



Physicochemical characteristics of squid amplang prepared using two-step vacuum frying at various dough resting times

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ABSTRACT

Amplang crackers are traditional snacks from Eastern Borneo, commonly made from fish or other marine products with high protein content. This study focuses on developing squid amplang as a product diversification using a two-step vacuum frying method to produce low-moisture amplang. The research aimed to determine the effect of dough resting time on the physicochemical characteristics of squid amplang crackers and to identify the best treatment based on quality parameters. A Completely Randomized Design (CRD) without factorial treatment was applied, with various dough resting times as treatments. The observed parameters included moisture content, swellability, hardness, and protein content. The results showed that dough resting time did not significantly affect the physicochemical properties of squid amplang crackers ($p > 0.05$). The tested products had moisture content ranging from 0.98–1.65% (wb), expansion ratio of 514.01–710.21%, hardness between 24.57–33.49 N, and protein content from 6.06–12.16%. All characteristics met the Indonesian National Standard (SNI 8272:2016) for fish crackers. The best squid amplang crackers were obtained at a 6-hour resting time, resulting in 0.98% (wb) moisture content, 514.01% swellability, 30.71 N hardness, and 12.16% protein content. The selection was based on low moisture, high swellability, low hardness, and high protein. These findings indicate that dough resting time has minimal influence, suggesting that resting time treatment can be omitted in the production process of squid amplang crackers without reducing quality.

Keywords: amplang; squid; dough resting time; two-step vacuum frying

INTRODUCTION

Squid represents one of Indonesia's high-value marine resources with substantial nutritional benefits (Torrinha

et al., 2014; Zamroni et al., 2024). National production reached 193,583 tons in 2019, increasing to 234,681 tons by 2023 (Kementerian Kelautan dan Perikanan, 2025). Despite this

abundance, the utilization of fresh squid for direct consumption in Indonesia remains hindered by cultural preferences and a lack of processed product diversity. Furthermore, squid's high susceptibility to Gram-negative bacterial contamination leads to rapid post-harvest spoilage (Tomac et al., 2014; Xuan et al., 2025). One promising application is the production of amplang, a traditional fish-based cracker.

Amplang is characterized by its round or oval shape, yellowish-brown color, crisp texture, and an expansion ratio of two to three times its original dough size (Devi et al., 2019). While the amplang industry is growing rapidly, most small-scale producers still rely on conventional deep-frying methods. Preliminary observations indicate that conventional frying of squid amplang for 35 minutes results in a moisture content of approximately 15%, which leaves the core of the product insufficiently dried (Wang et al., 2021). Conversely, vacuum frying alone often produces an overly hard texture that fails to expand optimally. Consequently, a two-step frying method, combining conventional and vacuum frying, is proposed as an alternative to enhance product quality (Ravli et al., 2013).

The quality of crackers is primarily determined by moisture content, expansion ratio, and hardness. These parameters are closely interrelated, as the moisture level during the frying process dictates the internal steam pressure required for starch gelatinization and subsequent pore formation, which determines the final

crunchiness (Ren et al., 2021). Processing optimization significantly affects physical attributes across food matrices (Rizaldi et al., 2025). Dough resting time facilitates uniform moisture distribution and starch hydration, enhancing expansion and texture (Liu et al., 2021). Limited studies exist on squid amplang as mackerel alternative despite abundant production. Therefore, this study aims to determine the effect and optimal conditions of dough resting time (0, 2, 4, and 6 h) with two-stage frying on the characteristics of squid amplang..

METHODOLOGY

1. Equipment and Materials

The equipment used in this study included a vacuum fryer, blender, analytical balance, moisture balance (MOC-120), penetrometer, centrifuge (model LS-04S), visible spectrophotometer (Model 721), digital microscope (G1200 type), sigmat, mixing bowls, and glassware.

The main ingredients were squid and tapioca flour. The selected squid were fresh, non-slippery, undamaged, with intact skin, bright reddish-white color, free from fishy odor, and a minimum body length of 18 cm. Additional ingredients included cooking oil (Bimoli brand), eggs, flavor enhancer, ground pepper, sugar, salt, garlic powder, acetate buffer (pH 5), Biuret reagent, and distilled water.

2. Research Procedure

Raw Material Preparation

Raw materials were weighed according to the specified

formulation. Each dough batch consisted of minced and cleaned squid (30.24%), tapioca flour (52.04%), eggs (12.39%), sugar (1.86%), salt (1.24%), ground pepper (0.62%), flavor enhancer (0.62%), and garlic powder (0.99%).

Mixing Process

Eggs were whisked until foamy, then minced squid meat was added and mixed evenly. Subsequently, sugar, salt, pepper, flavor enhancer, and garlic powder were added according to the predetermined formulation and stirred until homogeneous. Tapioca flour was then gradually incorporated while kneading until the dough became smooth and non-sticky.

Dough Molding Process

The finished dough was shaped using a stainless-steel mold to obtain amplang dough pieces of uniform size and shape.

Dough Resting Time

The molded squid amplang dough was placed on trays and labeled according to the treatment. Samples were subjected to different resting times of 0, 2, 4, and 6 hours prior to frying. The resting was conducted at room temperature under uncovered conditions.

Frying Process

The first frying stage (conventional frying) was conducted using the deep-frying method to allow dough expansion at a temperature of 120 °C. When air bubbles started to diminish, the second frying stage

(vacuum frying) was performed at 115 °C to reduce the moisture content until air bubbling inside the vacuum chamber decreased significantly.

Experimental Design

The experiment employed a Completely Randomized Design (CRD) with a single factor and three replications for per treatment. The collected data were analyzed using one-way ANOVA (Analysis of Variance) with a 5% significance level in SPSS 25. Prior to ANOVA, data normality and homogeneity tests were conducted. If significant differences were found among treatments, Duncan's Multiple Range Test (DMRT) was applied at a 5% significance level.

Analytical Methods

The chemical characteristics of squid amplang were determined from moisture content (AOAC, 2005) using a moisture balance (MOC-120H) and protein content (AOAC, 2005) using the Biuret method with a visible spectrophotometer. The physical characteristics analyzed included expansion ratio (Akbar et al., 2018) and hardness using a penetrometer (Bourne, 2002).

Determination of the Best Treatment

After all analyses were completed, the best treatment was determined using a scoring system with a scale of 1–4. This determination was not based on the ANOVA results. The highest score was assigned to the parameter exhibiting the most desirable characteristic. The total

score for each treatment was then summed to identify the optimal resting time that yielded the best amplang quality. In cases where total scores were equal, the treatment with the lowest moisture content was selected as superior.

The priority criteria used for evaluation were as follows:

1. Lowest moisture content.
2. Highest expansion ratio.
3. Lowest hardness value.
4. Highest protein content.

RESULTS AND DISCUSSION

1. Dough Moisture Content Analysis

Moisture content serves as a key characteristic in amplang production to ensure desirable texture, expansion, and extended shelf life. **Figure 1** shows the dough moisture content after varying resting times. As resting time increased, dough moisture content decreased, likely due to evaporation of free water into the environment. The lowest moisture

content (33.20% wb) occurred at 6 hours, while the highest (35.38% wb) was at 0 hours.

Moisture reduction during storage results from air flow facilitating the escape of heat, gases, and water (Juwitaningtyas & Nurul Khairi, 2018). Environmental humidity also influences evaporation; lower humidity enhances water vapor transfer, promoting drying (Fachruri et al., 2019). This study, conducted in Malang with low average humidity, supported such reductions. ANOVA at 5% significance showed no significant effect of resting time on dough moisture ($p > 0.05$), attributed to minimal evaporation over 6 hours. Resting time affects dough elasticity and porosity via rheological changes (Jha et al., 2017), though some studies report non-significant impacts. Findings align with Liu et al. (2021), where resting time strengthens water binding to starch and protein via hydrogen bonds, stabilizing distribution after 30 minutes.

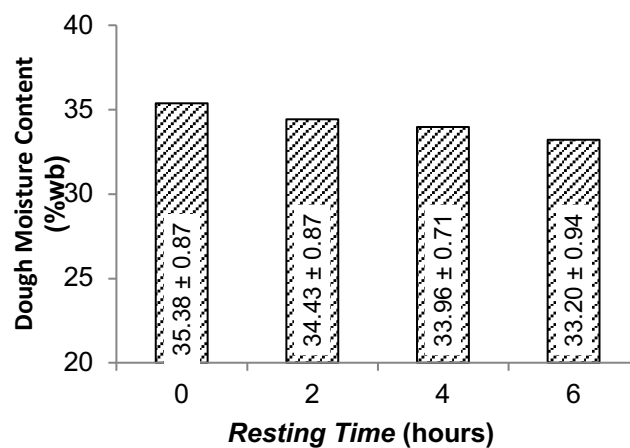


Figure 1. Moisture content of squid amplang dough

2. Amplang Moisture Content Analysis

Final amplang moisture influences shelf life during storage. **Figure 2** illustrates amplang moisture across resting times, decreasing with longer resting due to lower initial dough moisture. The lowest (0.98% wb) was at 6 hours, highest (1.65% wb) at 0 hours.

Overall values (0.98 ± 0.20 to 1.65 ± 0.74 % wb) were lower than Mario et al. (2015) (6.85–8.32% for catfish/tilapia amplang) and met SNI 7762:2013 ($\leq 4\%$) (BSN, 2013). Reductions stem from frying heat and duration, evaporating water (Susanna et al., 2018).

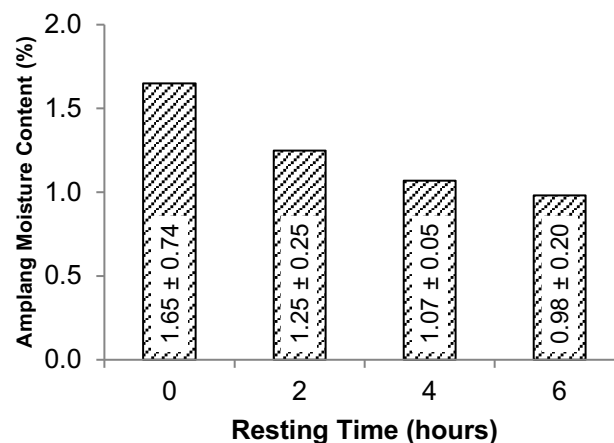


Figure 2. Moisture content of squid amplang.

Figure 3 confirms higher initial dough moisture yields higher final amplang moisture, consistent with Norhasanah et al. (2020). ANOVA showed no significant effect ($p > 0.05$), as minor dough moisture differences (0.67% wb max) limited

evaporation impact. The two-step frying (conventional then vacuum) achieved low moisture by vacuum extraction preventing pore closure (Akbar et al., 2018), enhancing shelf life by inhibiting microbes (Kresnasari, 2021) and improving crispness (Rachim et al., 2019).

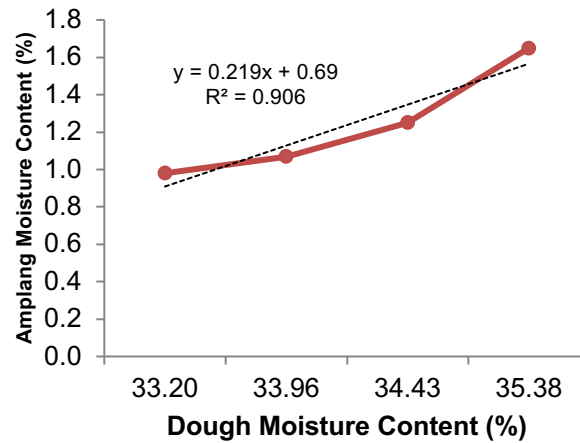


Figure 3. Relationship between dough and amplang moisture content

3. Expansion Ratio Analysis

Expansion ratio determines cracker quality via crisp texture influence.

Figure 4 shows highest expansion

(710.21%) at 0 hours, lowest (514.01%) at 6 hours. Values (514.01–710.21%) exceeded Maisur (2019) (max 462.82% for snakehead fish amplang).

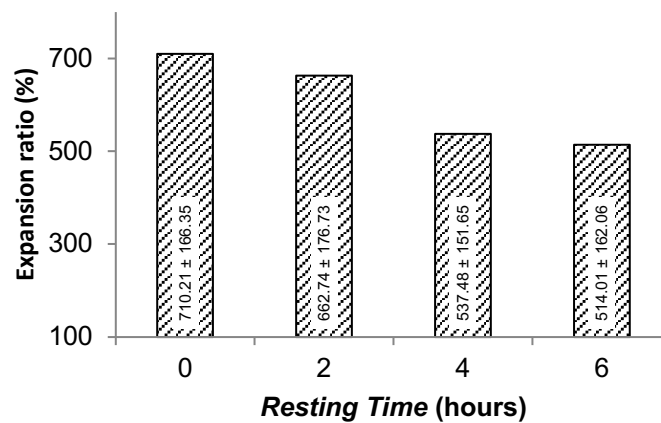


Figure 4. Expansion ratio of squid amplang.

Decline with resting time links to lower initial moisture (35.38% wb at 0 hours), reducing steam pressure for expansion (Qosthari & Anna, 2016). Higher moisture generates more vapor thrust, boosting volume (Susilowati & Dewati, 2024). ANOVA indicated no significant effect ($p > 0.05$), influenced by high tapioca

flour (52.04%), which enhances expansion via amylopectin ((Armin et al., 2020; Mustaring et al., 2020). As non-dried crackers, homogenization and amylopectin promote porous, crisp structures (Sari et al., 2021; Zai et al., 2021).

4. Hardness Analysis

Hardness measures maximum force for molar compression until fracture (Chandra & Shamasundar, 2015;

Polat et al., 2020). **Figure 5** reveals fluctuating hardness: lowest (24.57 N) at 2 hours, highest (33.49 N) at 4 hours, lower than Rosiani et al. (2015) (22.44–34.53 N).

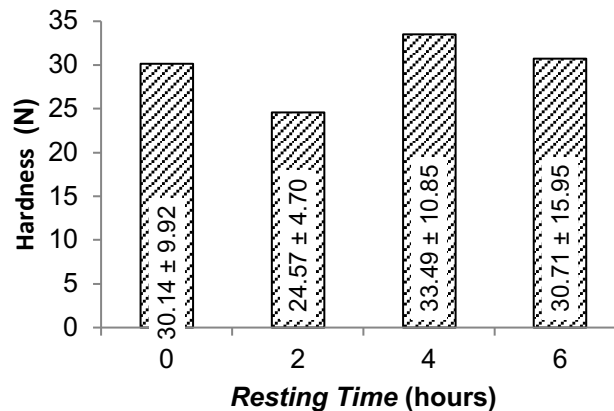


Figure 5. Hardness of squid amplang

Fluctuations arise from moisture filling pores (Dhamayanti et al., 2018) and poor expansion yielding small pores (Zikirah et al., 2021). Lower moisture should reduce porosity and crispness, but microscopy (**Figure 6**) shows P2 (2 hours) with large, abundant pores versus dense P3 (4 hours) pores, linking expansion to lower breakage force (Pakpahan & Nelinda, 2019; Sumbodo et al., 2019). ANOVA showed no significance ($p > 0.05$). Tapioca's high amylopectin (72.61–87.71%; Fajiah et al., 2020) forms branched chains aiding porous, crisp textures via

gelatinization (Seyfi Cankal et al., 2025).

5. Protein Content Analysis

Proteins comprise amino acid chains linked by peptide bonds, with nitrogen ~16% (Dhamayanti et al., 2018). **Figure 7** shows protein with resting time: highest (12.16%) at 6 hours, lowest (6.06%) at 0 hours, higher than Mario et al. (2015) (3.29% patin amplang) and meeting SNI $\geq 7\%$. Longer resting shortened total frying (**Table 1**), reducing denaturation (Chen et al., 2024).

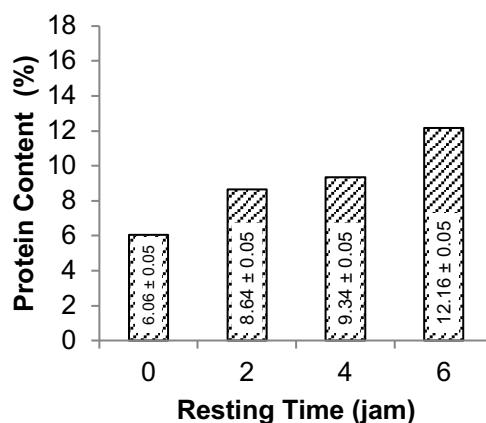


Figure 7. Protein Content of squid amplang

ANOVA showed no significance ($p > 0.05$). Lower frying preserves protein; oil absorption dilutes it at high heat (Yusuf & Musali, 2021). Squid (14.65%

protein; Santoso et al., 2008) yields less than mackerel (28%), plus high tapioca lowers content (Muflih et al., 2018; Priyanto et al., 2020).

Table 1. Frying time

| <i>Resting Time</i> (h) | <i>Conventional frying time</i> (min.) | <i>Vacuum frying time</i> (min.) | <i>Total frying time</i> (min.) |
|-------------------------|--|----------------------------------|---------------------------------|
| 0 | 16.67 | 21.83 | 38.5 |
| 2 | 17.33 | 19.00 | 36.3 |
| 4 | 16.00 | 19.00 | 35.0 |
| 6 | 13.00 | 19.50 | 32.5 |

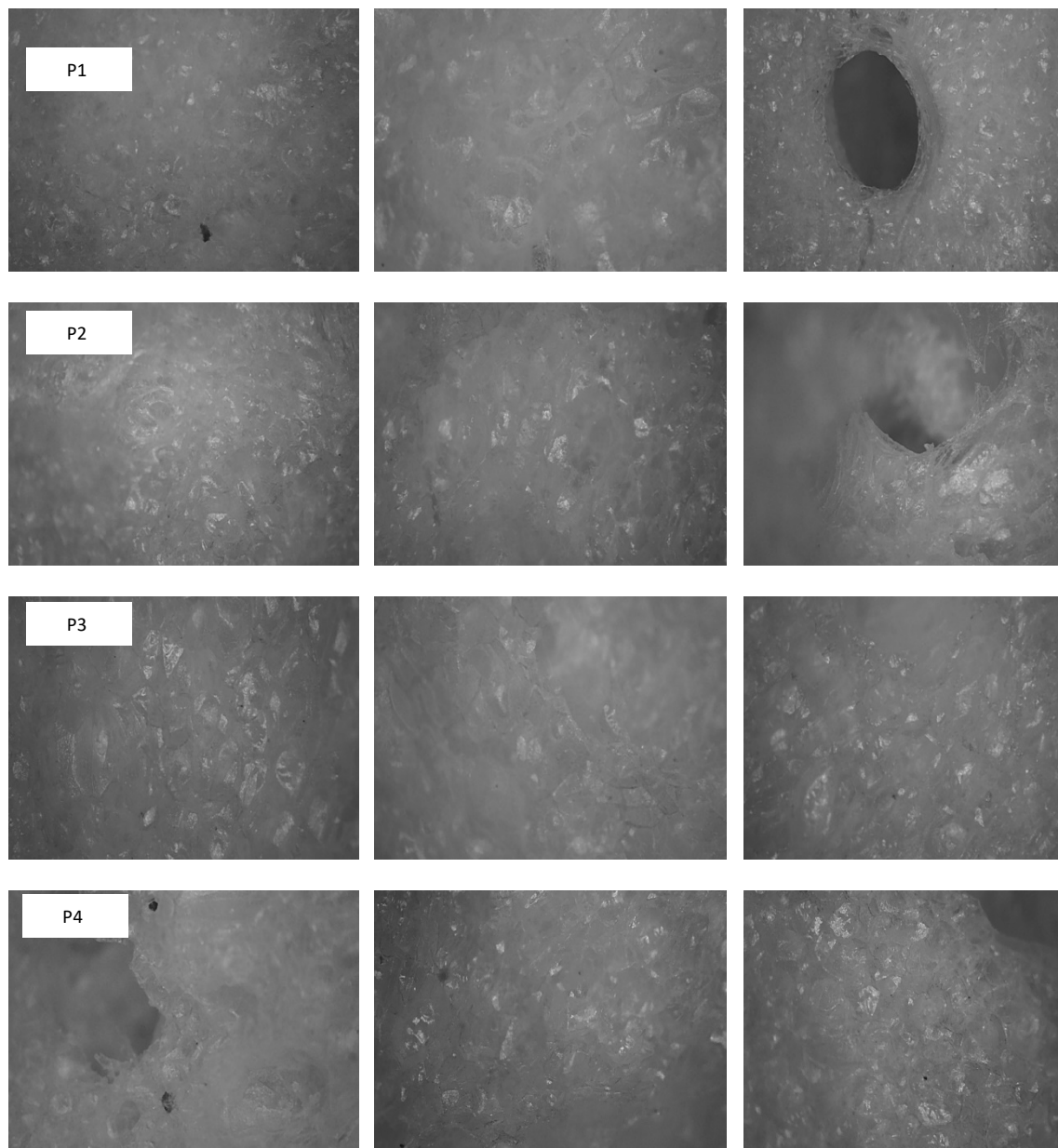


Figure 6. Microscopy images of squid amplang cross-sections (P1: 0 h; P2: 2 h; P3: 4 h; P4: 6 h)

6. Best Treatment Determination

Scoring (1–4) identified optimal traits: moisture/protein per SNI 7762:2013 ($\leq 4\%$, $\geq 7\%$); expansion (highest), hardness (lowest) per prior studies.

Table 2 shows ties at 22 (2 and 6 hours); lowest moisture (0.98% wb) selects 6 hours as best. Resting time thus minimally impacts industrial/household amplang quality.

Table 2. Best treatment

| Characteristics | Resting Time | | | |
|--------------------------------------|---------------|---------------|---------------|---------------|
| | 0 h | 2 h | 4 h | 6 h |
| Moisture content of amplang (%) (wb) | 1.65 (1) | 1.25 (2) | 1.07 (3) | 0.98 (4) |
| Expansion ratio (%) | 710.21 (4) | 662.74 (3) | 537.48 (2) | 514.01 (1) |
| Hardness (N) | 30.14 (3) | 24.57 (4) | 33.49 (1) | 30.71 (2) |
| Protein content (%) | 6.06 (1) | 8.64 (2) | 9.34 (3) | 12.16 (4) |
| Total score | 18 | 22 | 18 | 22 |

CONCLUSION

Resting time variations in squid amplang production using two-step frying (conventional followed by vacuum) showed no significant effects on physicochemical characteristics, moisture content, expansion ratio, hardness, and protein content. Produced amplang met SNI 8272:2016 standards for fish/shrimp/mollusk crackers. The optimal treatment occurred at 6 hours resting time (moisture 0.98% wb, expansion 514.01%, hardness 30.71 N, protein 12.16%), selected via scoring prioritizing lowest moisture, highest expansion, lowest hardness, and highest protein.

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