Utilization of Seaweed (*Kappaphycus alvarezii*) Flour as Filler in Making Tempeh Nugget

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**Abstract** Tempeh is high protein food product and has a distinctive soybean aroma which is less favorable. Tempeh can be processed into preferred food such as tempeh nugget. Tempeh has a soft texture, so it is necessary to add filler to improve the texture. The fillers are commonly used are cassava flour, wheat flour, and corn starch. Seaweed flour has high in dietary fiber are used as filler for nugget. The purpose of this research was to substitute cassava flour with 10%, 20%, 30%, 40%, 50% seaweed flour and 0% as control nugget. Physical testing was carried out on each tempeh nugget. Storage testing was carried out on 3 (three) types of tempeh nugget (0% control nuggets without preservatives, 0% control nuggets with preservatives, and the best formulation nugget without preservatives). Tempeh nugget with substitution 50% of seaweed flour was chosen as the best formulation which has the most similar texture, color, and frying shrinkage, compare to commercial chicken nugget and also resulted in higher value 9.88% of fiber, while 0% control tempeh nugget 4.24%. Storage test in the freezer (-20°C) showed that nuggets with 50% seaweed flour substitution could not maintain the physical quality of tempeh nuggets in one week compared to control nugget.

**Keywords:** dietary fiber, nugget, seaweed flour, tempeh

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**Introduction**

In Indonesia, there are a variety of processed food products, including nuggets. Nuggets that are widely sold commercially are chicken nuggets and fish nuggets. According to Indonesian National Standardization (SNI, 2014), chicken nuggets are processed from chicken and made from a mixture of chicken meat with or without the addition of other food ingredients, or permitted food additives, given coating, sold with or without frying and freezing. Tempeh is a food product high in nutrients and many produced in Indonesia. Tempeh has not been processed into preferable food products such as nugget. Tempeh has a soft texture, so tempeh nugget needs filler to improve the texture.

An example of a common filler used in nugget is cassava starch or cassava flour. Indonesia is a country that is rich in seaweed. The production of seaweed in Indonesia increases up to 1,341,141 tons in 2006 (Directorate General of Aquaculture [1]). One type of seaweed that is usual in Indonesia is *Kappaphycus alvarezii*. Seaweed can be made into flour and use for cassava starch substitution as a filler of nugget. The addition of fillers can increase the value-added of meat products (Kusumaningrum et al. [2]).

**Materials and methods**

The main materials used in this research were seaweed types *Kappaphycus alvarezii*, soybeans, preservative sodium benzoate, wheat flour "Segitiga Biru", tapioca starch "Rose Brand", salt, sugar, Mono Sodium Glutamate, garlic flour, pepper, binder ISP, cold water, bread crumb, and cooking oil. The chemical used for the analysis were H₂SO₄, NaOH, pH indicator, starch indicator, KI, Na₂S₂O₃, HCl, alcohol, methyl red, boric acid, pepsin enzyme, ethanol, sodium phosphate buffer, and 96% alcohol.

The equipment used in this research were frying pan, deep fat fryer, food processor, freezer, desiccator, erlenmeyer, dry blender, pH meter, blast furnace, sieve tyler, drum dryer, kjeldahl equipment, soxhlet, chromatometer, fat extraction tools, oven.

**Research Procedures**

This research consists of phase I and phase II. Phase I research aims to determine the best formulation where cassava flour filler is substituted with seaweed flour with different concentrations which produce tempeh nuggets with the best physical and organoleptic
characteristics. Physical parameters are the main parameters in determining the characteristics of tempeh nuggets and organoleptic parameters function as supporting parameters. Phase II research aims to determine the type of tempeh nuggets and storage time which produces characteristics that are not different from before storage.

**Research Phase I**

**Tempeh Making**

Soybean are sorted and washed in water and then soaked in water for 12 hours. Then peeled off the skin and boiled for 20 minutes. Make sure the soybean is cooled before yeast were added and wrapped in banana leaves and fermented for 48 hours at room temperature. The process of making tempeh can be seen in Fig.1

![Tempeh Making Process Diagram](image)

**Seaweed Flour Making**

The seaweed are processed into seaweed flour. The process of making seaweed flour can be seen in Fig. 2. The use of a drum dryer in this research is due to the fact that seaweed has a hard texture, so it is necessary to reduce the size by using a drum dryer to produce a good flour texture.

![Seaweed Flour Making Process Diagram](image)

**Tempeh Nugget Making**

Tempeh is steamed for 10 minutes and then crushed using a food processor. The remaining ingredients are mixed and cut to size,
coated with batter and followed by coating with bread crumbs. Freezing in the freezer (-20 °C) for 30 minutes and then fry in deep fat fryer 160°C, 3 minutes.

**Research Phase II**

**Storage Test**
Nugget with the best formulations in phase I were tested the frozen storage and compared with some type of tempeh nugget. Storage was done in the freezer (-20 °C) (0 weeks, 1 week, 2 weeks). Nugget would be fried in deep fat fryer temperature of 180°C, 3 minutes.

Statistical analysis in the Phase I and Phase II research were obtained using the Statistical Package for the Social Sciences (SPSS) program.

**Analysis**
The analysis conducted in this study were total soluble solid (FSSAI, 2012), pH (AOAC, 2005), total titratable acidity (OIV, 2012), alcohol content (FSSAI, 2015), clarity (Cheirsilp and Umsakul, 2008; OIV, 2008) 2012), color (Nielsen, 2010), organoleptic tests (Lawless and Heymann, 2010), total phenolics (Alara et al., 2018), total flavonoids (Lamien-Meda et al., 2008), antioxidant activity (Parlina et al., 2012), and alcohol content (Satapathy and Joshi, 2019).

**Making Tempeh Nuggets with Seaweed Flour Filler Substitution**
The formulation for making tempeh nuggets which are substituted with seaweed flour filler and the table for the battering nugget formulation can be seen in Table 1 and Table 2.

**Table 1. Formulation of Making Nugget in 100 g of ingredients**

<table>
<thead>
<tr>
<th>Formulation</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tempeh</td>
<td>70</td>
</tr>
<tr>
<td>Rock ice</td>
<td>10</td>
</tr>
<tr>
<td>Filler (Cassava and seaweed Flour)</td>
<td>13</td>
</tr>
<tr>
<td>Binder</td>
<td>0.3</td>
</tr>
<tr>
<td>Salt</td>
<td>1.5</td>
</tr>
<tr>
<td>Sugar</td>
<td>0.5</td>
</tr>
<tr>
<td>MSG</td>
<td>0.4</td>
</tr>
<tr>
<td>Pepper</td>
<td>0.8</td>
</tr>
<tr>
<td>Garlic Powder</td>
<td>3</td>
</tr>
<tr>
<td>Sodium Benzoat* (preservative)</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Note: *) this will be applied in Research Phase II

Source: Loa [5] with modification

**Table 2. Formulation of Battering**

<table>
<thead>
<tr>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salt</td>
</tr>
<tr>
<td>Wheat Flour</td>
</tr>
<tr>
<td>Water</td>
</tr>
</tbody>
</table>

Source: Pebri, et al.[6] with modification

The stages of making tempeh nuggets can be seen in Fig. 3.
**Research Phase II**

Research Phase II is using nuggets with the best formulation from phase I and compared to control nuggets without using preservatives and control nuggets with preservative and doing storage testing of storage nuggets in the same storage box. The preservative used is sodium benzoate with 0.05%.

Flow Diagram of Tempeh Nugget storage can be seen in Fig 4.

**Results and discussion**

**Tempeh Making**

The characteristics of tempeh can be seen in Table 3.

**Table 3. Characteristic of Steam Tempeh**

<table>
<thead>
<tr>
<th>(%)</th>
<th>Steam Tempeh (Research)</th>
<th>Steam Tempeh (*)</th>
<th>SNI Soybean Tempeh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>54.97±1.08</td>
<td>53.41</td>
<td>Max 65</td>
</tr>
<tr>
<td>Ash</td>
<td>0.59±0.06</td>
<td>1.44</td>
<td>Max 1.5</td>
</tr>
<tr>
<td>Protein</td>
<td>13.86±0.71</td>
<td>16.27</td>
<td>Min 16</td>
</tr>
<tr>
<td>Fat</td>
<td>7.13±0.33</td>
<td>6.54</td>
<td>Min 10</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>23.45±1.25</td>
<td>10.93</td>
<td>-</td>
</tr>
<tr>
<td>Total Fiber</td>
<td>11.50</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Yield</td>
<td>155.33±6.55</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
*) Source: Astuti et al., 2014[8]

**Seaweed Flour Making**

The characteristics of seaweed flour (*Kappaphycus alvarezii*) can be seen in Table 4.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water content</td>
<td>14.72 ±0.62</td>
</tr>
<tr>
<td>Ash content</td>
<td>10.96±0.48</td>
</tr>
<tr>
<td>Protein content</td>
<td>7.40±0.28</td>
</tr>
<tr>
<td>Fat content</td>
<td>1.31±0.08</td>
</tr>
<tr>
<td>Carbohydrate content</td>
<td>65.60±0.96</td>
</tr>
<tr>
<td>Total Fiber content</td>
<td>10.71</td>
</tr>
<tr>
<td>Degree of Whiteness</td>
<td>73.86 ± 0.25</td>
</tr>
<tr>
<td>Water absorption</td>
<td>226.40±5.09</td>
</tr>
<tr>
<td>Yield</td>
<td>3.58±0.02</td>
</tr>
</tbody>
</table>

**Table 4. Characteristic of Seaweed Flour (*Kappaphycus alvarezii*)**

**Effect of Seaweed Flour Substitution on Characteristics of Tempeh Nugget**

**Lightness**

Based on the results of statistical analysis of the lightness as physical characteristics of tempeh nugget, there is no effect (p <0.05) of seaweed flour filler substitution, towards lightness tempeh nugget. Results showed the lightness of tempeh nugget with different concentration of seaweed flour substitution can be seen in Fig. 5. The highest lightness value is in nugget with concentrations of 0% or without addition of any seaweed flour. This could be compared to tempeh nugget without seaweed flour with only use cassava starch as a filler has a whiteness of more than 90%. The results of lightness test in commercial chicken nugget is 68.20%. These results indicate that seaweed flour substitution at concentrations of 0% (means no substitution with seaweed flour) has a lightness value approaching the commercial chicken nugget.

![Figure 5. Effect of seaweed flour filler substitution on lightness of tempeh nugget](image)

Note: Different letter notations indicate a significant difference (p ≤ 0.05)

**Frying Loss**

Based on the results of the statistical test on frying loss in tempeh nuggets, the data p>0.05, so that there was no effect of substitution of seaweed flour filler on the frying loss of tempeh nuggets. According to Loa [5], frying loss is an indicator of nutritional value and is related to the amount of water.

**Hardness**

Based on the results of statistical test to hardness of tempeh nuggets, the data p<0.05, there is an effect of seaweed flour filler substitution to the hardness of tempeh nuggets. Hardness value tends to increase in line with the addition of seaweed flour. Changes in value are possible because the texture of seaweed contains carrageenan which has high in water holding capacity resulting in higher texture (Prastyawan et al., 2015 [9]). Hardness test results on commercial chicken nuggets is 207.74 gram. These results indicate seaweed flour substitution at a concentration of 50% has a hardness that approaching to commercial chicken nugget.
**Springiness**
Based on the results of statistical test to springiness in tempeh nuggets, the data \( p<0.05 \), so there is an effect of seaweed flour filler substitution to springiness of tempeh nuggets. Springiness also called elasticity (Wijayanti, et al., 2015 [10]). Increased percentage of seaweed flour tends to increase springiness in tempeh nuggets. Springiness value of commercial chicken nugget is 0.967mm. Springiness value approaching to chicken nugget substituted with 50% seaweed flour.

**Cohesiveness**
Based on the results of statistical test to cohesiveness of tempeh nuggets, the data \( p<0.05 \), so there is an effect of seaweed flour filler substitution to cohesiveness of tempeh nugget. Increased percentage flour seaweed tends to increase cohesiveness on tempeh nuggets. According Herdiani [11], the addition of high starch concentration of seaweed that the higher cause textures formed more hard and brittle. Value cohesiveness of commercial chicken nugget is 0.51 kg.sec. This means the value of cohesiveness approaching tempeh nuggets, chicken nugget was substituted with 50% flour seaweed.

**Chewiness**
Based on the results of statistical test to chewiness on tempeh nuggets produce data \( p<0.05 \), so there is an effect of the concentration of starch filler seaweed against chewiness tempeh nuggets. Increased percentage flour seaweed tends to increase the value of chewiness on tempeh nuggets. According Aveline [12], plasticity can be influenced by the added of seaweed flour concentration. Chewiness value of commercial chicken nugget is 103.95 g.mm. This means the value of chewiness approaching chicken nugget is tempeh nugget was substituted with 50% seaweed flour.

**Hedonic Test**
The hedonic organoleptic test of tempeh nuggets was carried out with a rating scale starting from 1-7. Scale of 7 indicates strongly favored, while a scale of 1 indicates strongly disliked. Statistical test results on organoleptic hedonic or preference where the color data showed that \( p>0.05 \), while the texture, aroma, firmness, and overall produce data \( p<0.05 \). These results can be concluded that there is the significant different of substitution of seaweed flour filler with different concentrations of the level of preference of panelist on texture, aroma, firmness, and overall of tempeh nuggets whereas no effect of hedonic test color in tempeh nuggets. This shows panelists like tempeh nugget which produces the characteristic is not too hard, brown, chewy and not very flavorful tempeh.

**Determination of Seaweed Flour Filler Substitution to the Best Characteristics of Tempeh nugget**
The test results of hardness, cohesiveness, springiness and chewiness showed tempeh nugget with seaweed flour 50% has value close to the commercial chicken nugget. The highest value of \( \text{9h}\text{ue} \) is nugget without seaweed flour substitution (0%). According to Hutching [13], the range of values resulting from the \( \text{9h}\text{ue} \) nugget is in the range of 54-90 that shows yellow red. Based on test of lightness and color (\( \text{9h}\text{ue}, \text{a} \text{ and b of chromameter} \) tempeh nugget without seaweed flour substitution (0%) have the highest lightness value and approaches the lightness and color of chicken nugget. But from the scoring test texture and elasticity tempeh nugget with 50% of seaweed flour substitution has the highest scores. So, based on the physical and organoleptic test conducted, it is concluded that the best tempeh nuggets is nugget with 50% seaweed flour substituted. This formulation are used for the storage test in research phase II together with 0% seaweed flour with and without preservatives (three samples). The three samples are stored at the same temperature -20°C for 1-2 week and the effect of storage time on the characteristics of three types of tempeh nuggets are analyzed for the physical properties and proximate analysis.

**pH**
Based on the results of statistical analysis of the physical characteristics of the pH nugget, type of tempeh nugget and storage time had an effect (\( p<0.05 \)), while the interaction between the types of tempeh nugget and storage time has no effect (\( p>0.05 \)). The results of the pH value of the nugget can be seen in Fig. 6 and Fig. 7. The highest pH is in tempeh nugget without seaweed flour substitution and without preservatives. While the lowest pH value is tempeh nugget with 50% of seaweed flour substitution without preservatives. According Prastyawan, et al. [9], the higher of concentration of seaweed flour added, it can increase the pH. The best tempeh nugget is a tempeh nugget without seaweed flour substitution (0%) without preservatives, because it produces the highest pH. In the first week of storage, pH tempeh nuggets tend to decrease and after 2 weeks of storage, the pH tends to increase. The decrease in soybean pH associated with the formation of acid due to fermentation. The increase in pH levels due to the degradation of soy protein into amino acids by proteolytic enzyme activity by mold. Best storage time is one week due to the nugget decreased pH values has no different than before storage. Chicken nugget storage is done as a comparison and showed pH of chicken nugget before storage has a value of 6.39 and 6.40 on week 1 and week 2. It can be seen that during storage the pH value of the commercial nugget tend to increase.
In the hardness test, a nugget seaweed flour substitution with 50% deposit 1 week resulted in a value that is not different hardness value prior to storage. In springiness test, the type of nugget and storage time generating value did not differ significantly. On the test of cohesiveness and pH, the best nugget is a nugget of 0% without preservative with a storage time of 1 week.

In the test chewiness, best nugget is a nugget of 0% with preservative with one week storage time. Then it was concluded that the best nugget is a tempeh nugget without flour substitution seaweed (0%) without preservative with a storage time of 1 week. Seaweed flour substitution Kappaphycus alvarezii and the addition of preservatives cannot maintain a physical quality of tempeh nuggets.

**Proximate Analysis of Tempeh Nugget**

The three types of Tempeh Nuggets proximate analysis results are shown in Table 5

<table>
<thead>
<tr>
<th>Content (%)</th>
<th>Tempeh Nugget 0% without seaweed flour*</th>
<th>The Best Tempeh Nugget 50% seaweed flour**</th>
<th>SNI Nugget</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>44.26±1.57</td>
<td>58.41±0.48</td>
<td>Max 50 %</td>
</tr>
<tr>
<td>Ash</td>
<td>1.62±0.03</td>
<td>1.94±0.03</td>
<td>-</td>
</tr>
<tr>
<td>Protein</td>
<td>10.31±0.07</td>
<td>12.36±0.32</td>
<td>Min 12 %</td>
</tr>
<tr>
<td>Fat</td>
<td>13.74±0.19</td>
<td>14.86±0.42</td>
<td>Max 20%</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>29.49±0.78</td>
<td>12.43±0.34</td>
<td>Max 20%</td>
</tr>
<tr>
<td>Dietary Fibre</td>
<td>4.24</td>
<td>9.88</td>
<td>-</td>
</tr>
</tbody>
</table>

The dietary fiber content of control tempeh nuggets without substitution of 0% seaweed flour was 4.24%, while the best tempeh nuggets with 50% seaweed flour substitution resulted in 9.88% dietary fiber content. This shows that an increase in the percentage of seaweed flour substitution can increase the dietary fiber content of tempeh nuggets. Based on the test results of proximate tempeh nuggets, it can be seen that the best tempeh nuggets chosen from this research increase in protein, ash, moisture, fat, and dietary fiber comparing to control tempeh nuggets.
Conclusions

*Kappaphycus alvarezi* seaweed flour has high carbohydrate 65.6%, protein 74.04%, and total dietary fiber content 10.71%. But having small yield 3.58% when making dry seaweed into seaweed flour and also having water absorption 226.40%. The best formulation of tempeh nuggets is tempeh with 50% seaweed flour substitution, based on the physical and organoleptic test (texture, color, scoring and hedonic) results which are approaching the value of commercial chicken nuggets.

Frozen storage can maintain the physical quality of tempeh nuggets. Tempeh nuggets which produce characteristics that are not different from before storage, are tempeh nuggets without 0% seaweed flour and without the addition of preservatives with a storage time of 1 week. Frozen storage 1 week is able to maintain the physical quality of tempeh nuggets without seaweed flour substitution and without the addition of preservatives. Nugget with the best formulation from this research (with 50% seaweed flour substitution) cannot maintain the physical quality of tempeh nugget in the same 1 week. In further storage research, the TPC (Total Plate Count) test can be carried out for storage research to determine the microbes that appear after storage.

Conflicts of interest

There is no conflict of interest regarding the publication of this paper because this publication is the result of the author's research in the laboratory using materials selected by the authors and identified in a government laboratory.

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