran, 2003), its economic value remains relatively low. Despite the high production volume, cooked purpleback flying squid is considered less palatable than other squid species, and when stored for a long time, it tends to develop an acid taste. Additionally, dried squid often turns black, reducing its market value. Nevertheless, the stable supply of purpleback flying squid presents an opportunity to develop value-added products.

Seafood is a rich source of high-quality proteins valued for their functional properties and nutritional benefits (Tahergorabi et al., 2011). The gelling capacity of food proteins is an important functional attribute in food manufacturing (Zayas, 1997). During the production of squid sausage mixed with seaweed, the texture of the raw material after grinding is crucial for gel (paste) formation, which plays a key role in developing the desired product texture. Gel formation, or gelation, is an important characteristic of proteins that affects the microstructure and palatability of meat products (Sun & Holley, 2011).

Protein gel structures form under conditions that disrupt native protein structures, provided that the protein concentration, thermodynamic conditions, and other factors are optimal for forming a stable tertiary matrix (Schmidt, 1981). Myofibrillar proteins largely determine the textural properties of processed protein products (Yasui et al., 1980; Asghar et al., 1985). Gelation is a two-step process consisting of denaturation and aggregation (Kinsella et al., 1994; Matsumura & Mori, 1996). Gelling properties are also influenced by several factors, including the type of myofibrillar proteins, muscle type, species, and processing conditions such as protein concentration, pH, ionic strength, pressure,

heating rate, and temperature (Sun & Holley, 2011).

A gel is an intermediate phase between a solid and a liquid, technically defined as a substantially diluted system that exhibits no steady flow. Protein gelation refers to the transformation of proteins from a sol state (viscous material) to a gel-like state (elastic material). When seafood muscle tissue is comminuted in the presence of NaCl, a viscous soul initially forms, which, upon heating, transforms into a viscoelastic gel. Although the terms gelation and coagulation are often used interchangeably, gelation can be theoretically defined as a protein aggregation phenomenon in which polymer-polymer and polymer-solvent interactions are balanced by attractive and repulsive forces, resulting in a well-ordered tertiary network or matrix capable of trapping large amounts of water (Schmidt, 1981).

Lipids in seaweeds are present in relatively low amounts (1 - 5% of dry matter), yet they are beneficial to human health, as nearly half of these lipids are polyunsaturated fatty acids such as eicosapentaenoic acid (EPA) and arachidonic acid (AA). Seaweeds also contain significant amounts of essential minerals (Na, K, Ca, and Mg), trace elements (Fe, Zn, Mn, and Cu), and various vitamins such as L-ascorbic acid (vitamin C), thiamine (B1), riboflavin (B2), cobalamin (B12), folic acid and its derivatives (5-methyltetrahydrofolate, 5-formyltetrahydrofolate, and tetrahydrofolate), and tocopherols (vitamin E) (Peng et al., 2015). Additionally, seaweed is rich in dietary fiber, accounting for 32 - 50% of its dry matter. The soluble fiber fraction represents 51 - 56% of total fibers in green (ulvans) and red algae (agars, carrageenans, and xylans), and 67 - 87%

in brown algae (laminaria, fucus, and others). Soluble fibers are generally associated with cholesterol-lowering and hypoglycemic effects (Dharmananda, 2002).

There have been few studies on products made from purpleback flying squid, as well as limited research on the gelation properties of squid proteins. Therefore, this study aimed to develop a new value-added product from purpleback flying squid and seaweed.

2. Materials and Methods

2.1. Materials and sample preparation

Squid (*Sthenoteuthis oualaniensis*) were purchased at BRAV company (ward 12, district 4, Ho Chi Minh City, Vietnam). Pangasius fish were purchased from a local market. Squid and pangasius were cleaned and rinsed with water to remove the impurities. Seaweed (*Undaria pinnatifida*) is used in grinded and dried form. Squid and pangasius was cut into pieces (3 x 4 cm) and frozen at -18°C for 4 h. After freezing, squid (60%) and pangasius (40%) were grinded with salt (0.5 - 2%). Following the first experiment on suitable salt concentration, the seaweed proportion was surveyed by adding seaweed at 0, 0.5, 1, and 2% during the grinding process. Lastly, the spice and additive ratio for the product was investigated.

Minced squid and pangasius was stuff into collagen case (diameter 24 cm x length 15 cm). The sausages were cooked at 90°C for 30 min in a water bath. Six to eight sausages were prepared for each treatment group.

2.2. Color analysis

The color of gels was measured with a colorimeter (CR-400/410, Konica Minolta).

Including L^* (white), a^* (+a, red; -a, green) and b^* (+b, yellow; -b, blue). The whiteness of gels was then calculated from the formula: whiteness = $100 - [(100 - L)^2 + a^2 + b^2]^{1/2}$ (Ramirez-Suarez & Morrissey, 2006).

2.3. Drip loss

About 2 g sample was wrapped in filter paper then put into a tube and centrifuged at 6000 r/min in 20 min by a centrifuge (Universal 320R centrifuge, Hettich, USA). Samples were weighed before and after centrifugation to calculate drip loss as following:

$$\text{Drip loss (\%)} = \frac{m_1 - m_2}{m_1}$$

With:

m_1 : mass of the sample before centrifugation (g),

m_2 : mass of the sample after centrifugation (g).

2.4. Gel strength

The method of Truong et al. (2017) was employed to determine gel forming ability. A folding test was performed by measuring the resistance of slices (3 mm thickness and 3.5 cm width) folded according to Suzuki (1981) with a 5 point grade system: 5 = no crack showing when folded twice; 4 = no crack showing when folded in half; 3 = cracks develops gradually when folded in half; 2 = crack occurs immediately when folded; 1 = breaks when pressed by fingers.

2.5. Protein solubility

The method of Truong et al. (2017) was employed to measure protein solubility of gels: About 4 g of sample were homogenised for 1 min with 40 mL of a 30 g L⁻¹ NaCl solution. The resulting solution was centrifuged at 4500 r/min

in 15 min. Take 1 mL supernatant aliquot was mixed with 10 mL of a 30 g L⁻¹ NaCl solution and homogenised again. The protein concentration was determined by the Lowry method at 550 nm (Lowry et al., 1951).

2.6. Texture profile analysis (TPA)

In the first experiment samples (24 mm diameter and 15 mm height) were tempered at 20°C for about 1 h and removed from their casings. Brookfield food texture analyzer (CT3, USA) was used to test for TPA. TPA was measured by a cylindrical-shaped probe, 31.1 mm in diameter and 20 mm L height. Samples were compressed at 3 mm/sec to 8 mm of height. In the second experiment, samples (27 mm diameter and 15 mm height) were tempered at 20°C for about 1 h and removed from their casings. Brookfield food texture analyzer (CT3, USA) was used to test for TPA. TPA was measured by a cylindrical-shaped probe, 31.1 mm in diameter and 20 mm L height. Samples were compressed at 3 mm/sec to 5 mm of height.

2.7. Sensory analysis

The sensory evaluation of the final products was conducted using affective test methods (Lawless & Heymann, 2010). One common approach to assess consumer preference for food products is to employ a rating scale that measures the degree of liking or disliking. In this study, the traditional nine-point hedonic scale, which is widely used for sensory evaluation (Lawless & Heymann, 2010), was applied. Each test sample was presented on a white plate and labeled with a three-digit random code. During the evaluation, each panelist received the coded samples, a cup of water for palate cleansing, and an answer sheet. Panelists rinsed their mouths with water after each sample and rated the color, flavor,

and texture of the products. The experiment was arranged into four treatments (NT), with the spice ratios added to 1 kg of raw material as follows:

- NT1: 4% sugar; 0.5% MSG (monosodium glutamate); 0.7% garlic powder; 1% seaweed; 0.25% pepper powder.

- NT2: 4% sugar; 0.5% MSG; 0.7% garlic powder; 2% seaweed; 0.25% pepper powder.

- NT3: 4% sugar; 0.5% MSG; 0.7% garlic powder; 2% seaweed; 0.5% chili powder; 1% chili sauce.

- NT4: 4% sugar; 0.5% MSG; 0.7% garlic powder; 1% seaweed; 0.5% chili powder; 1% chili sauce.

2.8. Statistical analysis

All analytical measurements were performed in triplicates and the results are reported as mean value $\pm$ standard deviation. Data were analysed by one-way analysis of variance (ANOVA) and least significant difference (LSD) at the significance level of $P < 0.05$ using IBM SPSS software version 22.

3. Results and Discussion

3.1. Proximate composition

The proximate composition analysis of the red-eye squid, *Sthenoteuthis oualaniensis*, revealed that the primary constituents of its fresh mass were water (80.75%) and protein (17.57%), with minor fractions of lipid (1.19%) and ash (1.07%). A comparative evaluation with the common cuttlefish, *Sepia officinalis*, highlights key species-specific variations in biochemical profile. While both species exhibited comparable moisture content (*S. officinalis*: 80.85%), the most

notable difference was observed in the major energy components. *S. officinalis* contained a significantly higher Protein content (21%) than *S. oualaniensis* (17.57%). Conversely, *S. oualaniensis* possessed a markedly higher concentration of lipid (1.19%), which was approximately 4.4 times greater than the 0.27% recorded for *S. officinalis*.

The remaining ash content was similar between the two species (1.07% for *S. oualaniensis* vs. 1.2% for *S. officinalis*). These findings underscore that while both species are high-protein, low-fat marine resources, *S. oualaniensis* represents a relatively richer source of lipid compared to *S. officinalis*.

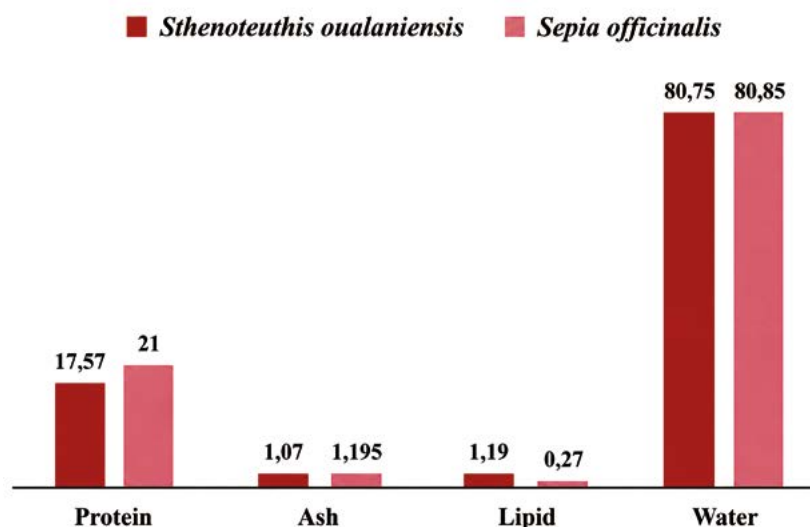


Figure 1. Proximate analysis of *Sthenoteuthis oualaniensis* in comparison to *Sepia officinalis*.

3.2. Effects of salt on quality of sausage

3.2.1. Color of squid sausage

The whiteness of gels prepared with different salt concentrations is presented in Table 1. The whiteness values of treatments NT1 (0.5% salt) and NT2 (1% salt) were not significantly different from each other ($P > 0.05$). However, both NT1 and NT2 exhibited significantly lower whiteness compared to NT3 (1.5% salt) and NT4 (2% salt) ($P < 0.05$). This indicates that increasing the salt concentration above 1% led to a noticeable improvement in the whiteness of the gels. The higher whiteness observed in NT3 and NT4 may be associated with enhanced protein solubilization and gel network formation

at higher ionic strengths, which promote light scattering and thus increase the perceived whiteness.

Whiteness has been reported to be influenced by the degree of protein denaturation and water-holding capacity (WHC) of the gel (Shie & Park, 1999). Although the addition of salt altered the whiteness of the samples, the difference was difficult to distinguish by visual observation. This trend is consistent with findings by Montero et al. (1997), who suggested that the highest whiteness values occur in heat-induced gels due to protein denaturation and aggregation. Overall, salt concentration up to 2% slightly enhanced the whiteness of squid gels, but the effect was not pronounced beyond 1.5%.

Table 1. Results of whiteness of squid gels at different salt concentrations

Treatment	NT1	NT2	NT3	NT4
	0.5% salt	1% salt	1.5% salt	2% salt
Whiteness	67.93 ± 0.27 ^A	68.8 ± 0.37 ^A	71.36 ± 0.95 ^B	71.47 ± 0.6 ^B

Different letters (A, B, C) in the same row indicate significant differences ($P < 0.05$). NT1: treatment 1; NT2: treatment 2; NT3: treatment 3; NT4: treatment 4.

3.2.2. Gel forming ability of squid sausage

Table 2. Folding score of squid gels at different salt concentrations

Treatment	NT1	NT2	NT3	NT4
	0.5% salt	1% salt	1.5% salt	2% salt
Score	2.33 ± 0.58 ^A	3.33 ± 0.58 ^A	4.33 ± 0.58 ^{BA}	4.67 ± 0.58 ^{CA}

Different letters (A, B, C) in the same row indicate significant differences ($P < 0.05$). NT1: treatment 1; NT2: treatment 2; NT3: treatment 3; NT4: treatment 4.

The folding score of squid gels at different salt concentrations is presented in Table 2. The gel prepared with 2% salt (NT4) exhibited the highest folding score among all treatments, while the lowest score was observed in the sample containing 0.5% salt (NT1). The folding scores of NT3 (1.5% salt) and NT4 (2% salt) were significantly higher than those of NT1 and NT2 ($P < 0.05$), indicating that increasing salt concentration markedly enhanced the gel-forming ability of the product. The improvement in gel strength with higher salt concentrations can be attributed to the increased solubilization of myofibrillar proteins, particularly myosin, under elevated ionic strength. The presence of Cl⁻ ions disrupt electrostatic interactions among muscle proteins, promoting protein unfolding and enabling greater exposure of reactive sites for intermolecular bonding during heating. These interactions facilitate the formation of a more cohesive and elastic gel matrix. Furthermore, salt enhances protein-protein interactions by

stabilizing ionic bonds between myosin filaments and improving water-holding capacity (Offer & Knight, 1988).

These results indicated that salt addition up to 2% significantly improved the folding score, reflecting better gel elasticity and structural integrity of squid gels prepared under the same gelling conditions.

3.2.3. Drip loss of squid sausage

The drip loss of squid gels prepared with different salt concentrations is shown in Table 3. There was no significant difference in drip loss among NT1 (0.5% salt), NT2 (1% salt), and NT3 (1.5% salt) ($P > 0.05$). However, NT4 (2% salt) exhibited a significantly lower drip loss compared with the other treatments ($P < 0.05$). This finding indicates that increasing salt concentration to 2% markedly improved the water-holding capacity (WHC) of the squid gels.

Table 3. Drip loss of squid gels at different salt concentrations

Treatment	NT1	NT2	NT3	NT4
	0.5% salt	1% salt	1.5% salt	2% salt
Drip loss	40.17 ± 3.82 ^A	38.17 ± 0.76 ^A	40.33 ± 2.52 ^A	26.33 ± 1.04 ^B

Different letters (A, B) in the same row indicate significant differences ($P < 0.05$). NT1: treatment 1; NT2: treatment 2; NT3: treatment 3; NT4: treatment 4.

The reduction in drip loss at higher salt levels can be attributed to enhanced solubilization and swelling of myofibrillar proteins, particularly myosin, under increased ionic strength (Gordon & Barbut, 1992). Salt promotes protein unfolding and exposes reactive sites for intermolecular cross-linking during the heating process. These structural changes strengthen the gel network, allowing it to better retain water within the protein matrix. Consequently, higher salt concentrations contribute to reduced exudate formation and improved gel stability during processing and storage.

3.2.4. Protein solubility of squid sausage

The protein solubility of squid gels at different salt concentrations is presented in Figure 2. Protein solubility decreased significantly as the

salt concentration increased ($P < 0.05$). The NT1 (0.5% salt) exhibited the highest solubility (89.87%), whereas NT4 (2% salt) showed the lowest value (70.1%). The reduction in protein solubility with increasing salt content is indicative of protein denaturation and aggregation, particularly of myofibrillar proteins such as myosin, which tend to precipitate following denaturation (Ramírez et al., 2000). The elevated ionic strength at higher salt concentrations likely promotes protein-protein interactions and reduces protein solubility, contributing to the formation of a stronger and more cohesive gel network.

The results suggest that increasing the salt concentration decreases the solubility of squid proteins, reflecting enhanced protein aggregation and gel formation.

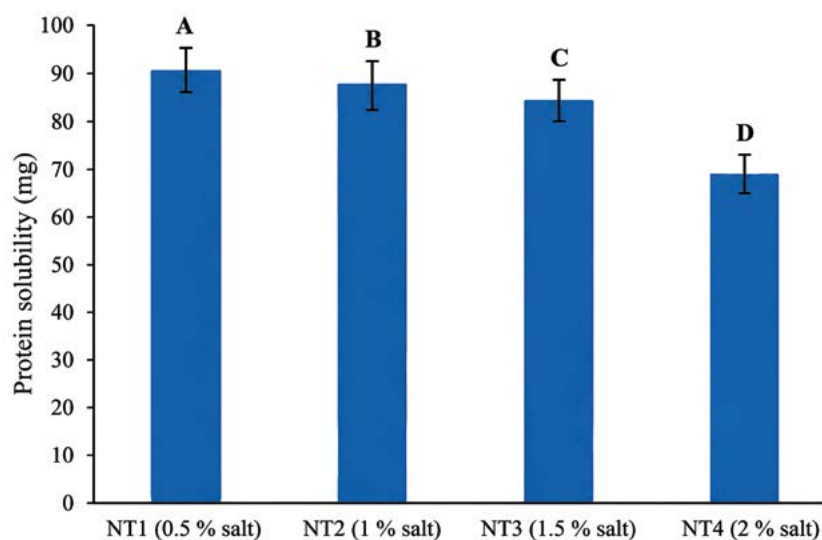


Figure 2. Protein solubility of squid sausage at different salt concentrations.

Different letters (A, B, C, D) indicate significant differences ($P < 0.05$).

3.2.5. Texture profile analysis (TPA) of squid sausage

The texture profile analysis (TPA) of squid gels at different salt concentrations was presented in Figure 3. The hardness of gels increased significantly with increasing salt concentration, with NT4 (2% salt) exhibiting the highest hardness among all treatments ($P < 0.05$). Gels containing 0.5, 1, and 1.5% salt showed lower and statistically similar hardness values, indicating that higher salt levels enhance gel firmness.

The springiness of gels was not significantly affected by salt concentration ($P > 0.05$), although a slight increase was observed in NT3 (1.5%) and NT4 (2%), suggesting that elasticity was largely maintained across treatments. Cohesiveness, however, increased progressively with salt concentration, with NT3 and NT4 showing significantly higher values than NT1 and NT2 ($P < 0.05$), reflecting a more compact and stable gel network at higher ionic strengths.

Gumminess, calculated as the product of hardness and cohesiveness, decreased with increasing salt concentration. NT1 (0.5% salt) exhibited the highest gumminess (10.06 N), while NT4 had the lowest value (34.8 N), indicating that higher salt levels produced gels that were firmer but less sticky. Chewiness, representing the energy required to masticate the gels,

increased significantly with salt addition. NT4 (2% salt) exhibited the highest chewiness (221.18 mJ), whereas NT1 had the lowest (60.8 mJ), highlighting that increased salt concentration enhances the structural integrity and solidity of the gels ($P < 0.05$).

The observed changes in textural properties can be attributed to the effect of salt on myofibrillar proteins. During emulsification, salt facilitates solubilization of myosin and promotes the interaction between actin and myosin filaments, enhancing gel network formation and water retention (Nguyen, 2006). Consequently, higher salt concentrations result in gels that are harder, more cohesive, and chewier, while maintaining elasticity. In general, the addition of salt markedly altered the texture of squid gels, producing samples with improved gel strength and structural integrity as the salt concentration increased.

The 2% salt concentration (NT4) was determined to be the optimal treatment, as it resulted in the highest whiteness, the maximum folding score (reflecting superior gel-forming ability and elasticity), and the lowest drip loss (indicating significantly enhanced water-holding capacity), thus promoting the formation of the most stable, cohesive, and texturally firm gel structure.

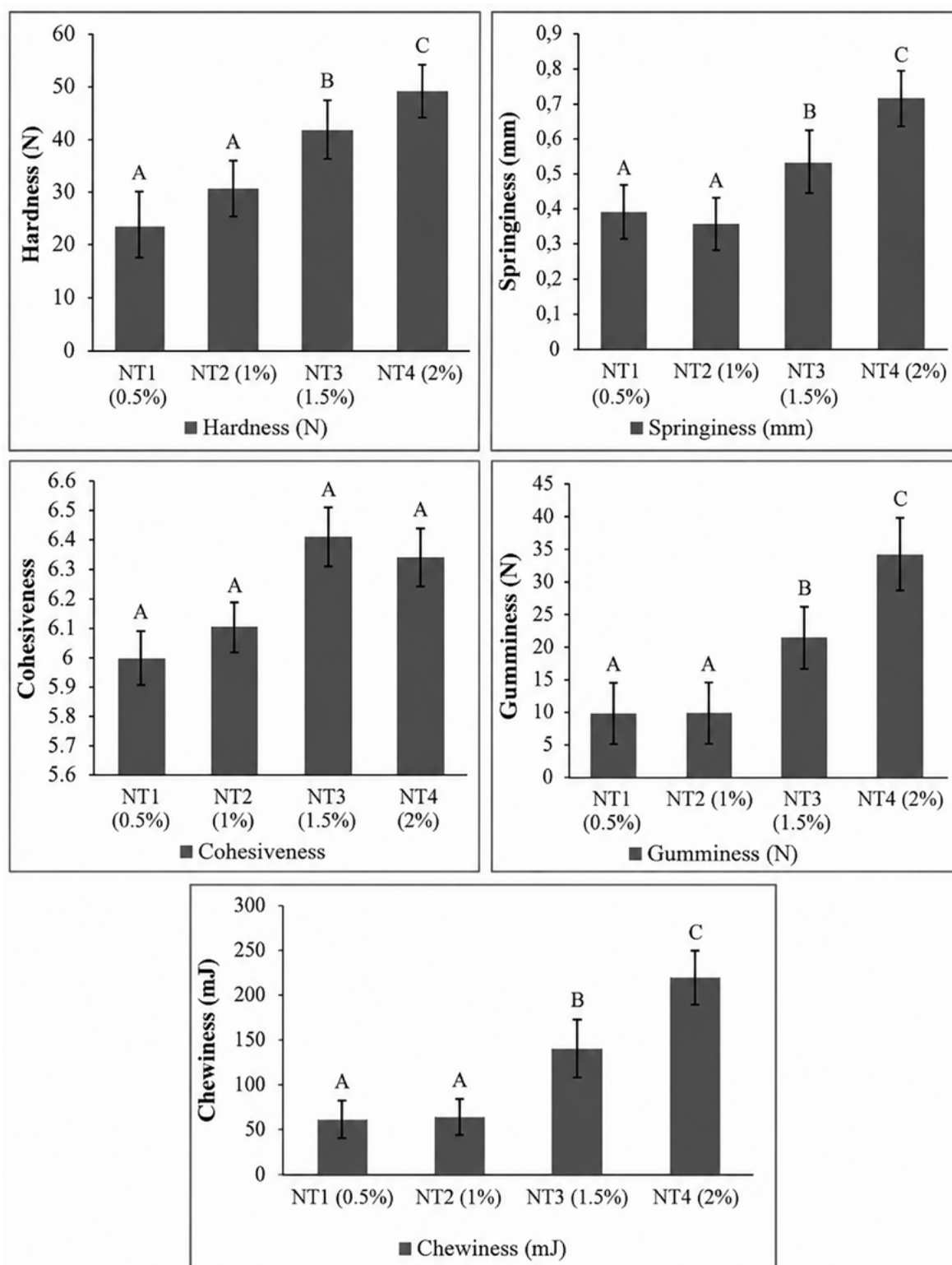


Figure 3. Changes in hardness, springiness, cohesiveness and chewiness of squid gels. Different letters (A, B, C) indicate significant differences ($P < 0.05$).

3.3. Effects of seaweed on quality of sausage

3.3.1. Effect of seaweed addition on the color of squid sausage

Table 4. Results of whiteness of squid gels

Treatment	NT1	NT2	NT3	NT4
	0% seaweed	1% seaweed	1.5% seaweed	2% seaweed
Whiteness	71.9 ± 0.74 ^A	70.2 ± 0.01 ^B	65.63 ± 0.13 ^C	54.22 ± 0.12 ^D

Different letters (A, B, C, D) in the same row indicate significant differences ($P < 0.05$). NT1: treatment 1; NT2: treatment 2; NT3: treatment 3; NT4: treatment 4.

The effect of seaweed addition on the color of squid gels was presented in Table 4. Whiteness decreased significantly as the proportion of seaweed increased ($P < 0.05$). NT1 (0% seaweed) exhibited the highest whiteness (71.9), whereas NT4 (2% seaweed) showed the lowest value (54.22), indicating a clear inverse relationship between seaweed content and gel whiteness.

The reduction in whiteness can be attributed to the natural green pigments present in seaweed, which impart color to the gels and reduce light reflectance. As a result, higher seaweed levels progressively darken the gel and decrease its perceived whiteness. These changes are noticeable by visual observation and are likely to influence the sensory perception and overall appearance of the final product.

These results indicate that increasing seaweed concentration significantly decreases the whiteness of squid gels, highlighting the impact of added

ingredients on the visual quality of the product.

3.3.2. Effect of seaweed addition on gel strength

The folding score of squid gels at different seaweed concentrations is presented in Table 5. No significant differences were observed in folding point among the treatments (NT1 - NT4) ($P > 0.05$), indicating that the addition of seaweed up to 2% did not markedly affect this textural parameter.

Despite the similarity in folding score, the experimental results suggest that the incorporation of seaweed contributes to a firmer and more resilient gel network. This effect may be attributed to the interaction between seaweed polysaccharides and myofibrillar proteins, which can enhance gel cohesion and water retention, improving the overall structural stability of the squid gels.

Table 5. Results of point of squid gels

Treatment	NT1	NT2	NT3	NT4
	0% seaweed	1% seaweed	1.5% seaweed	2% seaweed
Point	4.67 ± 0.58	4.67 ± 0.58	5.00 ± 0.00	5.00 ± 0.00

NT1: treatment 1; NT2: treatment 2; NT3: treatment 3; NT4: treatment 4.

3.3.3. Effect of seaweed addition on texture profile

Table 6. Texture profile analysis of squid gels at different levels of seaweed

Treatment	NT1	NT2	NT3	NT4
	0% seaweed	1% seaweed	1.5% seaweed	2% seaweed
Hardness (N)	22.67 ± 1.08 ^A	22.3 ± 01.26 ^A	35.17 ± 0.87 ^B	45.39 ± 1.22 ^C
Springiness (mm)	4.66 ± 0.05 ^A	4.98 ± 01.49 ^A	4.42 ± 0.04 ^{BA}	4.41 ± 0.06 ^A
Cohesiveness	0.8 ± 0.02 ^A	0.58 ± 0.1 ^{BA}	0.72 ± 0.01 ^A	0.7 ± 0.02 ^A
Gumminess (N)	17.73 ± 0.81 ^A	13.6 ± 2.92 ^A	25.21 ± 0.4 ^B	31.71 ± 1.44 ^C
Chewiness (mJ)	82.58 ± 4.61 ^A	64.99 ± 3.94 ^B	111.5 ± 2.28 ^C	139.72 ± 6.36 ^D

Different letters (A, B, C) in the same row indicate significant differences ($P < 0.05$). NT1: treatment 1; NT2: treatment 2; NT3: treatment 3; NT4: treatment 4.

The results of the texture profile analysis (TPA) of squid gels with different levels of seaweed were presented in Table 6. The addition of 0.5% seaweed (NT2) did not significantly affect the hardness of the squid sausage compared to the control (NT1) ($P > 0.05$), while higher concentrations of 1.5% (NT3) and 2% (NT4) significantly increased hardness ($P < 0.05$), with NT4 exhibiting the highest hardness of 45.39 N. These results indicate that the incorporation of seaweed contributes to a firmer gel structure. Springiness and cohesiveness showed no significant differences among treatments ($P > 0.05$), although NT2 had the highest springiness (4.98 mm) and NT4 the lowest (4.41 mm), suggesting that low levels of seaweed slightly improve elasticity, whereas higher levels may reduce it. Cohesiveness was highest in NT3 (0.72), but the overall change due to seaweed addition was minimal. Gumminess increased with seaweed concentration, with NT4 showing the highest value (31.71 N), indicating that seaweed enhances the firmness and chewable quality of the product. Chewiness differed significantly

among treatments ($P < 0.05$); it decreased in NT2 compared to the control but increased markedly in NT3 and NT4, reaching a maximum of 139.72 mJ in NT4. Overall, seaweed addition had a significant effect on hardness, gumminess, and chewiness, while springiness and cohesiveness remained largely unchanged, demonstrating that seaweed can improve the textural properties of squid sausages, resulting in a firmer and more resilient product.

The 1% seaweed concentration (NT2) was selected as the optimal formulation, as it maintained high gel strength (Folding Score equivalent to other treatments) while yielding the most visually appealing color score (6.41) among all treatments.

The results of the sensory evaluation of the sausage products were presented in Table 7. There were no significant differences in flavor and color scores among the treatments ($P > 0.05$), although NT2 received the highest average color score of 6.41, while NT4 had the lowest at 5.96. The NT2 was noted by many panelists

for having the most visually appealing color. In terms of flavor, all treatments were similarly rated, with NT3 slightly higher at 6.00, indicating that seaweed addition did not markedly affect the overall flavor perception. However, significant differences were observed in the structure scores among treatments ($P < 0.05$), with NT4 achieving the highest rating of 6.55, reflecting a firmer and more acceptable texture.

3.4. Effect of seaweed addition on sensory quality

Table 7. Results on sensory test of sausage product

Treatment	NT1	NT2	NT3	NT4
Color	5.98 ± 1.25 ^A	6.41 ± 1.46 ^A	6.13 ± 1.28 ^A	5.96 ± 1.17 ^A
Flavour	5.96 ± 1.5 ^A	5.87 ± 1.23 ^A	6.00 ± 1.31 ^A	5.95 ± 1.29 ^A
Structure	5.47 ± 1.16 ^A	5.98 ± 1.22 ^{BC}	6.27 ± 1.05 ^C	6.55 ± 1.04 ^{DC}

Different letters (A, B, C, D) in the same row indicate significant differences ($P < 0.05$). NT1: treatment 1; NT2: treatment 2; NT3: treatment 3; NT4: treatment 4.

4. Conclusions

This study shows that the functional quality of squid sausage made from *Sthenoteuthis oualaniensis* is influenced by the combined effects of salt concentration and seaweed content. Increasing salt levels improved the structural properties of the gel matrix, with the 2% salt treatment providing the most desirable characteristics, including markedly enhanced gel stability and reduced moisture loss. Higher level of seaweed increased gel hardness, however, they also reduced product whiteness. The 1% seaweed level was identified as the most appropriate balance, providing high textural strength while maintaining a more desirable appearance, as supported by the sensory evaluations. The optimized seasoning formulation with 2% salt, 4% sugar, 0.5% MSG, 0.7% garlic powder, 1% seaweed, 0.5% chili powder, and 1% chili sauce,

contributed to enhancing the sensory perception of the product.

Overall, the study demonstrates that optimizing salt concentration, seaweed content and seasoning components can significantly enhance the quality and acceptability of squid sausage produced from *Sthenoteuthis oualaniensis*, thereby supporting its potential for developing value added products.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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