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Effect of Packaging Type and Storage Time on the Quality Characteristics of Chicken Nugget Substituted with Jack Bean (*Canavalia ensiformis* L.) Tempeh Flour

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Abstract

Chicken nuggets with jack bean tempeh flour substitution are a type of perishable food, thus having a short shelf life. The shelf life of chicken nuggets with jack bean tempeh flour substitution and its quality were affected by the storage conditions. This study aimed to determine the effect of packaging type and storage time during 20 days of cold storage under vacuum packaging condition on the quality characteristics of chicken nuggets with jack bean tempeh flour substitution. The research design consisted of two factors, the first factor was packaging type (nylon/polyethylene (PE), nylon/polyethylene (PE)/polyamide (PA), and polyethylene (PE)/polyamide (PA)) and the second factor was storage time (0 day, 5 days, 10 days, 15 days, and 20 days). The results showed that the packaging type and storage time significantly affected the quality characteristics of chicken nuggets with jack bean tempeh flour substitution ($p < 0.05$). In conclusion, PE/PA was the most suitable plastic packaging for maintaining the quality characteristic of chicken nuggets substituted with jack bean tempeh flour during 20 days of cold storage under vacuum packaging conditions. The physical and chemical quality of chicken nuggets substituted with jack bean tempeh flour on the 20th day of storage were pH of 6.43, cooking loss of 9.85%, moisture content of 39.46%, protein content of 24.51%, TVBN content of 16.44 mg N/100 g, and TPC of 5.36 log cfu/g. Meanwhile, the result of the sensory evaluation showed that scores for attributes were color 3.63, aroma 3.45, taste 3.5, texture 3.29, and overall 3.53 (like slightly) on the 20th day of storage.

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Introduction

Nuggets are made from seasoned ground meat, mixed with a binder, then molded into a certain shape, steamed, cut, coated with a flour adhesive (batter), and covered with breadcrumbs (breading). Nuggets are ready-to-eat frozen food products that have been partially cooked (pre-cooked) and then frozen (Revitriani et al., 2022). There are main ingredients in the making of nuggets, such as beef or chicken meat. Chicken meat provides high protein and low fat. As a main ingredient, chicken meat can be substituted with plant-based ingredients such as legumes that contain a high content of protein. Despite its rich nutritional content, chicken meat has a high content of polyunsaturated fatty acids, which shorten its shelf life due to oxidative deterioration during storage (El-Sohaimy et al., 2022). Also, since chicken meat as the main ingredient is typically more expensive, the usage of plant-based ingredients would reduce the production cost. Therefore, a substitution with plant-based ingredients is needed in making nuggets to reduce the amount of chicken meat used without reducing its nutritional composition and the price is more affordable.

So far, plant-based ingredients such as legume flour are the most widely used as a substitution for chicken meat which will enhance the quality of chicken nuggets. In Indonesia, jack beans (*Canavalia ensiformis* L.) have been developed as a local alternative protein source to replace soybeans. Jack bean tempeh flour is an alternative process of making semi-finished products to extend shelf life and be more applicable in the production of food products. The nutritional content of

jack bean tempeh flour was 10.91% moisture content, 1.55% ash content, 27.92% protein content, 5.55% fat content, and 65.04% carbohydrate content (Affandi et al., 2020). The high protein content of jack bean tempeh flour can be used as a substitution for the main ingredient in making chicken nuggets.

Moreover, chicken nuggets with jack bean tempeh flour substitution are a type of perishable food. This may cause the growth of spoilage and pathogenic microbes, thus having a short shelf life (Rohaya et al., 2024). The shelf life of chicken nuggets with jack bean tempeh flour substitution and its quality were affected by the storage conditions. The storage temperature is closely related to the shelf life and quality of chicken nuggets with jack bean tempeh flour. Low temperatures can inhibit the growth and reproduction of microorganisms, reduce enzyme activity, and slow down various biochemical reactions in processed meat products such as chicken nuggets with jack bean tempeh flour substitution (Tian et al., 2022). Salama et al. (2016) reported that cold storage plays a major role in extending the shelf-life of chicken nuggets in combination with vacuum packaging and coating of packaging material surface with rosemary or oregano extracts.

Effective packaging could maintain the quality of chicken nuggets with jack bean tempeh flour substitution. Vacuum packaging of processed meat products can decrease the rate of oxidation and spoilage when compared to oxygen-permeable packaging. By simply packaging the processed meat products in a high-barrier packaging from which air is removed, vacuum packaging extends the shelf life of packaged processed meat products by preventing the growth of aerobic bacteria and delaying lipid oxidation (Salama et al., 2016). According to Abbasi et al. (2020), common packaging available in the market is made up of polyethylene (PE) and polyamide (PA). Polyethylene and nylon are the easiest types of packaging to find and have a transparent color so that the product is more easily observed from outside the package (Furqon et al., 2016).

Lindriati et al. (2022) studied the effect of various types of plastic for vacuum packaging on chicken nuggets substituted with meat analog from cocoyam and soy protein isolates packaged using high-density polyethylene (HDPE), low-density polyethylene polyamide (LDPE), and polypropylene (PP) at cold storage. Their results showed that HDPE, LDPE, and PP could maintain the quality of chicken nuggets substituted with meat analogs from cocoyam and soy protein isolates. Previous research by Mastini et al. (2015) showed that storage with the type of plastic with two layers of polyethylene (PE) and nylon plastic packaging was the best treatment for extending dough satay (*luluh*) shelf life. In this study, the types of plastic used as vacuum packaging were polyethylene (PE), polyamide (PA), and nylon. Therefore, it is necessary to assess the effect of packaging type and storage time on the quality characteristics of a chicken nugget with jack bean tempeh flour substitution, including physical (pH and cooking loss), chemical (moisture content, protein content, and total volatile base nitrogen), microbiological (total plate count), and sensory characteristics.

Materials and Methods

Materials

The materials used for the production of jack bean tempeh flour and chicken nuggets were jack bean tempeh obtained from BUMR Paramasera, Bogor, West Java, broiler chicken thigh and breast fillets obtained from Superindo supermarket (Pamulang, South Tangerang), jack bean tempeh flour, salt (Cap Segitiga Emas, Bogor), sugar (Gulaku, Lampung), pepper (Ladaku, East Java), garlic, onion, tapioca flour (Gunung Agung, Lampung), corn starch (Maizenaku, Jakarta), skim milk (Indoprima, Semarang), chicken flavored seasoning (Royco, Bekasi), chicken eggs purchased at Superindo supermarket (Pamulang, South Tangerang), breadcrumbs flour (Sari Tepung, Jakarta), cooking oil (Tropical, Bekasi), Nylon/PE (0.075 mm) (Berlian 90, Bandung), Nylon/PA/PE (0.09 mm) (DePlastik, Tangerang), and PA/PE (0.19 mm) (ARR Store Indonesia, Jakarta). The material used for chemical analysis were aquadest, K_2SO_4 (Pudak Scientific, Bandung), $CuSO_4.5H_2O$ (Pudak Scientific, Bandung), H_2SO_4 (Merck, Germany), NaOH 30% (Pudak Scientific, Bandung), boric acid (Merck, Germany), methyl orange indicator, methyl blue indicator, HCl 0.02 N (Pudak Scientific, Bandung), K_2CO_3 (Merck, Jakarta), plate count agar (Merck, Germany), and buffered peptone water (Merck, Germany).

The primary equipment used for the production of jack bean tempeh flour and chicken nuggets were blender (Philips series 5000-HR2221/30, Netherlands), food processor (Cosmos FP-313, Indonesia), food dehydrator (LocknLock EJO316, South Korea), 60 mesh test sieve (B-ONE SS 304, China), chest freezer (GEA AB-318-R, China), vacuum food sealer (UPUPIN, China), and showcase (RSA AGATE-200N, China). The equipment used for physical measurement and chemical analysis were a pH meter (pH700, Thermo Scientific Eutech, United Kingdom), oven (Oxone OX-828, Indonesia), Kjeldahl set, drying oven (Daihan Labtech LDO-060E, South Korea), desiccator, and analytical balance (Fujitsu FS-AR 210, Japan).

Methods

Preparation of Jack Bean Tempeh Flour (Giovani et al., 2023)

First, jack bean tempeh was sliced with a thickness of 0.2 cm using a knife. Then, jack bean tempeh slices were blanched using steam for 10 minutes at 80°C. The jack bean tempeh slices were laid out on a tray and dried using a food dehydrator for 6 hours at 60°C. The dried jack bean tempeh was then ground using a dry mill blender and sieved using a 60-mesh sieve.

Preparation of Chicken Nugget with Jack Bean Tempeh Flour Substitution (Hafid et al., 2021 with modifications)

The process of making nuggets using the following procedure is based on the formulation shown in Table 1. Chicken meat, consisting of chicken breast and chicken thigh, was cut into small cubes and minced using a food processor. Chicken nugget batter was prepared by mixing jack bean tempeh flour, tapioca flour, corn starch, skim milk, egg yolk, and spice mixture until homogeneous. The spice mixture contained garlic,

onion, pepper, salt, sugar, and chicken-flavored seasoning. The whole mixture was molded into a baking tray with a thickness of ± 0.5 cm. After that, it was steamed for 10 minutes at 70-80°C. The semi-cooked nuggets were cut into square pieces approximately 3 cm x 3 cm, then immersed in the batter (egg yolk), and finally breaded with breadcrumbs. The prepared nuggets were frozen in the freezer for 10 minutes. Next, pre-frying was carried out at 150-170°C for 10 minutes in a microwave. The nuggets were cooled at room temperature for 20 min before packaging.

Then, the nuggets were vacuum packaged by using a vacuum sealer, placed in plastic bags (Nylon/PE, Nylon/PE/PA, and PE/PA), and stored at 4°C in a showcase until further analysis at 0, 5, 10, 15, and 20 days of the storage to determine changes in quality characteristics before the chicken nuggets deterioration. The frying oil was maintained at 180 ± 2°C. Chicken nuggets were then deep-fried at 180°C for 3 minutes. After frying, the nuggets were immediately removed from the oil and blotted gently with dry tissue papers to remove the excess oil from their surfaces. The nuggets were then kept warm before sensory evaluation.

Table 1. Formulation of Chicken Nugget Substituted with Jack Bean Tempeh Flour

Ingredients	(g)
Jack bean tempeh flour	10
Chicken meat	40
Tapioca flour	45
Corn starch	12
Skim milk	5
Egg yolk	20
Garlic	10
Onion	10
Sugar	4
Salt	2.5
Pepper	1.25
Chicken flavored seasoning	2.5

Physical Characteristic of Chicken Nugget with Jack Bean Tempeh Flour Substitution

Cooking Loss

Cooking loss was measured according to the method described by Tian et al. (2022). The chicken nugget (initial weight) was fried at 180 ± 2°C for 3 min. The fried samples were allowed to cool for 1 h and weighed (frying weight). Cooking loss (%) was determined by calculating the weight differences of chicken nuggets with jack bean flour substitution before and after cooking as follows:

$$\text{Cooking Loss } (\%) = \frac{\text{initial weight} - \text{frying weight}}{\text{initial weight}} \text{ x } 100$$

pH

pH values of nuggets were determined according to the method described by Hur et al. (2013) using a pH meter (pH700, Eutech Instruments, UK), which was calibrated with standard buffers of pH 4.0, pH 7.0, and pH 10.0 before the measurement. The chicken nugget (5 g) was cut into small pieces, and then 45 mL of distilled water was added. A slurry was made using a blender until smooth and placed in a 50 mL beaker glass. The pH electrode was then dipped into the slurry, measured for about 10 minutes, and recorded.

Chemical Characteristic of Chicken Nugget with Jack Bean Tempeh Flour Substitution

Moisture Content

Moisture content was determined according to the method described by Sinaga et al. (2022) with modifications. Chicken nugget samples were mashed using a mortar. Two grams of finely mashed chicken nuggets were placed into a weighing bottle whose constant weight was known. Then, dried in an oven at 105 °C for 5 hours, cooled in a desiccator, and weighed again. The weight lost was assumed to be the water weight.

Protein Content

Protein content was determined according to the method described by Abubakar et al. (2022) with modifications. The nugget sample was crushed with a mortar, weighed 1 gram, and then put into the Kjehdahl flask. Added 7.5 grams of K_2SO_4 and 0.35 grams of $CuSO_4$ then added another 15 mL of H_2SO_4. Heated it over the Kjeldahl apparatus until the solution was clear. Cooled and put into the bottom flask and added 100 mL of distilled water, 30% NaOH (w/v), and distilled for a few minutes. The di stillate results were collected in an Erlenmeyer containing 4% (v/v) H_3BO_3 and the bromocresol green and methyl red indicator until the color changed to green. The distillate results were then titrated with standard 0.02 N HCl solution until the solution changed color from green to purple, and the volume of titrant used was recorded. The percentage of crude protein was expressed as a total nitrogen percentage and was multiplied by a factor of 6.25.

Total Volatile Bases Nitrogen (TVBN)

The total volatile bases nitrogen (TVBN) of chicken meat nuggets was determined as described by Choi et al. (2018) according to Conway's micro-diffusion method. TVBN values were expressed in mg nitrogen/100 g nugget sample. The chicken nugget (5 g) was homogenized in 20 mL of deionized water. The homogenate was filtered through the Whatman filter paper Number 1. Then, the filtrate (1 mL) was transferred to the outer chamber, and 1 mL of 0.01 N H_3BO_3 and 100 µL of Conway solution (0.066% methyl red: 0.066% bromocresol green, 1:1; using 99.99% alcohol as solvent) as an indicator were added to the inner part of the Conway dish. The Conway unit was sealed immediately after pouring 1 mL of 50% K_2CO_3 into the outer chamber. The dish was incubated at 37℃ for 120 min. The TVBN contents were determined following the addition of 0.02 N H_2SO_4 to the inner chamber of the Conway unit. A blank test was conducted following the same process without adding a sample. The concentration of TVBN (in mg N/100 g sample) was computed as follows:

$$\text{mg N}/100\text{ g} = \frac{14.007 \text{ x } (a - b) \text{ x f x } 100 \text{ x c}}{S}$$

where a is the titer for the sample (mL), b is the titer for the blank (mL), f is the factor of H_2SO_4 (0.02 N), S is the sample weight (g), and c is the dilution ratio.

Microbiological Characteristic of Chicken Nugget with Jack Bean Tempeh Flour Substitution

Total Plate Count (TPC)

The total plate count (TPC) of chicken meat nuggets was determined as described by Banerjee et al. (2019) with modifications. About 10 g of the sample was aseptically weighed and homogenized for 2 minutes in a sterile mortar containing 90 mL of 0.1% sterile peptone water to make 10^{-1} dilution. 1 mL of 10^{-1} dilution was mixed with 9 mL of 0.1% peptone water to obtain 10^{-2} dilution and so on. In 1000 mL of distilled water, 23.5 g plate count agar was dissolved and autoclaved at 121°C for 15 minutes. About 20 mL of plate count agar hat 44-46°C was poured gently into each dish and rotated in clockwise and anticlockwise directions 7-8 times to mix the media uniformly. The plates were incubated at 37 ± 1°C for 48 hours. The total microbial count was determined in chicken nuggets at 4°C during 20 days of storage with 5-day intervals.

Sensory Evaluation of Chicken Nugget with Jack Bean Tempeh Flour Substitution

The sensory evaluation used was a hedonic test as described by Hairunnissa et al. (2021) with a total of 35 semi-trained panelists aged between 18 and 35 years old, both male and female students and workers from the Faculty of Science and Technology, Department of Food Technology, Universitas Al-Azhar Indonesia. Each chicken nugget was evaluated in terms of color, aroma, taste, texture, and overall. The samples were evaluated using a 5-point hedonic scale ranging from extreme with the assessment scores used being 5 (very like), 4 (like), 3 (like slightly), 2 (dislike), and 1 (very dislike). The samples were then kept warm at 30°C before sensory evaluation. Small pieces of different samples (2 × 2 × 2 cm) were prepared on a round plate and coded with the three-digit random number. The panelists were also required to cleanse their palates with water between tasting the samples.

Data Analysis

The research design consisted of two factors, the first factor was packaging type (nylon/polyethylene (PE), nylon/polyethylene (PE)/polyamide (PA), and polyethylene (PE)/polyamide (PA)) and the second factor was storage time (0 day, 5 days, 10 days, 15 days, and 20 days). The data obtained were analyzed by Two Way Analysis of Variance (ANOVA) at a significance level of $\alpha = 0.05$ using SPSS Statistics V27.0. If there was a significant difference, it was followed by further tests using Duncan's Multiple Range Test (DMRT) at a significance level of $\alpha = 0.05$.

Results and Discussion

Physical Characteristics

pH

The packaging type and storage time under vacuum had a significant effect ($p < 0.05$) on the pH of chicken nuggets. The results of the pH value of chicken nuggets are shown in Table 2. As can be seen, PE/PA can maintain the quality of chicken nuggets with jack bean tempeh flour substitution based on changes in pH. This may be attributed to the highest thickness of 0.19 mm among other types of packaging, which may be a result of low gas permeability, so there was less CO_2 absorption. Hur et al. (2013) reported that the pH can decrease during storage owing to the production of lactic acid through lactic acid bacteria metabolism and the dissolution of CO_2 into the meat product aqueous phase.

Table 2. Effect of Packaging Type and Storage Time on pH of Chicken Nuggets

Packaging Type	Storage Time (Day)				
	0	5	10	15	20
Nylon/PE	6.45±0.00^{ab}	6.44±0.00^{ab}	6.42±0.01^{bcd}	6.42±0.01^{bcd}	6.40±0.02^{cde}
Nylon/PE/PA	6.40±0.00^{def}	6.40±0.00^{cde}	6.38±0.00^{efg}	6.36±0.01^{fg}	6.36±0.01^{g}
PE/PA	6.46±0.01^{a}	6.44±0.04^{abc}	6.43±0.04^{abcd}	6.42±0.02^{bcd}	6.43±0.04^{abcd}

Note: The values with different superscripts differ significantly ($p < 0.05$)

The initial pH values of chicken nuggets with jack bean tempeh flour substitution ranged from 6.40 to 6.46. On the 20th day of storage, the pH reached 6.40 in Nylon/PA, while it was 6.36 in Nylon/PE/PA and 6.43 in PE/PA. This however implies that chicken nuggets packed in PE/PA plastic packaging with higher pH had better water-holding capacity thereby improving product quality (Abiala et al., 2022). The normal pH of meat ranges from 5.3 to 5.9 depending on the rate of postmortem glycolysis and muscle glycogen. The pH value of meat and meat products in general ranges from 4.6 to 6.4 (Falahudin et al., 2022).

pH of meat never reaches below 5.3 because at a pH below 5.3 enzymes involved in the glycolysis are inactive. Cooking causes a decrease in the acidic group so that the isoelectric point increases. Therefore, the pH of chicken nuggets increased compared to the pH of meat (Kariang et al., 2023). However, our results were in agreement with Sujarwanta et al. (2019) who obtained the pH of chicken nuggets with curcuma flour fortification about 6.51. In the present study, the pH of the chicken nuggets slightly decreased throughout the storage time. According to Talab et al. (2023), the formation of lactic acid from glycogen as a result of autolysis was the cause of the decline in pH during storage.

Furthermore, after 20 days, a decrease in pH could be caused by aerobic microorganism growth induced by the reduction in oxygen and enhancement of CO_2 content. In addition, the reduction in pH might be related to the fermentation of some ingredients or to the addition of spices (Moosavi-Nasab et al., 2019). This was in agreement with the results observed by Hatta et al. (2020), the pH of *dangke* nuggets decreased from 7.31 on the 0th day to 6.77 on the 14th day. Also, these findings are in agreement with the result reported by El-Sohaimy et al. (2022), the pH of quinoa-coated chicken nuggets gradually decreased with the increasing storage time. It is a fact that the decreasing of pH values results in the

growth of lactic acid bacteria (LAB) which produce lactic acid in the product.

Cooking Loss

The packaging type and storage time had a significant effect ($p < 0.05$) on the cooking loss of the chicken nuggets. The results of cooking loss of chicken nuggets are shown in Table 3. As can be seen, the minimum cooking loss (%) of chicken nuggets was observed in the PE/PA. This may be attributed to the low water vapor permeability of PE/PA related to the thickness of PE/PA of 0.19 mm which decreased water loss. High cooking loss of meat products is an indicator of weak protein binding and a lot of fluid comes out of meat products (drip) due to decreased water holding capacity. The loss of weight or fluid is mostly water, proteins, fats, vitamins, and other solutions (Dewi & Prihharsanti, 2012).

As can be seen, the percentage of cooking loss increased with increasing storage time. The initial cooking loss of chicken nuggets with jack bean tempeh flour substitution ranged from 4.58 to 5.22%. On the 20th day of storage, the cooking loss reached 13.42% in Nylon/PE, while it was 10.68% in Nylon/PE/PA and 9.85% in PE/PA. As a similar result, the cooking loss of refrigerated beef nuggets increased with increasing storage time from 26.67% (0 days) to 21.63% (21 days) (Talukder et al., 2013). Water holding capacity of chicken nugget will decrease with decreasing pH (Table 2) during cold storage for 20 days caused the protein denaturation of the chicken nugget had many weakly bound water molecules so that the amount of protein will decrease (Dewi & Prihharsanti, 2012). The lower cooking loss indicates the better water-holding capacity of the meat product (Ma'ruf et al., 2019).

The cooking loss in this study was still in the range of the cooking loss of commercial chicken nuggets, which is in the range of 3.37 to 13%. This was likely caused by the usage of tapioca flour, corn starch, and jack bean tempeh flour as fillers in the chicken nuggets, resulting in a low cooking loss, which showed that the chicken nugget has a good water-holding capacity. Protein content affected cooking loss in meat products. According to Kusuma et al. (2017), the high protein content of meat products plays an important role in the higher binding of the water.

Table 3. Effect of Packaging Type and Storage Time on Cooking Loss (%) of Chicken Nuggets

Packaging Type	Storage Time (Day)				
	0	5	10	15	20
Nylon/PE	5.22±0.64^{gh}	7.84±1.11^{ef}	10.42±0.82^{bcd}	11.17±2.03^{ab}	13.42±1.42^{a}
Nylon/PE/PA	4.94±1.31^{gh}	6.42±1.93^{fgh}	7.91±0.83^{def}	8.37±0.51^{cdef}	10.68±0.14^{bc}
PE/PA	4.58±1.48^{h}	6.08±0.55^{fgh}	6.18±0.01^{fgh}	7.44±0.57^{efg}	9.85±0.52^{bcde}

Note: The values with different superscripts differ significantly ($p < 0.05$)

Table 4. Effect of Packaging Type and Storage Time on Moisture Content (%) of Chicken Nuggets

Packaging Type	Storage Time (Day)				
	0	5	10	15	20
Nylon/PE	33.40±0.59^{f}	36.12±1.29^{e}	37.62±0.78^{cd}	38.30±1.08^{c}	40.68±0.60^{a}
Nylon/PE/PA	33.87±0.62^{f}	35.86±0.57^{e}	36.94±0.87^{de}	38.09±1.10^{cd}	40.33±0.87^{ab}
PE/PA	33.51±0.81^{f}	34.58±0.53^{f}	38.01±0.90^{cd}	37.92±0.40^{cd}	39.46±0.32^{b}

Note: The values with different superscripts differ significantly ($p < 0.05$)

Chemical Characteristics

Moisture Content

The packaging type and storage time had a significant effect ($p < 0.05$) on the moisture content of the chicken nuggets. The results of the moisture content of nuggets are shown in Table 4. As can be seen, PE/PA can maintain the quality of chicken nuggets with jack bean tempeh flour substitution based on changes in moisture content. This may be attributed to the low water vapor permeability of PE/PA related to the thickness of PE/PA of 0.19 mm. The thicker the packaging the less amount of water vapor can penetrate packaging materials so the better the packaging protects the product inside (Sulandari, 2017). In this study, the moisture content of chicken nuggets in PE/PA packaging was lowest compared to other types of packaging, this indicated that PE/PA has a greater ability to inhibit water vapor into the packaging.

As can be seen, the moisture content increased with increasing storage time. The initial moisture content of chicken nuggets with jack bean tempeh flour substitution ranged from 33.4 to 33.87%. Alrawashdeh & Abu-Alruz (2022) reported that the moisture content of low-fat chicken nuggets was 40.53%. On the 20th day of storage, the moisture content reached 40.68% in Nylon/PE, while it was 40.33% in Nylon/PE/PA and 39.46% in PE/PA. This occurs due to the migration or transfer of water from the surrounding environment into the product, such as water vapor absorption. Packaging permeability can be determined by determining the value of the water vapor transmission rate (WVTR). WVTR value for plastics is a maximum of 0.0292 g/m^2/hour (Aini et al., 2021). Sulandari (2017) states that nylon packaging absorbs water vapor. Nylon packaging has a rate of water vapor transmission rate (WVTR) of 260 g/m^2/day. This might be the cause of the moisture content of chicken nuggets packed with nylon/PE and nylon/PE/PA showed a higher moisture content than those packed with PE/PA on the 20th day of storage.

The surface of chicken nuggets can become a suitable medium for microbial growth due to texture instability caused by increased moisture content. The

moisture content influences the quality of chicken nuggets. Microorganisms including bacteria, molds, and yeasts more likely to multiply quickly with high moisture content (Rohaya et al., 2024). According to Indonesia National Standard (ISN) No 01-6683-2014, the maximum moisture content in the combination nuggets is 60%, so all chicken nuggets packed in nylon/PE, nylon/PE/PA, and PE/PA have met the ISN requirements because the highest moisture content obtained was 40.68% on the 20th day of storage.

Protein Content

The packaging type and storage time had a significant effect ($p < 0.05$) on the protein content of the chicken nuggets. The results of the protein content of nuggets are shown in Table 5. As can be seen, PE/PA can maintain the quality of chicken nuggets with jack bean tempeh flour substitution based on changes in protein content. This may be attributed to the highest thickness of 0.19 mm among other types of packaging, which may be a result of low gas permeability. The number of bacteria present on the packaging is closely related to the gas permeability of the packaging.

Thick plastic packaging has a low oxygen transmission rate (OTR) (Fatharani et al., 2020). This might be caused by PE/PA can reduce the amount of oxygen (O_2) gas that passes through the packaging. The O_2 that is in the packaging can be used for microbial growth. Proteolytic bacteria are classified as aerobic bacteria that will grow optimally in the presence of O_2. The more O_2 in the environment, the more optimal the growth of proteolytic bacteria (Furqon et al., 2016).

Table 5. Effect of Packaging Type and Storage Time on Protein Content (%) of Chicken Nuggets

Packaging Type	Storage Time (Day)	
	0	20
Nylon/PE	35.72 ± 0.98^{b}	13.30 ± 2.96^{d}
Nylon/PE/PA	42.02 ± 3.95^{ab}	14.00 ± 1.97^{d}
PE/PA	46.22 ± 1.97^{a}	24.51 ± 4.94^{c}

Note: The values with different superscripts differ significantly ($p < 0.05$)

As can be seen, the protein content decreased with increasing storage time. The initial protein content of chicken nuggets with jack bean tempeh flour substitution ranged from 35.72 to 46.22%, higher than the protein content of chicken nuggets with chicken skin and wheat fiber mixture ranged from 25.13 to 27.36% (Kim et al., 2015). On the 20th day of storage, the protein content reached 13.30 in Nylon/PE, while it was 14.00 in Nylon/PE/PA and 24.51 in PE/PA. The decrease in protein content was caused by the activity of proteolytic bacteria that can digest proteins during storage so that it can cause protein degradation.

Proteolytic bacteria can grow optimally at room temperature, but over time can continue to grow and develop at refrigerator temperature so that proteolysis occurs (Furqon et al., 2016). According to Indonesia National Standard (ISN) No 01-6683-2014 for combined chicken nuggets, the minimum protein content in a chicken nugget is 9%, which means that all chicken nuggets packed in nylon/PE, nylon/PE/PA, and PE/PA substitution had higher protein content than ISN. The higher protein content of chicken nuggets can enhance the water-holding capacity so that the higher hardness value of the texture (Mawla et al., 2018).

Total Volatile Base Nitrogen (TVBN)

The packaging type and storage time had a significant effect ($p < 0.05$) on the TVBN content of the chicken nuggets. The results of TVBN content of chicken nuggets are shown in Table 6. The recommended limit of TVBN for palatability of meat products is 20 mg N/100 g (Raeisi et al., 2021). The chicken nuggets substituted with jack bean tempeh flour in all chicken nuggets packed in nylon/PE, nylon/PE/PA, and PE/PA were less than the recommended limit on the 20th day of storage. The vacuum packaging of chicken nuggets affects the formation rate of TVBN since it lowers the formation of TVBN as compared to aerobic packaging which appears in the fast spoilage of aerobic packaging (Salama et al., 2016).

Table 6. Effect of Packaging Type and Storage Time on TVBN Content (mg N/100 g) of Chicken Nuggets

Packaging Type	Storage Time (Day)	
	0	20
Nylon/PE	5.60 ± 0.03^{c}	11.09 ± 0.07^{b}
Nylon/PE/PA	5.58 ± 0.01^{c}	11.18 ± 0.01^{b}
PE/PA	5.50 ± 0.02^{c}	16.44 ± 0.06^{a}

Note: The values with different superscripts differ significantly ($p < 0.05$)

As can be seen, the TVBN content increased with increasing storage time. Salama et al. (2016) also reported the TVBN content of chicken nuggets was increased as storage time increased. The initial TVBN content of chicken nuggets with jack bean tempeh flour substitution ranged from 5.50 to 5.60 mg N/100 g. Previous research has found that storage at 5°C on day 0 showed the TVBN content of fish nuggets 1.12 mg N/100 g (Dalle et al., 2021). On the 20th day of storage, the TVBN content reached 11.09 mg N/100 g in Nylon/PE, while it was 11.18 mg N/100 g in Nylon/PE/PA and 16.44 mg N/100 g in PE/PA. The TVBN content of chicken nuggets packaged with PE/PA on day 20 was highest among other types of packaging might be caused by the compression process of the vacuum packaging, so there can be a deterioration reaction in the chicken nuggets (Razie & Widawati, 2018).

The longer the storage time, the higher the TVBN content, but vacuum packaging can inhibit the increase in TVBN due to the absence of oxygen in the packaging so that it can inhibit the oxidation process (Brainerd & Junianto, 2021). TVBN content is an important indicator for evaluating the freshness of meat products which measure mainly trimethylamine (TMA), ammonia, and dimethylamine (DMA). TVBN content can increase with either enzymatic or bacterial degradation (Raeisi et al., 2021). The TVBN content increased slightly during the first days of storage, this slight increase may reflect the amines production by autolytic processes (Maghraby et al., 2013).

Table 7. Effect of Packaging Type and Storage Time on TPC (log cfu/g) of Chicken Nuggets

Packaging Type	Storage Time (Day)				
	0	5	10	15	20
Nylon/PE	4.18±0.05^{g}	4.89±0.03^{ef}	4.99±0.02^{d}	5.28±0.01^{b}	5.38±0.60^{a}
Nylon/PE/PA	3.85±0.18^{h}	4.87±0.03^{ef}	4.97±0.02^{de}	5.12±0.01^{c}	5.37±0.87^{a}
PE/PA	3.77±0.12^{h}	4.85±0.04^{f}	4.94±0.03^{def}	5.11±0.02^{c}	5.36±0.32^{ab}

Note: The values with different superscripts differ significantly ($p < 0.05$)

Microbiological Characteristics

Total Plate Count (TPC)

The packaging type and storage time had a significant effect ($p < 0.05$) on the TPC of the chicken nuggets. The results of the TPC of chicken nuggets are shown in Table 7. According to Indonesia National Standard (ISN) No 01-6683-2014, cooked meat products such as nuggets may be consumed if the allowable limit of microbial contamination does not exceed 5 log cfu/g. In the present study, the TPC of chicken nuggets in all types of packaging remained lower than the allowable limit of Indonesian standard for cooked meat products up to 10 days of cold storage indicating that the chicken nuggets were microbiologically safe in cold storage for 10 days.

As can be seen, the TPC increased slightly with increasing storage time. The initial TPC of chicken nuggets with jack bean tempeh flour substitution ranged from 3.77 to 4.18 log cfu/g. On the 20th day of storage, the TPC of chicken nuggets with jack bean tempeh flour substitution reached 5.38 log cfu/g in Nylon/PE, while it was 5.37 log cfu/g in Nylon/PE/PA and 5.36 log cfu/g in PE/PA. A similar result by El-Sohaimy et al. (2022), was an increase in TPC from 1.30 at 0 days to 3.76 log cfu/g on the 24th day of cold storage of quinoa-coated chicken nuggets.

Chicken nuggets packaged with PE/PA showed better quality than those of nylon/PE and nylon/PE/PA. This may be attributed to the highest thickness of 0.19 mm among other types of packaging, which may be a result of the low permeability of water vapor and oxygen (O_2). The low permeability of O_2 reduces the oxidation and growth of aerobic microbes; whereas, the low permeability of water vapor decreases water content lower than that required by the microbes especially molds (Zahra et al., 2016). This indicates that PE/PA can retard the growth of microorganisms are a major cause of deterioration of chicken nuggets resulting to extend shelf life.

Sensory Evaluation of Chicken Nugget with Jack Bean Tempeh Flour Substitution

Sensory evaluation has been a useful tool to evaluate the changes in chicken nugget quality during storage. The hedonic quality analysis of chicken nuggets packaged in three vacuum packaging types during cold storage was evaluated for color, aroma, taste, texture, and overall acceptance as shown in Figure 1. Regarding storage time, sensory attributes tended to decrease with the increase in storage time. Similar findings were observed by Rani et al. (2024) upon cold storage of fiber-enriched chicken nuggets.

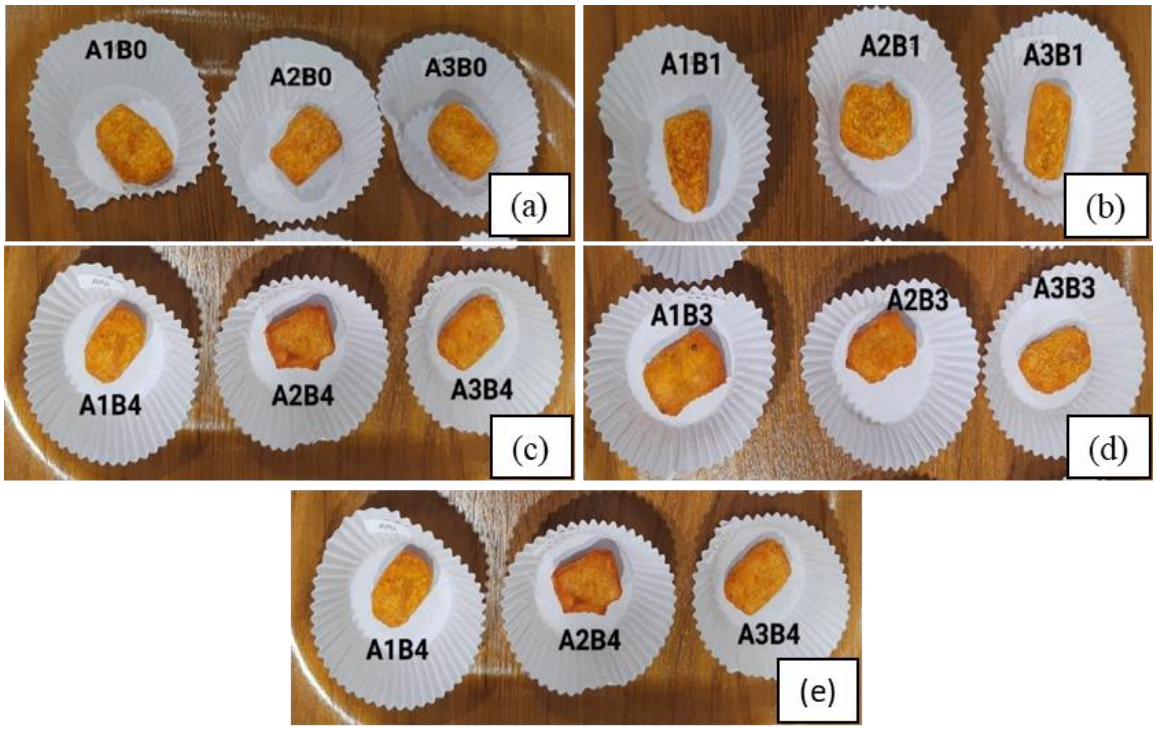

Figure 1. Chicken Nuggets with Jack Bean Tempeh Flour Substitution During Cold Storage: (a) Day 0 (b) Day 5 (c) Day 10 (d) Day 15 (e) Day 20

The packaging type and storage time had a significant effect ($p < 0.05$) on the color acceptability score of the chicken nuggets. The results of color acceptability scores of chicken nuggets are shown in Table 8. The use of vacuum packaging is more effective in resisting discoloration than non-vacuum packaging (Silvia et al., 2022). As can be seen, the color acceptability score of the chicken nugget with jack bean tempeh flour substitution ranged between 3.5 to 4.1 (like slightly to like). This score was slightly decreased with increasing the storage time.

On the 20th day of storage, the color acceptability score reached 3.5 in Nylon/PE, while it was 3.58 in Nylon/PE/PA and 3.63 in PE/PA. This result is in agreement with the results of Moosavi-Nasab et al. (2019) who obtained that the color acceptability score of fish and surimi nuggets was slightly decreased with increasing the storage time. Chicken nuggets packed with PE/PA plastic showed the best color sensory score. The decrease in color acceptability score with the increase in storage days could be attributed to non-enzymatic browning resulting from a reaction between lipid oxidation products and amino acids (Kumar et al., 2011).

The packaging type and storage time had no significant effect ($p > 0.05$) on the aroma acceptability score of the chicken nuggets. The results of the aroma acceptability scores of chicken nuggets are shown in Table 9. As can be seen, the aroma acceptability score of the chicken nugget with jack bean tempeh flour substitution ranged between 3.42 and 3.89 (like slightly). This score was slightly decreased with increasing the storage time. The presence of lipase enzymes produced by microbes causes damage and oxidation of fat in the chicken nugget by air so that rancidity occurs rancidity. On the 20th day of storage, the aroma acceptability score reached 3.5 in Nylon/PE, while it was 3.42 in Nylon/PE/PA and 3.45 in PE/PA. Vacuum packaging is better than non-vacuum packaging because it can inhibit the oxidation process of food products (Silvia et al., 2022).

Table 8. Effect of Packaging Type and Storage Time on Color Attribute of Chicken Nugget

Packaging Type	Storage Time (Day)				
	0	5	10	15	20
Nylon/PE	4.0±0.69^{abc}	3.92±0.71^{abcde}	3.55±0.86^{de}	3.53±0.79^{de}	3.5±0.97^{e}
Nylon/PE/PA	4.08±0.67^{ab}	3.92±0.67^{abcde}	3.68±0.96^{bcde}	3.66±0.74^{cde}	3.58±0.79^{cde}
PE/PA	4.1±0.76^{a}	3.95±0.76^{abcd}	3.71±0.65^{abcde}	3.66±0.90^{cde}	3.63±0.81^{cde}

Note: The values with different superscripts differ significantly ($p < 0.05$)

Table 9. Effect of Packaging Type and Storage Time on Aroma Attribute of Chicken Nugget

Packaging Type	Storage Time (Day)				
	0	5	10	15	20
Nylon/PE	3.89±0.72^{a}	3.76±0.91^{ab}	3.76±0.88^{ab}	3.68±0.80^{ab}	3.5±0.86^{ab}
Nylon/PE/PA	3.87±0.81^{ab}	3.71±0.76^{ab}	3.68±0.84^{ab}	3.61±0.88^{ab}	3.42±0.85^{b}
PE/PA	3.76±0.67^{ab}	3.66±0.81^{ab}	3.53±0.82^{ab}	3.63±0.97^{ab}	3.45±0.95^{ab}

Note: The values with different superscripts differ significantly ($p < 0.05$)

Table 10. Effect of Packaging Type and Storage Time on Taste Attribute of Chicken Nugget

Packaging Type	Storage Time (Day)				
	0	5	10	15	20
Nylon/PE	3.81±0.76^{ab}	3.74±0.79^{abcd}	3.45±0.86^{bcd}	3.26±0.92^{d}	3.37±0.94^{bcd}
Nylon/PE/PA	4.08±0.85^{a}	3.71±0.95^{abcd}	3.5±1.00^{bcd}	3.32±1.11^{cd}	3.39±1.00^{bcd}
PE/PA	4.16±0.67^{a}	3.76±0.94^{abc}	3.68±0.90^{abcd}	3.47±0.95^{bcd}	3.5±0.97^{bcd}

Note: The values with different superscripts differ significantly ($p < 0.05$)

The packaging type and storage time had a significant effect ($p < 0.05$) on the taste acceptability score of the chicken nuggets. The results of taste acceptability scores of chicken nuggets are shown in Table 10. As can be seen, the taste acceptability score of the chicken nugget with jack bean tempeh flour substitution ranged between 3.26 and 4.16 (like slightly to like). This score was slightly decreased with increasing the storage time. On the 20th day of storage, the taste acceptability score reached 3.37 in Nylon/PE, while it was 3.39 in Nylon/PE/PA and 3.5 in PE/PA. The reduction in taste acceptability scores with the increase of storage time could be attributed to microbial growth and oxidative rancidity resulting in off-flavor (Kumar et al., 2011).

The packaging type and storage time had a significant effect ($p < 0.05$) on the texture acceptability score of the chicken nuggets. The results of texture acceptability scores of chicken nuggets are shown in Table 11. As can be seen, the texture acceptability score of the chicken nugget with jack bean tempeh flour substitution ranged between 3.0 to 3.87 (like slightly). This score was slightly decreased with increasing the storage time.

Table 11. Effect of Packaging Type and Storage Time on Texture Attribute of Chicken Nugget

Packaging Type	Storage Time (Day)				
	0	5	10	15	20
Nylon/PE	3.55±0.72^{abcd}	3.53±0.91^{abcde}	3.24±0.88^{cde}	3.05±0.80^{de}	3.0±0.86^{e}
Nylon/PE/PA	3.79±0.81^{ab}	3.5±0.76^{abcde}	3.42±0.84^{abcde}	3.32±0.88^{bcde}	3.26±0.85^{bcde}
PE/PA	3.87±0.67^{a}	3.61±0.81^{abc}	3.45±0.82^{abcde}	3.34±0.97^{abcde}	3.29±0.95^{bcde}

Note: The values with different superscripts differ significantly ($p < 0.05$)

Table 12. Effect of Packaging Type and Storage Time on Overall Attribute of Chicken Nugget

Packaging Type	Storage Time (Day)				
	0	5	10	15	20
Nylon/PE	3.74±0.72^{ab}	3.66±0.93^{ab}	3.55±1.05^{ab}	3.39±1.02^{ab}	3.37±1.05^{b}
Nylon/PE/PA	3.87±0.70^{ab}	3.68±0.80^{ab}	3.61±0.82^{ab}	3.45±1.00^{ab}	3.42±0.91^{ab}
PE/PA	3.92±0.78^{a}	3.71±0.86^{ab}	3.45±0.76^{ab}	3.63±1.14^{ab}	3.53±1.05^{ab}

Note: The values with different superscripts differ significantly ($p < 0.05$)

On the 20th day of storage, the texture acceptability score reached 3.0 in Nylon/PE, while it was 3.26 in Nylon/PE/PA and 3.29 in PE/PA. Previous studies showed that the activity of microorganisms can degrade protein which causes the texture of chicken nuggets to become soft. The texture of the chicken nuggets decreased after 20 days of storage could be because of increased loss of water, reduction in pH, and degradation of muscle fiber protein by bacterial activity (Kumar et al., 2011). The activity of microorganisms at cold storage is lower so the rate of change in chicken nugget texture is slower compared to chicken nuggets stored at room temperature (Lindriati et al., 2022). Nursafira et al. (2021) reported that vacuum packaging in meat products will inhibit the circulation of air and water vapor which can inhibit the microbial growth.

The packaging type and storage time had a significant effect ($p < 0.05$) on the overall acceptability score of the chicken nuggets. The results of the overall acceptability scores of chicken nuggets are shown in Table 12. As can be seen, the overall acceptability score of the chicken nugget with jack bean tempeh flour substitution ranged between 3.37 and 3.92 (like slightly). This score was slightly decreased with increasing the storage time.

On the 20th day of storage, the overall acceptability score reached 3.37 in Nylon/PE, while it was 3.42 in Nylon/PE/PA and 3.53 in PE/PA. This score indicates that the chicken nuggets were still suitable for consumption at the end of storage. Despite good quality characteristics even on day 20, owing to the development of slight off-flavor and low tenderness.

Conclusion

The packaging type and storage time significantly affected the quality characteristics of chicken nuggets substituted with jack bean tempeh flour ($p < 0.05$). PE/PA was the most suitable plastic packaging for maintaining the quality characteristic of chicken nuggets substituted with jack bean tempeh flour during 20 days of cold storage under vacuum packaging conditions. The physical and chemical quality of chicken nuggets substituted with jack bean tempeh flour on the 20th day of storage were pH of 6.43, cooking loss of 9.85%, moisture content of 39.46%, protein content of 24.51%, TVBN content of 16.44 mg N/100 g, and TPC of 5.36 log cfu/g. Meanwhile, the result of the sensory evaluation showed that scores for attributes were color 3.63, aroma 3.45, taste 3.5, texture 3.29, and overall 3.53 (like slightly) on the 20th day of storage. The best storage time of chicken nuggets substituted with jack bean tempeh flour in all types of packaging was microbiologically safe after cold storage for 10 days.

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References

Abbasi, M., Ahari, H., Tabari, M. 2020. Comparative study of polyethylene and polyamide packaging containing silver nanoparticles in reduction of meat products (mince meat) microbial load. Journal of Food Biosciences and Technology 10(1): 87-102. https://journals.srbiau.ac.ir/.

Abiala, O., Abiala, M., Omojola, B. 2022. Quality attributes of chicken nuggets extended with diferent legume fours. Food Production, Processing and Nutrition 4(20): 1-11. DOI: https://doi.org/10.1186/s43014-022-00099-9.

Abubakar, A., Frima, C.A., Silvia, V., Fitri, C.A., Hanum, Z., Mariana, E. 2023. Quality and organoleptic test of beef nuggets with tempeh flour substitution. IOP Conference Series: Earth and Environmental Science, 1183, 012067. DOI: https://doi.org/10.1088/1755-1315/1183/1/012067.

Affandi, D.R., Ishartani, D., Wijaya, K. 2020. Physical, chemical and sensory characteristics of jack bean (*Canavalia ensiformis*) tempeh flour at various drying temperature. AIP Conference Proceedings 2219, 070004. DOI: https://doi.org/10.1063/5.0004674.

Aini, A. F. N., Hasojuwono, B. A., Suhendra, L. 2021. Characteristics of cornstarch and glucomannan bioplastik composites on treatment of type and concentration of filler. Jurnal Rekayasa dan Manajemen Agroindustri 9(4): 456-468. (In

Bahasa Indonesia). DOI: https://doi.org/10.24843/JRMA.2021.v09.i04.p03.

Alrawashdeh, H., Abu-Alruz, K. 2022. Development of high-fiber, low fat chicken nuggets. International Journal of Food Studies 11(2): 354–373. DOI: https://doi.org/10.7455/ijfs/11.2.2022.a8.

Banerjee, D.K., Devadason, I.P., Mendiratta, S.K., Agrawal, R.K., Dhineshkumar, V. 2019. Physico-chemical, sensory and microbiological quality characteristics of tray packaged chicken nuggets wrapped with different films and stored at frozen condition. International Journal of Current Microbiology and Applied Sciences 8(7): 793-808. DOI: https://doi.org/10.20546/ijcmas.2019.807.096.

Brainerd, E., Junianto, J. 2021. Review article: Use of vacuum packaging in smoked fish products. Global Scientific Journals 9(11): 119-125. http://www.globalscientificjournal.com.

Choi, M.J., Abduzukhurov, T., Park, D.H., Kim, E.J., Hong, G.P. 2018. Effects of deep freezing temperature for long-term storage on quality characteristics and freshness of lamb meat. Korean Journal for Food Science of Animal Resources 38(5): 959-969. DOI: https://doi.org/10.5851/kosfa.2018.e28.

Dalle, D., Natsir, H., Dali, S. 2021. Effect of adding 2.5% chitosan to fish nuggets through analysis of total volatile base (TVB) and organoleptic tests. Indonesian Journal of Chemical Analysis (IJCA) 4(1): 1-10. (In Bahasa Indonesia). DOI: https://doi.org/10.20885/ijca.vol4.iss1.art1.

Dewi, S.H.C., Prihharsanti, A.H.T. 2012. The effect of different meat shop on meat physical characteristics and bacteria population. Journal of Indonesian Tropical Animal Agriculture 37(1): 59-63. DOI: https://doi.org/10.14710/jitaa.37.1.59-63.

El-Sohaimy, S.A., El-Wahab, M.G.A., Oleneva, Z.A., Toshev, A.D. 2022. Physicochemical, organoleptic evaluation and shelf-life extension of quinoa flour-coated chicken nuggets. Journal of Food Quality. DOI: https://doi.org/10.1155/2022/9312179.

Falahudin, A., Rahmah, U. I. L., Ismail, T. 2022. Physical and organoleptic characteristics of discarded laying hens nuggets with the addition of purple sweet potato flour (*Ipomoea batatas*). AGRIVET Jurnal Ilmu Pertanian dan Peternakan 10(2): 238-244. (In Bahasa Indonesia). DOI: https://doi.org/10.31949/agrivet.v10i2.3960.

Fatharani, A., Bintoro, N., Saputro, A.D. 2020. Respiration rate modeling of sugar palm fruit (*Arenga pinnata*) in modified atmospheric packaging (MAP). agriTECH 40(2): 124-132. (In Bahasa Indonesia). DOI: https://doi.org/10.22146/agritech.50247.

Furqon, A., Maflahah, I., Rahman, A. 2016. Effect of packaging type and storage time on product quality of gembus nuggets. AGROINTEK Jurnal Teknologi Industri Pertanian 10(2): 70-75. (In Bahasa Indonesia). DOI: https://doi.org/10.21107/agrointek.v10i2.2468.

Giovani, S., Aidina, R., Komalasari, E., Puteri, N.E. 2023. Formulation and organoleptic characteristic of the composite flour from blends of red seaweed, yellowfin tuna fishbone, and jack bean tempeh. Jurnal Teknologi Pangan 17(2): 55-69. (In Bahasa Indonesia). http://www.ejournal.upnjatim.ac.id/.

Hafid, H., Patriani, P., Nuraini, Agustina, D., Fitrianingsih, Inderawati, Ananda, S.H. 2021. Properties of organoleptic nuggets with basic materials chicken intestine and breadfruit flour. IOP Conference Series: Earth and Environmental Science, 782, 022077. DOI: 10.1088/1755-1315/782/2/022077.

Hairunnissa, L., Sari, A.K., Jati, I.S., Shalihah, I.M., Akifah, S.D., Izzati, A.N., Putri, N.A., Najah, Z. 2021. Chemical and organoleptic characteristics of chicken nugget based on composite flour from MOCAF, brown rice, and corn starch. Food ScienTech Journal Vol. 3 (1): 76-83. DOI: http://dx.doi.org/10.33512/fsj.v3i1.12224.

Hatta, W., Abustam, E., Arham. 2020. The effect of brown rice flour on the quality of dangke nuggets during cold storage. IOP Conference Series: Earth and Environmental Science, 492, 012045. DOI: 10.1088/1755-1315/492/1/012045.

Hur, S.J., Jin, S.K., Park, J.H., Jung, S.W., Lyu, H.J. 2013. Effect of modified atmosphere packaging and vacuum packaging on quality characteristics of low-grade beef during cold storage. Asian-Australasian Journal of Animal Sciences 26(12): 1781-1789. DOI: https://doi.org/10.5713/ajas.2013.13225.

Kariang, L., Sembor, S.M., Ratulangi, F.S., Waani, M.R. 2023. Physical and organoleptic properties of chicken nuggets using broccoli (*Brassica oleracea var italica*). Zootec 43(1): 118-129. (In Bahasa Indonesia). https://ejournal.unsrat.ac.id/v3/index.php/zootek/article/view/47981/43058.

Kim, H.Y., Kim, K.J., Lee, J.W., Kim, G.W., Choe, J.H., Kim, H.W., Yoon, Y., Kim, C.J. 2015. Quality evaluation of chicken nugget formulated with various contents of chicken skin and wheat fiber mixture. Korean Journal for Food Science of Animal Resources 35(1): 19-26. DOI: http://dx.doi.org/10.5851/kosfa.2015.35.1.19.

Kumar, V., Biswas, A.K., Chatli, M.K., Sahoo, J. 2011. Effect of banana and soybean hull flours on vacuum-packaged chicken nuggets during refrigeration storage. International Journal of Food Science and Technology 46(1): 122–129. DOI: https://doi.org/10.1111/j.1365-2621.2010.02461.x.

Kusuma, C., Rusman, R., Jamhari, J. 2017. Meat preservation with addition of kecombrang leaves (*Etlingera elatior*) in refrigerator temperature. Animal Production 19(1): 61-69. DOI: http://dx.doi.org/10.20884/1.jap.2017.19.1.587.

Lindriati, T., Suwasono, S., Widiyaningsih, W.R. 2022. Applications of vacuum and non-vacuum packaging for chicken nugget substituted with meat analog from cocoyam and soy protein isolates. Jurnal Teknologi Pangan 6(1): 18-25. (In Bahasa Indonesia). DOI: https://doi.org/10.14710/jtp.2022.31564.

Ma'ruf, W., Rosyidi, D., Radiati, L.E., Purwadi, P. 2019. Physical and organoleptic properties of chicken nugget from domestic chicken (*Gallus domesticus*) meat with different corn flours as filler. Research Journal of Life Science 6(3): 162-171. DOI: https://doi.org/10.21776/ub.rjls.2019.006.03.2.

Maghraby, O., Hassouba, M.M., Eman, El-Mossalami, E. 2013. Effect of methodology on the determination of total volatile basic nitrogen as an index of quality of meat and fish. Egyptian Journal of Food Safety 1(2): 23-34. DOI: 10.21608/EJFSJ.2013.135900.

Mastini, L. P. W.S., Hartiati, A., Mulyani, S. 2015. Effect of packaging type and temperature storage of dough satay (*luluh*) based on some characteristics. Jurnal Rekayasa dan Manajemen Agroindustri 3(4): 1-12. (In Bahasa Indonesia). https://ojs.unud.ac.id/index.php/jtip/article/view/19576.

Mawla, A. M., Sutan, S. M., Hawa, L. C. 2018. The characteristics of various types of nuggets in cold storage. Teknotan Jurnal Industri Teknologi Pertanian 12(2): 17-22. (In Bahasa Indonesia). DOI: https://doi.org/10.24198/jt.vol12n2.4.

Moosavi-Nasab, M., Asgari, F., Oliyaei, N. 2019. Quality evaluation of surimi and fish nuggets from Queen fish (*Scomberoides commersonnianus*). Food Science and Nutrition 7(10): 3206-3215. DOI: https://doi.org/10.1002/fsn3.1172.

Nursafira, J., Munandar, A., Surilayani, D. 2021. Effect of different packaging materials on the quality of bandeng presto by vacuum packaging at cold temperature. Media Teknologi Hasil Perikanan 9(2): 59-68. (In Bahasa Indonesia). DOI: https://doi.org/10.35800/mthp.9.2.2021.33963.

Raeisi, S., Ojagh, S.M., Pourashouri, P., Salaün, F., Quek, S.Y. 2021. Shelf-life and quality of chicken nuggets fortified with encapsulated fish oil and garlic essential oil during refrigerated storage. Journal of Food Science and Technology 58(1): 121–128. DOI: https://doi.org/10.1007/s13197-020-04521-3.

Rani, R., Yadav, S., Thakur, N., Kumar, S., Han, H., Alturki, H.A., Ahmad, M.F., Raposo, A. 2024. Effect of incorporation of pumpkin seed powder and chia seed powder on storage stability of fiber enriched chicken meat nuggets. LWT - Food Science and Technology 191: 1-10. DOI: https://doi.org/10.1016/j.lwt.2023.115574.

Razie, F., Widawati, L. 2018. Combination of vacuum packaging and packing thickness to prolong the shelf life of tempe. AGRITEPA Jurnal Ilmu dan Teknologi Pertanian 5(1): 94-107. (In Bahasa Indonesia). DOI: https://doi.org/10.37676/agritepa.v5i1.721.

Revitriani, M., Puspitasari, D., Rejeki, F.S. 2022. Characteristic of wheat flour nuggets: study of cooking process and proportion of red beans. FOODSCITECH 5(2): 114-122. DOI: http://doi.org/10.25139/fst.vi.5085.

Rohaya, S., Rahmat, F., Sulaiman, I. 2024. Shelf-life prediction of chicken nuggets based on the thickness level of composite plastic packaging using accelerated shelflife testing (ASLT) method by the Arrhenius equation approach. IOP Conference Series: Earth and Environmental Science, 1297, 012078. DOI: https://doi.org/10.1088/1755-1315/1297/1/012078.

Salama, A., Ammar, M.S., Kadry, M.M. 2016. Effect of packaging system and herbs extracts on chemical and microbiological stability of chicken meat nuggets during cold storage. Al-Azhar Journal of Agricultural Research 26: 578-589. https://ajar.journals.ekb.eg/.

Silvia, D., Yusuf, M.R., Zulkarnain, Z. 2022. Analysis of pH levels and organoleptic chicken meat with vacuum and non-vacuum methods. Metana: Media Komunikasi Rekayasa Proses dan Teknologi Tepat Guna 18(1): 1-6. (In Bahasa Indonesia). DOI: 10.14710/metana.v18i1.40661.

Sinaga, E.F., Langi, T.M., Koapaha, T. 2022. Effect of additional flour of Moringa oleifera (*Moringa oleifera*) on organoleptic and chemical properties of tempe nugget. Applied Agroecotechnology Journal 3(2): 205-212. DOI: https://doi.org/10.35791/jat.v3i2.42716.

Sujarwanta, R.O., Jamhari, Suryanto, E., Yuliatmo, R., Prayitno, A.H. 2019. Physicochemical and sensory characteristics of chicken nugget with curcuma (*Curcuma zanthorrhiza*) flour fortification. IOP Conference Series: Earth and Environmental Science, 387, 012091. DOI: 10.1088/1755-1315/387/1/012091.

Sulandari, L. 2017. Effects of packaging types on moisture content, microbe total and peroxide value of instant ganyong (*Canna edulis Kerr*) yellow rice. UNEJ e-Proceeding: 379-383. https://jurnal.unej.ac.id/index.php/prosiding/article/view/5265.

Talab, A.S., Khallaf, M.M.M., El-Kalyoubi, M.H.O., Abdel-Fattah, A. A., Abou-Taleb, S.M. 2023. Effect of some food additives on carp fish nugget quality during frozen storage. Egyptian Journal of Aquatic Biology and Fisheries 27(4): 979-892. DOI: 10.21608/ejabf.2023.313285.

Talukder, M.A.K., Hashem, M.A., Rahman, S.M.E., Islam, M.S., Hossain, M.M., Ali, M.S., Azad, M.A.K., Luna, R. 2013. Study on varying salt level and storage time on physico-chemical and sensory quality of beef nugget. Progressive Agriculture 24(1-2): 149-158. DOI: http://dx.doi.org/10.3329/pa.v24i1-2.19280.

Tian, T., Kang, Y., Liu, L., Wang, X. 2022. The effect of super-chilled preservation on shelf life and quality of beef during storage. Food Science and Technology (Campinas) 42: 1-6. DOI: https://doi.org/10.1590/fst.73222.

Zahra, S.A., Butt, Y.N., Nasar, S., Akram, S., Fatima, Q., Ikram, J. 2016. Food packaging in perspective of microbial activity: a review. Journal of Microbiology, Biotechnology, and Food Sciences 6 (2): 752-757. DOI: 10.15414/jmbfs.2016.6.2.752-757.