Amerta Nutrition
e-ISSN: 2580-1163 (Online)
p-ISSN: 2580-9776 (Print)
Djamaludin et al. | Amerta Nutrition Vol. 8 Issue 3 (September 2024). 409-415

RESEARCH STUDY
English Version
OPEN ACCESS

Fortification of *Eucheuma cottonii* Flour in Vaname Shrimp Nugget as a Source of Iodine

Fortifikasi Tepung Eucheuma cottonii pada Nugget Udang Vaname sebagai Sumber Yodium

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ARTICLE INFO

Received: *09-01-2023*
Accepted: *17-05-2024*
Published online: *30-09-2024*

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DOI:
10.20473/amnt.v8i3.2024.409-415

Available online at:
https://e-journal.unair.ac.id/AMNT

Keywords:
E. cottonii, Fortification, Iodine, Nugget, Vanname Shrimp

ABSTRACT

Background: Humans require iodine as a micronutrient; a deficit in this mineral lowers IQ. Seaweed (*E. cottonii*) is a non-salt source of iodine. Fortification of E. cottonii flour can be done on food products, such as nuggets. Aside from that, Vanname Shrimp are a high-protein fishery product that can be utilized as a base for nuggets. Therefore, to prevent iodine deficit, Vanname Shrimp nuggets supplemented with *E. cottonii* flour can be developed as a substitute food.
Objectives: Fortification of *E. cottonii* flour in making Vanname Shrimp nuggets as an effort to increase the iodine content.
Methods: Three replications of a non-factorial Completely Randomized Design (CRD) were used in the study. The fisheries products laboratory at Brawijaya University's Faculty of Fisheries and Marine Sciences (FFMS) was the site of the research. There were four additions of *E. cottonii* flour: 0%, 7.5%, 10%, and 12.5%. Iodine content is the parameter for chemical testing; elasticity is the parameter for physical testing; and color, scent, taste, and texture are the criteria for organoleptic testing (the hedonic approach for determining the optimal treatment utilizing the de Garmo and proximal testing).
Results: The study found that adding different quantities of *E. cottonii* flour fortification significantly altered the iodine content and flexibility of Vanname Shrimp nuggets. *E. cottonii* flour is optimally fortified at a level of 7.5% treatment, with iodine content of 6.17 mcg/g, elasticity of 6.65 N, carbohydrate content of 77.04%, protein content of 7.78%, fat content of 3.67%, water content of 9.85%, and ash content of 1.66%.
Conclusions: In order to prevent and treat iodine deficiency, the Vanname Shrimp nugget product fortified with *E. cottonii* flour should be further developed as a food option.

INTRODUCTION

Iodine is a small (micro) component needed by the human body. Iodine plays a role in brain development as a component that regulates nerves and is a substance the human body needs. The iodine intake required by the body is around 150 µg per day[1]. Iodine deficiency manifests in a decrease in intelligence levels, weakened muscles, and causes the face and eyes to look puffy[2]. The source of iodine commonly used by people is iodized salt. This is because salt is easy to obtain, affordable, and practical. Sources of iodine other than salt can be obtained from various plants (vegetables) depending on the region's altitude. Other sources besides agriculture are seafood, such as fish, shellfish, and algae.

The highest nutritional content of seaweed, apart from fiber, is iodine. Dried seaweed contains iodine reaching 300-700 ppm/bk[3]. Seaweed contains high levels of iodine, such as *E. cottonii*. The iodine content of *E. cottonii* reaches 9 µg/g compared to other seaweeds, such as *Sargassum polycystum with* 7.66 µg/g and *Caulerpa lentilifera* with 4.78 µg/g[4]. *E. cottonii* seaweed is usually marketed as dried seaweed or flour. Fortification of *E. cottonii* seaweed flour, which is high in iodine content, can be carried out in food products that are popular with the public, such as fast food, as an effort to prevent and overcome cases of iodine deficiency or what is known as Iodine Deficiency Disorders (IDD) in Indonesia. Consuming fast food has become a behavior or habit among people because this type of food is easy to obtain and served quickly. Fast food is also easy to find on the market and is popular with people from children to adults[5]. One of the fast-food products that consumers are interested in is nuggets.

Nuggets are a mixture of ground meat, herbs, and spices. The characteristic of nuggets is that the product's surface is coated by bread flour. After being coated, the nuggets are stored in a cooler at a low temperature so that the product lasts longer[6]. The nutritional

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composition of nuggets is 75.45% water content, 6.22% fat, 13.89% protein, and 1.91% ash[7]. Various forms of nugget products are on the market with different brands. Nuggets are low in iodine but high in fat. Nutrient enrichment of nuggets through fortification of *E. cottonii* flour can be an alternative source of iodine. The nuggets fortified with *E. cottonii* seaweed flour has the highest iodine content (2.54 µg/g) compared to other sources such as fish (0.076 µg/g), spinach (0.834 µg/g), and carrots (0.193 µg/g).

One of the potential raw materials for making nuggets that have high nutritional content is shrimp. It is the best source of protein when compared to other seafood. Shrimp contain 25.83 g of protein per 100 g of meat. The proximate value of wet and dry Vanname Shrimp meat is quite different, where the proximate value of wet Vanname Shrimp meat (per 100 g) is 19.38% protein. The proximate value of dried Vanname Shrimp meat (per 100 g) is 70.81% protein. Vanname Shrimp meat contains other nutrients in the form of essential amino acids. Apart from that, Vanname Shrimp meat also contains essential fatty acids such as Eicosapentaenoic Acid (EPA) (9%) and Docosahexaenoic Acid (DHA) (11.2%)[8]. The presence of amino and essential fatty acids is required in the metabolic systems of humans who consume them[9].

Various efforts to diversify food products have been carried out, one of which is fortification made from fishery products such as seaweed or other fortifiers that can increase food products' macro-micro nutrient and mineral content[10-14]. However, the development of food products such as Vanname Shrimp nuggets with *E. cottonii* flour fortification has yet to be widely carried out. Therefore, it is necessary to develop nugget products made from Vanname Shrimp with the addition of *E. cottonii* flour as an alternative form to overcome the problem of iodine deficiency or IDD. This research aims to fortify *E. cottonii* flour in making Vanname Shrimp nuggets to increase the iodine content in processed fishery food products.

METHODS

This research consists of two stages: preliminary and main Study. The preliminary study aims to determine the best concentration of *E. cottonii* flour fortification for making Vanname Shrimp nuggets and the best concentration range. The main study aims to obtain information on the most appropriate concentration of *E. cottonii* flour fortification so that it can produce iodine levels that suit human needs.

Preliminary Study

Making Vanname Shrimp Nuggets

The process for making Vanname Shrimp nuggets is cleaning the shrimp using the Peeled Tail On (PTO) process and weigh 200 g. The Vanname Shrimp meat is mashed using a blender, and the garlic and shallots are mashed. Then, the finely ground shrimp meat is mixed with wheat and *E. cottonii* flour in varying levels of 0%, 10%, 15%, and 20%. The amount of *E. cottonii* flour added was obtained by calculating the concentration of *E. cottonii* flour multiplied by the weight of the main ingredients: Vanname Shrimp, bread flour, pepper, fine shallots, fine garlic, celery leaves, flavorings, salt, and eggs. The dough is kneaded until ingredients are evenly distributed, then poured into a baking dish and steamed for 45 minutes at 100°C. After steaming, the dough is cut into several pieces measuring 3×4cm and then glued together with batter mix, which is a mixture of wheat flour and water with a ratio of 2:1 (w/v), then coated in breadcrumbs, and finally fried until golden brown. To determine the best amount of fortification of *E. cottonii* flour, organoleptic parameter analysis of hedonic tests with 30 untrained panelists were utilized. The formulation for making Vanname Shrimp nuggets enriched with *E. cottonii* flour in preliminary research is presented in Table 1.

Table 1. Formulation for making Vanname Shrimp nuggets fortified with *E. cottonii* flour

Ingredient	Amount			
	Formula 1 (0%)	Formula 2 (10%)	Formula 3 (15%)	Formula 4 (20%)
Vanname Shrimps (g)	200	200	200	200
Wheat Flour (g)	50	50	50	50
Corn Starch (g)	9	9	9	9
Bread Crumb (g)	100	100	100	100
E. cottonii Flour (g)	0 (0% × 200)	20 (10% × 200)	30 (15% × 200)	40 (20% × 200)
Garlic (g)	20	20	20	20
Onion (g)	20	20	20	20
celery Leaves (g)	15	15	15	15
Salt (g)	2.5	2.5	2.5	2.5
Flavoring (g)	3	3	3	3
Pepper (g)	1.5	1.5	1.5	1.5
Egg	1	1	1	1
Cooking Oil (L)	1	1	1	1

Main Study

The best fortification amount of *E. cottonii* flour in the preliminary research was determined and used as a reference range of fortification amounts for *E. cottonii* flour. In the main research, the level of fortification of *E. cottonii* flour was 0%, 7.5%, 10%, and 12.5%. The process for making Vanname Shrimp nuggets at this stage is the same as the previous research; there are only differences

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in the fortification of *E. cottonii* flour. The formulation for making Vanname Shrimp nuggets enriched with *E. cottonii* flour in the primary research is presented in Table 2.

Table 2. Formulation for making Vanname Shrimp nuggets fortified with *E. cottonii* flour

Ingredient	Amount			
	Formula 1 (0%)	Formula 2 (7.5%)	Formula 3 (10%)	Formula 4 (12,5%)
Vanname Shrimps (g)	200	200	200	200
Wheat Flour (g)	50	50	50	50
Corn Starch (g)	9	9	9	9
Bread Crumb (g)	100	100	100	100
E. cottonii Flour (g)	0 (0% × 200)	15 (7.5% × 200)	20 (10% × 200)	25 (12.5% × 200)
Garlic (g)	20	20	20	20
Onion (g)	20	20	20	20
celery Leaves (g)	15	15	15	15
Salt (g)	2.5	2.5	2.5	2.5
Flavoring (g)	3	3	3	3
Pepper (g)	1.5	1.5	1.5	1.5
Egg	1	1	1	1
Cooking Oil (L)	1	1	1	1

This research mainly analyzes chemical and physical parameters. Chemical parameters include iodine content (spectrophotometric method), carbohydrate content (Rough-Scholl method), protein content (Kjeldahl method), fat content (Soxhlet method), water content (gravimetric method), and ash content (including gravimetric testing (gravimetry). Physical parameters include elastic testing using a texture analyzer type LLOYD 1000S with a maximum load specification of 5000 N (maximum extension 1000 mm).

Statistical Analysis

Research data analysis was done using the Statistical Product and Service Solutions (SPSS) version 26 application (IBM, New York, USA)—analysis of the fulfillment of normality and homogeneity assumptions using residual data. If the data meets the assumption of normality, the data is processed using parametric statistics and continued with analysis of variance. If the data does not meet the normality assumption, the data is processed using non-parametric statistics and continued with Kruskal-Wallis analysis. Research data for each parameter is analyzed with a confidence level of 95% and a significance level of 5% to justify accepting or rejecting the hypothesis based on significance or p-value (probability).

RESULTS AND DISCUSSIONS

Preliminary Study

In preliminary research, fortification of *E. cottonii* flour from Vanname Shrimp nugget products used three levels of treatment, namely formula 1 (10%), formula 2 (15%), and formula 3 (20%). Determining the best concentration is based on the results of organoleptic tests using the hedonic method, namely, measuring the level of liking for a product. Ratings use a scale of 5 (very liked), 4 (liked), 3 (neutral), 2 (disliked), and 1 (very disliked). There were 30 panelists. The data for the hedonic test results were analyzed using Kruskal-Wallis nonparametric statistics.

Organoleptic is a crucial aspect that must be studied in food product development. Sensory evaluation is an instrument used to measure food preferences using human sensory organs. It is usually used to calculate a food product's texture, appearance, aroma, and taste. Humans have five senses: taste, smell, touch, sight, and hearing. All senses are important when eating food[15]. Organoleptic testing uses a minimum of 30 panelists. If panelists do not like a particular food product's appearance, taste, aroma, or texture, they will give a low assessment score[10]. Therefore, the overall sensory experience resulting from organoleptic testing is critical to the commercial success of food products.

Hedonic of Appearance

Based on the results of the Kruskal-Wallis analysis, it was found that fortification of *E. cottonii* flour significantly affected the appearance of Vanname Shrimp nuggets. The graph in Figure 1 shows that the higher the fortification level of *E. cottonii* flour, the less the panelists like it. This is because the higher amount of fortification of *E. cottonii* flour causes the appearance of the Vanname Shrimp nugget product to be blackish green.

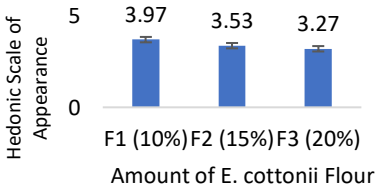

Figure 1. Hedonic value of appearance

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Hedonic of Aroma

Based on the results of the Kruskal-Wallis analysis, it was found that fortification of *E. cottonii* flour significantly affected the aroma of Vanname Shrimp nuggets. The graph in Figure 2 shows that the higher the fortification level of *E. cottonii* flour, the less it is liked by the panelists. This is because the higher the level amount of fortification of *E. cottonii* flour can reduce the level of panelists' liking for the aroma of the Vanname Shrimp nugget product. This explains that the panelists don't like the typical fishy smell of seaweed. The fishy aroma typical of seaweed must be combined with other ingredients (masking agents) to disguise the fishy aroma. The fishy aroma of seaweed is complex to disguise, even though the seaweed had been soaked in lime water[16].

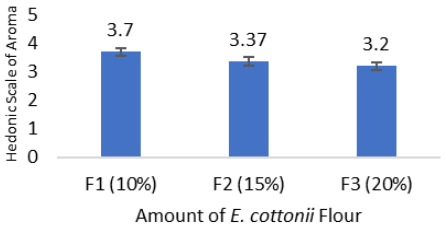

Figure 2. Hedonic value of aroma

Hedonic of Taste

Based on the results of the Kruskal-Wallis analysis, it was found that fortification of *E. cottonii* flour significantly affected the taste of Vanname Shrimp nuggets. The graph in Figure 3 shows that the higher the fortification level of *E. cottonii* flour, the less it is liked by the panelists. The Vanname Shrimp nugget product, before being fortified with *E. cottonii* flour, has a distinctive shrimp taste. In contrast, the Vanname Shrimp nugget, after fortification with *E. cottonii* flour, has a bitter taste. This is because fortifying *E. cottonii* flour can reduce the shrimp taste in nugget products. The higher fortification of seaweed causes a decrease in panelists' preference for the taste of seaweed cake products[17].

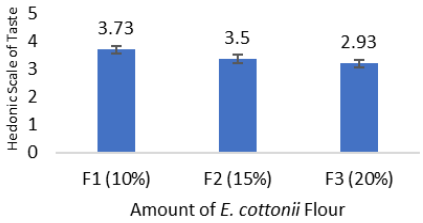

Figure 3. Hedonic value of taste

Hedonic of Texture

Based on the results of the Kruskal-Wallis analysis, it was found that fortification of *E. cottonii* flour significantly affected the texture of Vanname Shrimp nuggets. The graph in Figure 4 shows that the higher the level of fortification of *E. cottonii* flour, the less it is liked by panelists. The texture of the Vanname Shrimp nugget product before *E. cottonii* flour fortification was too chewy and compact, whereas the Vanname Shrimp nugget product after *E. cottoniii* flour fortification had a dense, chewy, slightly hard, and compact texture.

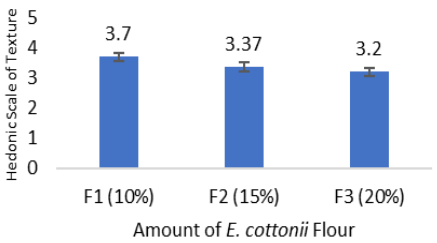

Figure 4. Hedonic value of texture

The organoleptic results showed that the Formula 1 treatment level with 10% fortification of *E. cottonii* flour was the fortification level with the highest value for the four parameters, namely appearance, aroma, taste, and texture. Therefore, it can be said that the panel prefers the fortification of *E. cottonii* flour, the Vanname Shrimp nugget product, at the treatment level of 10%. This concentration becomes a reference in determining the concentration range for the main research.

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Main Study

The primary study was carried out to find the most appropriate amount of fortification of *E. cottonii* flour by reducing the range of the best treatment level (10%) from the results of preliminary research and obtaining the range for the amount of fortification of *E. cottonii* flour in the main study, namely 0, 7.5, 10, and 12.5 (%). Apart from that, the main study also aims to characterize the Vanname Shrimp nugget product. Data were analyzed using parametric analysis of variance (ANOVA) statistics.

Iodine Content of Vanname Shrimp Nugget

Iodine is an important micromineral component for the growth and development of human brain cells. Iodine is also essential for the body's thyroid hormones. Iodine deficiency can cause the appearance of goiters, cretins, impaired growth and development. Iodine will be metabolized and absorbed in the body, then forming iodide. Iodine absorbed by the thyroid gland is at least 60 µg daily to balance thyroid hormone production[18].

Analysis of iodine levels using the spectrophotometry method. The iodine content of Vanname Shrimp nuggets fortified with *E. cottonii* flour is presented in Table 3. The ANOVA results illustrate that fortification of Vanname Shrimp flour significantly affects the iodine content of Vanname Shrimp nuggets. Duncan's Advanced test analysis showed that the treatment levels were significantly different. The average value of iodine content increased significantly as the level of fortification of *E. cottonii* flour increased.

Table 3. Iodine content of Vanname Shrimp nuggets enriched with *E. cottonii* flour

Treatment Levels for *E. cottonii* Flour	Iodine Content of Vanname Shrimp Nugget (mcg)
Formula 1 (0% *E. cottonii* flour)	2.21 ± 0.03[a]
Formula 2 (7.5% *E. cottonii* flour)	6.17 ± 0.11[b]
Formula 3 (10% *E. cottonii* flour)	7.43 ± 0.13[c]
Formula 4 (12.5% *E. cottonii* flour)	8.73 ± 0.10[d]

Note: Different letter notations in the same column show significant differences ($p<0.05$).

Seaweed flour contains high iodine of 300-700 ppm in 100 g dry weight, so fortifying *E. cottonii* flour can increase the iodine content of Vanname Shrimp nuggets compared to the negative control (Formula 1). Fortification with *E. cottonii* seaweed flour can cause an increase in iodine levels in white bread[3]. *E. cottonii* flour can increase iodine levels in sago cookie products and in vivo in experimental mice because *E. cottonii* seaweed contains nutrients in the form of dietary fiber and other substances, including iodine, in suitable proportions for human nutritional needs[19,20].

The Chewy Texture of Vanname Shrimp Nuggets

Firmness is the ability of a food product to return to its original shape after being styled and testing the physical properties of elastic texture using the Texture Analyzer tool. The values of the physical properties of the elasticity of Vanname Shrimp nuggets fortified with *E. cottonii* flour are presented in Table 4. The ANOVA results illustrate that the fortification of *E. cottonii* shrimp significantly affects the elasticity of Vanname Shrimp nuggets. Duncan's Advanced test analysis showed that the treatment levels were significantly different. The average elasticity value of Vanname Shrimp nuggets increased significantly as the fortification level of *E. cottonii* flour increased.

Table 4. Firmness value of Vanname Shrimp nuggets fortified with *E. cottonii* flour

Treatment Levels for *E. cottonii* Flour	Firmness Content of Vanname Shrimp Nugget (N)
Formula 1 (0% *E. cottonii* flour)	5.1 ± 0.07[a]
Formula 2 (7.5% *E. cottonii* flour)	6.65 ± 0.04[b]
Formula 3 (10% *E. cottonii* flour)	7.08 ± 0.07[c]
Formula 4 (12.5% *E. cottonii* flour)	8.00 ± 0.04[d]

Note: Different letter notations in the same column show significant differences ($p<0.05$).

The increase in elasticity value was due to the higher fortification of *E. cottonii* flour. The higher the fortification level of *E. cottonii* flour, the higher the elasticity value of the Vanname Shrimp nuggets produced. *E. cottonii* seaweed is a polysaccharide carbohydrate. Red macroalgae (seaweed) contain polysaccharides, including amylopectin glucan. Red algae polysaccharides can act as a good source of fiber for the human body's digestion (dietary fiber)[21]. Amylopectin in food products plays an important role in the gelatinization process. Amylopectin has a long chain that is strong enough to form a gel. This study used wheat flour and cornstarch, which affected the elasticity value. The amylopectin glucan content of seaweed can affect the elasticity of the product[22].

Vanname Shrimp Nuggets Proximate

Proximate analysis is the quantitative analysis of food and beverage products' macromolecules, water, and minerals. The purpose of proximate analysis is to determine the nutritional composition of a food product during processing.[23] The samples used in this proximate analysis have the best treatment chosen based on the de Garmo method. According to the characteristics of Vanname Shrimp nuggets, the best concentration is fortified with *E. cottonii* flour, namely a treatment level of 7.5%. The proximate value of Vanname Shrimp nuggets enriched with *E. cottonii* flour includes water, ash, protein, fat, carbohydrate content, and iodine. The results of the proximate analysis of Vanname Shrimp nuggets are presented in Table 5.

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Table 5. Proximate value of Vanname Shrimp nuggets fortified with *E. cottonii* flour

Proximate	Value	Comparison*	Comparison**
Moisture (%)	9.85	Max. 60.0%	
Ash (%)	1.66	Max. 2.5%	
Protein (%)	7.78	Min. 5.0%	
Fat (%)	3.67	Max. 15.0%	
Carbohydrate (%)	77.04	-	
Iodine (mcg)	6.09	-	0.73-4.09 mcg/g

Note: **)[24] ***)[25]

Table 5 shows that the macromolecular content, such as protein, fat, and carbohydrates, as well as water and minerals in the Vanname Shrimp nugget product fortified with *E. cottonii* flour, is by SNI 7758:2013. The high protein content in Vanname Shrimp nugget products is due to *E. cottonii* seaweed containing 1.53% protein, so the more seaweed flour fortification in processing Vanname Shrimp nuggets, the higher the protein in the food product.

Apart from that, Table 5 also shows that fortification of *E. cottonii* flour can increase the iodine content of Vanname Shrimp nugget products. Fortification of *E. cottonii* flour can increase the iodine content in instant noodle products. This is thought to be because *E. cottonii* seaweed is a food ingredient that contains iodine[26]. Therefore, Vanname Shrimp nugget products fortified with *E. cottonii* flour can be a form of diversification product and need further development and testing to become an alternative food to prevent and overcome iodine deficiency.

CONCLUSIONS

Fortification with *E. cottonii* seaweed flour significantly affects iodine levels and elasticity of VanName Shrimp nuggets. Fortification with *E. cottonii* seaweed flour with the best level of treatment, namely 7.5% with iodine content of 6.17 mcg/g, elasticity of 6.65 N, carbohydrate content of 77.04%, protein 7.78%, fat 3.67%, water 9.85%, and ash 1.66%. Vanname shrimp nugget products fortified with *E. cottonii* seaweed flour can be a form of diversification product and needs further development and testing to become an alternative food to prevent and overcome iodine deficiency.

ACKNOWLEDGEMENT

The author would like to thank all parties who have helped and supported this study.

CONFLICT OF INTEREST AND FUNDING DISCLOSURE

All authors have no conflict of interest in this article. This study was funded by *Fakultas Perikanan dan Ilmu Kelautan, Universitas Brawijaya*, through *Hibah Penelitian Doktor Lektor Kepala Tahun* 2022 (13/UN10.F06/PP/2022).

AUTHOR CONTRIBUTIONS

Write a description regarding the role of each author in writing this article. Author contribution roles: conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, resources, software, supervision, validation, visualization, roles/writing-original draft, writing-review & editing.

Example:

HD: formal analysis, writing–original draft, writing–review and editing; TDS: conceptualization, investigation, methodology, supervision; YEP: investigation, supervision; HN: writing–review and editing.

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