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Short Communication

Nutritional Composition, Physicochemical, and Sensory Properties of Snack Bars Produced from Catfish Head Powder (*Clarias gariepinus*) and Purple Sweet Potatoes (*Ipomoea batatas var Ayumurasaki*) as Emergency Food

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Abstract

During natural disasters, emergency food is often needed to meet the victims' nutritional intake such as protein, fat, carbohydrates, and energy. As an alternative, catfish heads, which are usually rich in nutritional content, can be developed into a snack bar product as emergency food. This research aimed to evaluate the chemical, physical and sensory properties of snack bars produced from catfish head powder (CHP) and purple sweet potato flour (PSPF). This research consisted of several stages, namely making CHP and PSPF, preparing snack bars, and analysing snack bars' chemical, physical, and sensory properties. The ratios of CHP and PSPF in the preparation of snack bars stage were F0 (0:100), F1 (25:75), F2 (50:50), and F3 (75:25). The CHP contained 43.52% protein, 21.24% lipid, 4.6% fiber, and 384.38 Kcal/100 g total energy. The addition of CHP and PSPF affected the chemical (proximate and antioxidant activity), physical (redness and hardness values), and sensory (aroma and overall acceptance) properties of the produced snack bars. All snack bars had protein content that complied with Indonesian National Standards (INS) for cereal bar biscuits. The protein, lipid, carbohydrate, and total energy content of the snack bar were in accord with the standards of the United States Department of Agriculture (USDA), Food Standards Australia New Zealand (FSANZ), and emergency food standards. It is also revealed that F2 was the best treatment based on its chemical, physical, and sensory properties. Indeed, snack bars from CHP and PSPF can be utilized as an emergency food alternative.

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1. Introduction

Indonesia is one of the countries that are prone to natural disasters because it is located at the meeting point of the tectonic plates, namely the Indo-Australian, Eurasian, and Pacific plates. The data from National Agency for Disaster Management (NADM) (2024) showed that in 2023, there were 5,400 natural disasters in Indonesia, such as earthquakes, volcanic eruptions, forest and land fires, extreme weather, floods, landslides, drought, tidal waves, and abrasion. The natural disasters caused 275 people to die, 33 people to go missing, 5,795 people to be injured, and 8,491,288 people to be displaced. To address the needs for nutritious food among the refugees and eventually reduce the death rate, emergency food has played a key role as a source of nutrition and energy.

Emergency food should meet several characteristics, such as safety, easy of consumption, sufficient nutritional value, and a shelf life of two years (Ainehvand *et al*., 2019). Apart from that, emergency food should also be acceptable in terms of color, appearance, aroma, taste, texture, ease of use, ease of carry, and availability at any time (Afifah *et al*., 2023). Emergency food can be formulated to meet a person's nutritional needs of 2,100 Kcal daily with 40–50% carbohydrate content, 10–15% protein and 35-45% lipid of total energy. The World Health Organization (WHO) recommends that protein make up 10-12% of total energy intake, while lipid consumption should be at least 17% during emergencies (Sayılı *et al*., 2023).

Intermediate moisture food (IMF) refers to foods with a moisture content of 20-50%, which are commonly used for emergency rations. Currently, various emergency food products have been developed from local commodities, such as intermediate moisture food (IMF) products from corn and tempeh flour (Aini *et al*., 2018); biscuits and flakes from millet flour and snakehead fish-tempeh flour koya (Anandito *et al*., 2018, 2019); snack bars from banana and mungbean flour (Mahendradatta *et al*., 2020); instant noodles from anchovies and pumpkin flour (Canti *et al*., 2021); food bars from broccoli flour, soybeans and mangrove fruit (Fatmah *et al*., 2021); biscuits from soybeans and bananas (Mulyo *et al*., 2022); seaweed jelly with the addition of wood apple juice and soy flour (Afifah *et al*., 2023); food bars from cassava and red bean flour (Hadiningsih *et al*., 2023); and cookies and food bars from cereals, tubers, pulses, and freshwater fish (Sumarto *et al*., 2023). It is apparent that among these products, food or snack bars have become one of the preferable options because of their solidity, resistance to pressure, and ease of distributions, not to mention their ease of consumption and rich nutritional values of protein, lipids, minerals, vitamins, calories, and carbohydrates. This study addresses a gap in existing research by developing snack bars from catfish head powder (CHP) and purple sweet potato flour (PSPF), which have not been previously explored for emergency food applications in disaster scenarios.

African catfish (*Clarias gariepinus*) is one of the freshwater fish widely cultivated in Indonesia. According to the Ministry of Maritime Affairs and Fisheries (MMAF) (2023), catfish production in Indonesia in 2022 reached 1,101,625.11 tons, increasing by 5.78% compared to the production in 2021. The protein content of catfish is at 66.31% db (Abdel-Mobdy *et al*., 2021), and yet the catfish consumption in Indonesia is still limited to their meat but not their by-products like catfish head. The underutilization of catfish by-products may present a missed opportunity given that these by-products, which make up approximately 55–65% of the total weight of catfish in the catfish fillets industry for floss and minced meat (Bechtel *et al*., 2019; Suryaningrum *et al*., 2023), have the potential to be processed into economical and nutritious food products. For instance, the catfish head is revealed to contain 49.83% protein, 21.13% ash, 5.68% calcium, and 3.78% phosphorus (Bechtel *et al*., 2017). Some previous studies have likewise demonstrated the beneficial use of fish by-products, such as the production of snack bars from tilapia by-product powder (Zulaikha *et al*., 2021) and the use of CHP to make fish crackers (Canti *et al*., 2023). This study focused on the use of CHP in making snack bars considering its high nutritional values.

Meanwhile, purple sweet potatoes (*Ipomoea batatas var ayumurasaki*) are one of the staple food substitutes for rice, which are often consumed boiled or fried. Purple sweet potatoes contain anthocyanin pigments, which are natural dyes that give the flesh a purple color. The antioxidant activity of purple sweet potato is 97.92%, with the total anthocyanin 361.69 mg/L (Dwiyanti *et al*., 2018). Purple sweet potatoes also have relatively high nutritional content, mainly carbohydrates. Purple sweet potatoes contain 92.78% db carbohydrate content, 62.83% wb moisture, 2.99% db ash, 3.22% db protein, 1.01% db lipid, and 2.99% resistant starch content (Nurdjanah *et al*., 2022). The high carbohydrate content of PSPF further implies that it can be used in food production, including snack bars.

Given the nutritional benefits of CHP and PSPF, both ingredients can be used to produce snack bars as emergency food after natural disasters. This study therefore aimed to evaluate the characteristics of such snack bars from CHP and PSPF, particularly their chemical, physical and sensory properties. This study fills a significant gap in the existing literature by exploring the potential of catfish head powder, a by-product that is underutilized in food production, in the development of high-nutrient emergency food.

2. Materials and Methods

2.1 Materials

2.1.1 The equipments

Several equipments were used in this research, such as food processor (Philip HR 2116, China), pressure cooker (Vicenza VP312, Indonesia), cabinet dryer (PT Agrowindo Sukses Abadi OVL-12, Indonesia), analytical scale (Shimadzu ATX 224, Philippines), oven (Oxone OX899-RC, Indonesia), oven (Memmert UN 110, Germany), furnace (Carbolite CWF 1100, UK), Kjeldahl (Behr Labor-Technik K8, Germany), Soxhlet (Iwaki, Thailand), hotplate stirrer (Thermo Scientific HPS RT2 Basic, USA), colorimeter (NR200, China), texture analyzer (Agrosta, France), spectrophotometer (Thermo Scientific Genesys 10S UV-Vis, USA), and 60-mesh sieve (Megah Gumilang Chemikatama ATE-210, Indonesia).

2.1.2 The materials

This study used catfish heads and purple sweet potatoes obtained from Slipi Market, West Jakarta, Indonesia. Other ingredients included full-cream milk powder (Frisian Flag), margarine (Blue Band), powdered sugar (Rose Brand), raisins (Sun-Maid), almonds (Almonesia), cinnamon powder (Koepoe-Koepoe), and chicken eggs. The chemicals used in the study were distilled water, ascorbic acid (Merck), ethanol (Merck), 1,1-Diphenyl-2-Picrylhydrazyl (DPPH) (Merck), protein catalyst tablets (Behr Labor-Technik GmbH), H_3BO_3 (Merck), $Na_2S_2O_3$ (Merck), Bromocresol Green-Methyl Red (BCG-MR) (Merck), H_2SO_4 (Merck), HCl (Merck), n-hexane (Merck), phosphate buffer pH 7 (Merck), alpha-amylase enzyme, pepsin, beta-amylase (Merck), methanol (Merck), acetone (Merck), and Whatman filter paper (Merck).

2.1.3 Ethical approval

This study does not require ethical approval because it does not use experimental animals.

2.2 Methods

2.2.1 Preparation of catfish head powder (CHP)

The CHP preparation was carried out following the method of Khasanah *et al.* (2020) with slight modifications in the methods and times of cooking. In previous research (Khasanah *et al*., 2020), the cooking method was carried out by steaming for 30 minutes and then using a pressure cooker for 15 minutes. In contrast, in this study, the cooking method was only carried out using a pressure cooker for 20 minutes. The catfish heads (5 kg) were washed with clean water to remove blood, mucus, gills, and other impurities. Then, catfish heads were cooked using a pressure cooker (Vicenza VP312, Indonesia) at 1 bar pressure for 20 minutes, after which the fish heads were crushed using a food processor (Philip HR 2116, China). After that, the fish heads were dried using a cabinet dryer (PT Agrowindo Sukses Abadi OVL-12, Indonesia) at 60°C for 48 hours before being ground again using a food processor. Lastly, the CHP was sieved using a 60-mesh sieve (Megah Gumilang Chemikatama ATE-210, Indonesia).

2.2.2 Preparation of purple sweet potato flour (PSPF)

Purple sweet potato flour (PSPF) was prepared following the method of Sohany *et al.* (2021). The purple sweet potatoes were washed and peeled before they were sliced thinly with a thickness of 0.2 cm. Afterwards, the purple sweet potatoes were dried using a cabinet dryer at 50°C for 24 hours. Finally, the purple sweet potatoes were mashed using a food processor and sifted using a 60-mesh sieve.

2.2.3 Preparation of snack bars

The preparation of snack bars was carried out following the method of Lucas *et al.* (2020), with modifications to the ingredients, temperature, and baking time. The formulation for the snack bars consisted of four treatment ratios for CHP and PSPF: F0 (0:100), F1 (25:75), F2 (50:50), and F3 (75:25). First, the ingredients were weighted according to each treatment ratio. The dry ingredients, consisting of CHP and PSPF, were then mixed with 20 g of powdered milk and 2 g of white cinnamon powder. Meanwhile, the wet ingredients were also mixed, including 35 g margarine, 1 g salt, 15 g powdered sugar and 10 g egg yolk. Both the dry and wet ingredients were mixed and added with 20 mL of water, and the mixture was stirred for 2 minutes until even. The resulting dough was added with 30 g of raisins and 20 g of almonds, and it was molded into a rectangle with 10 cm x 2.5 cm x 2 cm dimensions. The dough was finally baked in the oven (Oxone OX899-RC, Indonesia) at 100°C for 1 hour.

2.2.4 Analysis of the chemical properties of catfish

head powder (CHP), purple sweet potato (PSPF), and snack bars

2.2.4.1 Proximate analysis

Proximate analysis of CHP, PSPF, and snack bars was carried out using the AOAC method (2019). The analysis carried out includes moisture content (gravimetry), ash (dry ashing), protein (Kjeldahl), lipid (Soxhlet), and carbohydrates (by difference).

2.2.4.2 Total dietary fiber

Dietary fiber content was determined using the enzymatic-gravimetry method (AOAC, 2019). A total of 0.5 g of sample was put into an Erlenmeyer glass, into which were added 50 mL of phosphate buffer pH 7 and 0.1 mL of alpha-amylase enzyme. The solution was heated on a stirrer hotplate (Thermo Scientific HPS RT2 Basic, USA) at 100°C for 30 minutes. The sample was removed and cooled, and 20 mL of distilled water, 5 mL of 1 N HCl, and 1 mL of 1% pepsin enzyme were further added. The mixture was reheated at 100°C for 30 minutes. Afterwards, the Erlenmeyer flask was removed, and 5 mL of 1 N NaOH and 0.1 mL of beta-amylase enzyme were added, and this solution was heated at 100°C for 1 hour. The mixture was cooled and filtered using filter paper, with the residue washed using 10 mL of ethanol and 10 mL of acetone, each done twice. The samples were dried using an oven at 105°C for 12 hours and subsequently cooled in a desiccator. The final weight was calculated to determine the total insoluble dietary fiber.

The next stage was to obtain the soluble dietary fiber content. The resulting filtrate was dissolved in distilled water with a volume of 100 mL, into which 400 mL of 95% ethanol was added. The filtrate was left for 1 hour to settle, filtered using filter paper, and washed using 10 mL of ethanol and 10 mL of acetone, each done twice. The filtrate was dried in an oven at 105°C for 12 hours and cooled in a desiccator. The final weight of the dry filtrate was weighed to obtain the soluble dietary fiber content. Total dietary fiber was calculated using equations (1) and (2).

Total insoluble or soluble dietary fiber (%) = (final weight of sample (g)-initial weight of sample (g))/(final weight of sample (g)) × 100%............................(1)

Total dietary fiber (%) = total insoluble dietary fiber (%) + total soluble dietary fiber (%)......................(2)

2.2.4.3 Total energy

The total energy of CHP, PSPF, and snack bars was calculated using equation (3) (Kassegn, 2018).

Total energi (Kcal) = (protein content x 4 Kcal/g)+(lipid content x 9 Kcal/g)+(carbohydrate content x 4 Kcal/g)..(3)

2.2.4.4 Antioxidant activity

Antioxidant activity was determined using the 1,1-diphenyl-2-picryl hydrazyl (DPPH) method (Baliyan *et al*., 2022). DPPH solution was prepared by dissolving 24 mg DPPH in 100 mL methanol. The sample extract was made by mixing 0.5 g of the sample in 50 mL of methanol and stirring for 1 minute. Then, the sample solution was filtered using filter paper to obtain a sample extract. A total of 2 mL of DPPH solution was added to 1 mL of sample extract. The blank used 3 mL of a solution containing DPPH in 100 µL of methanol. As a comparison, ascorbic acid was used with a 100 µg/mL concentration. The mixture was left in a dark room for 1 hour. Then, the absorbance of the sample was measured at a wavelength of 517 nm using a spectrophotometer (Thermo Scientific Genesys 10S UV-Vis, USA). The antioxidant activity was calculated using equation (4):

Antioxidant activity (%) = 1-(sampel absorbance / control absorbance)×100%....................................(4)

2.3 Analysis of the Physical Properties of Snack Bars

2.3.1 Color

The color analysis was carried out using a colorimeter (NR200, China). The specified color parameters consist of L* (lightness), which refers to the brightness of the sample with a range of 0-100 (black to white). A positive a* (redness) value indicates the intensity of the red color, while a negative indicates the intensity of the green color. A positive b* (yellowness) value indicates yellow, while a negative indicates blue. Based on the L*, a*, and b* values, ΔE could be determined, which is the total color change in the sample, with the standard calculated by equation (5) (Sakiroff *et al*., 2022).

$\Delta E = \sqrt{((L^* - L^*_0)^2 + (a^* - a^*_0)^2 + (b^* - b^*_0)^2}$.........(5)

Where :

L^*_0, a^*_0, and b^*_0 are standards

2.3.2 Texture

The snack bars texture was analysed using a texture analyzer (Agrosta, France) to determine its mechanical properties, namely hardness (grams). Hardness measurement was performed with a pre-test speed of 1 mm/s and a post-test speed of 10 mm/s.

2.4 Sensory Analysis of Snack Bars

Sensory analysis was conducted using hedonic tests (Meilgaard *et al.*, 2016). The analysis was performed by 50 untrained panelists from 19 to 50 years old. The hedonic test included the panelists' acceptance of color, aroma, taste, aftertaste, texture, and overall rating. The assessment score range used a scale of 1 to 7 with the following criteria: 1 (dislike very much), 2 (dislike moderately), 3 (dislike slightly), 4 (neither like nor dislike), 5 (like), 6 (like moderately), and 7 (like very much).

2.5 Analysis Data

The data obtained were analysed twice using statistical analysis carried out using the IBM SPSS 25.0 software at a significant level of 5%. The data obtained were first tested for normality using the Shapiro-Wilk test. If the data were evenly distributed, an Analysis of Variance (ANOVA) test was conducted, after which a further test was conducted using the Duncan test. If the data were not evenly distributed, a Kruskal Wallis test was performed, followed by the Mann-Whitney test.

3. Results and Discussion

3.1 Results

3.1.1 Nutritional composition of CHP, PSPF, and snack bars

The results showed that the CHP had a high protein content of 43.52 ± 0.30% (Table 1), which was higher than the protein content found in the previous study (30.89 ± 0.11% db) (Canti *et al.*, 2023). The moisture, ash, protein, fiber, and carbohydrate content of the snack bars in all treatments were significantly different ($p < 0.05$). Meanwhile, the lipid content of F1 and F2 and the total energy of F0 and F1 were not significantly different ($p > 0.05$). It is also evident that F3 had the highest protein, lipid content and total energy of all treatments.

3.1.2 Antioxidant activity of CHP, PSPF, and snack bars

Based on Figure 1, the antioxidant activity of PSPF (42.20 ± 9.76%) was significantly higher than that of CHP (12.04 ± 2.14%) ($p < 0.05$). The antioxidant activity of F1, F2, and F3 was significantly lower than F0 and PSPF ($p < 0.05$). However, F2 had antioxidant activity that was not significantly different from F3 ($p > 0.05$), and the antioxidant activity of F0 was also not significantly different from PSPF ($p > 0.05$).

3.1.3 Physical properties of snack bars

The L* and b* values for all snack bars treatments were not significantly different ($p > 0.05$) (Table 2). Meanwhile, the a* values for F1, F2, and F3 were significantly different from those for F0 ($p < 0.05$). The more CHP that was added, the lower the L* and a* values of the snack bars and the higher the b* value; this was supported by the finding that CHP had a brownish colour with L*, a, and b* values of 58.66, 5.22, and 14.65, respectively. ΔE is the colour difference of a sample from the standard. The ΔE values for F1, F2, and F3 were not significantly different ($p > 0.05$), but F3 was noted to have the highest ΔE value (5.86 ± 0.86) compared to other treatments because the CHP addition ratio in F3 was 75%.

The highest hardness value was shown at F0, and the lowest was shown at F3 (Table 2). All sample treatments had hardness values that were not significantly different ($p > 0.05$). The more CHP that was added, the lower the hardness value of the snack bars.

3.1.4 Sensory evaluation of snack bars

The sensory evaluation of snack bars with the addition of CHP and PSPF is shown in Figure 2. Re garding the color attribute, all snack bars treatments were not significantly different ($p > 0.05$). The aroma of F3 was significantly different from F0, F1, and F2 ($p < 0.05$). The sensory evaluation results showed that the panelists' acceptance of the taste and aftertaste attributes for all snack bars treatments was not significantly different ($p > 0.05$). Adding more CHP could reduce the level of panelists' acceptance of texture attributes, but it is not significantly different ($p > 0.05$). The overall acceptance of F3 was significantly different from F0 ($p < 0.05$) but not significantly different from F1 and F2 ($p > 0.05$). In addition, the overall acceptance of F0, F1, and F2 was also not significantly different ($p > 0.05$).

3.2 Discussion

3.2.1 Nutritional composition of CHP, PSPF, and snack bars

The high protein content in CHP could therefore be used as a food ingredient in developing food products. The CHP also had a high lipid content, so it could potentially be used as a source of fish oil. However, the ash (24.19 ± 0.56%) and lipid (21.24 ± 0.28%) contents of CHP in this study were lower than those in previous studies (Canti *et al.*, 2023). Besides that, the CHP was found to be rich in calcium and phosphorus, amounting to 21.83% db and 10.26% db, respectively

Table 1. Nutritional composition of catfish head powder (CHP), purple sweet potato flour (PSPF), and snack bars.

Parameters	Catfish head powder (CHP)	Purple sweet potato flour (PSPF)	F0	F1	F2	F3
Moisture (%)	6.26 ± 0.14[e]	6.38 ± 0.19[e]	15.42 ± 0.15[a]	14.98 ± 0.12[b]	14.42 ± 0.29[c]	12.87 ± 0.11[d]
Ash (%)	24.19 ± 0.56[a]	2.22 ± 0.05[e]	2.78 ± 0.03[e]	5.58 ± 0.06[d]	7.92 ± 0.06[c]	9.85 ± 0.07[b]
Protein (%)	43.52 ± 0.30[a]	3.51 ± 0.09[f]	7.90 ± 0.08[e]	9.84 ± 0.22[d]	13.43 ± 0.31[c]	17.29 ± 0.37[b]
Lipid (%)	21.24 ± 0.28[b]	0.02 ± 0.00[d]	19.18 ± 0.67[c]	21.67 ± 0.47[b]	20.74 ± 0.44[b]	28.12 ± 0.28[a]
Dietary fibre (%)	4.60 ± 0.05[e]	11.36 ± 0.26[b]	9.04 ± 0.23[d]	11.24 ± 0.20[b]	14.23 ± 0.17[a]	10.29 ± 0.17[c]
Carbohydrate (%)	4.79 ± 0.13[f]	87.90 ± 0.23[a]	54.72 ± 0.64[b]	47.94 ± 0.43[c]	43.49 ± 0.48[d]	31.88 ± 0.28[e]
Total energy (Kcal/100 g)	384.38 ± 4.21[d]	365.64 ± 0.56[e]	423.06 ± 3.84[b]	426.15 ± 1.60[b]	414.30 ± 0.84[c]	449.70 ± 2.11[a]

Data shown are means ± standard deviations from two repetitions (n = 2). Different letters in the same row indicate significant differences ($p < 0.05$). CHP: catfish head powder, PSPF: purple sweet potato flour. Formula of snack bars with ratio of catfish head powder (CHP):purple sweet potato flour (PSPF) as follows: F0 (0:100), F1 (25:75), F2 (50:50), F3 (75:25)

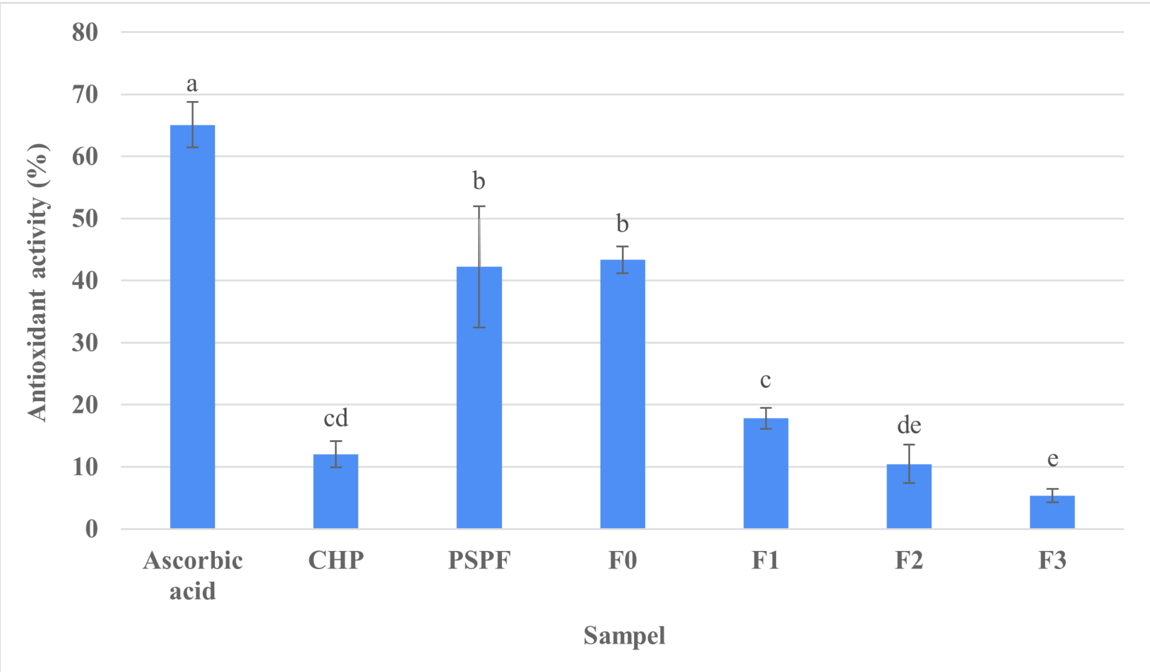

Figure 1. Antioxidant activity of CHP, PSPF, and snack bars.

(Canti *et al*., 2023). It is worth noting that the nutritional composition of CHP is influenced by fish age, size, sex, environment, feeding cycle, and sampling location (Shim *et al*., 2017). Factors that influence the proximate content of fish can be endogenous and exogenous (Ahmed *et al*., 2022). Endogenous factors are mainly related to the fish life cycle, such as life stage, size, age, sex, and anatomical position in the fish and are essentially genetically controlled. These factor influence the nutritional composition of fish. According to Ahmed *et al.* (2022), the moisture, ash, protein, lipid, carbohydrate and mineral content of male fish was higher than that of female fish. Meanwhile, exogenous factors include environmental fluctuations, changes in the composition and availability of food in the fish living zone, and temperature and salinity. Diet is one of the factors found to have a relatively significant effect on the nutritional composition of fish. In contrast, other factors such as changes in temperature, pH, light, oxygen concentration, and salinity

Table 2. Physical properties of snack bars.

Parameters	F0	F1	F2	F3
Lightness, L*	44.20 ± 3.07[a]	42.96 ± 1.10[a]	42.85 ± 1.66[a]	42.45 ± 0.51[a]
Redness, a*	8.21 ± 1.49[a]	5.75 ± 0.90[b]	5.06 ± 0.89[b]	4.34 ± 0.17[b]
Yellowness, b*	3.75 ± 2.78[a]	5.29 ± 1.12[a]	5.64 ± 0.93[a]	6.16 ± 0.66[a]
ΔE	-	4.45 ± 0.91[a]	4.59 ± 1.43[a]	5.86 ± 0.86[a]
Texture (N)	3.97 ± 0.63[a]	2.91 ± 0.39[b]	2.57 ± 0.53[b]	1.92 ± 0.54[c]

Data shown are means ± standard deviations from two repetitions (n = 2). Different letters in the same row indicate significant differences ($p < 0.05$). CHP: catfish head powder, PSPF: purple sweet potato flour. Formula of snack bars with ratio of catfish head powder (CHP):purple sweet potato flour (PSPF) as follows: F0 (0:100), F1 (25:75), F2 (50:50), F3 (75:25)

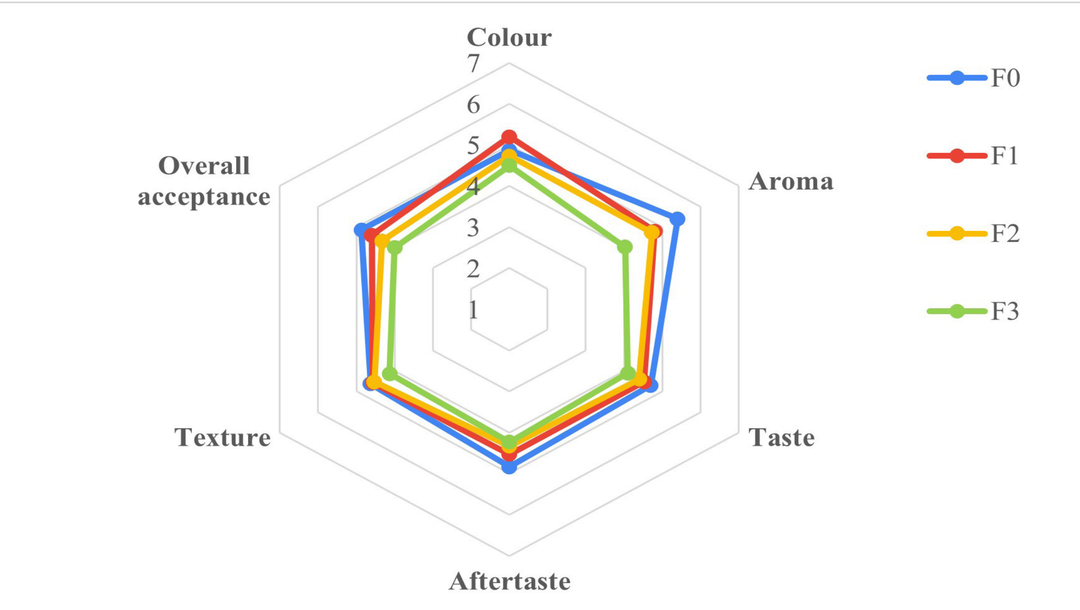

Figure 2. Sensory evaluation of snack bars with the addition of CHP and PSPF, (n=50).

have a limited effect on the proximate content of fish. Noordin *et al*. (2019) reported that juvenile African catfish (average length 4 cm) cultured with different feeds significantly affected their moisture, protein, lipid and total energy. On the other hand, the PSPF had a high carbohydrate (87.90 ± 0.23%) and low protein (3.51 ± 0.09%), echoing the findings of Ambarsari *et al*. (2020), who demonstrate that PSPF can be a good source of carbohydrates in developing food products.

The snack bars in this study were found to contain higher protein (9.84–17.29%) than snack bars produced from 70–80% purple sweet potato and 20–30% soybeans (10.53–13.28%) (Rahmi *et al*., 2021). Further, snack bars from CHP and PSPF had higher total energy (414.30–449.70 Kcal/100 g) than those made from pumpkin, coconut, plum and apricot (386–372 kcal/100 g) (Szydłowska *et al*., 2022). When compared with the commercial snack bars (*Soyjoy raisin almonds*) with 30 g nutritional content that consists of 5 g protein, 7 g lipid, 3 g fiber, 15 g carbohydrates and 140 Kcal total energy, the snack bars from CHP and PSPF were found to contain higher protein, lipid, and fiber but lower carbohydrate and total energy. The differences in nutritional content in these snack bars are attributed to the raw ingredients used and processing methods. Ekafitri *et al*. (2022) state that the baking process at different temperatures significantly affected snack bars' moisture, ash and lipid content. On the other hand, Zulaikha *et al*. (2021) reported that snack bars produced using baking and no-baking methods did not affect their proximate content. The difference in total energy of CHP and PSPF snack bars compared to commercial snacks was 5.09–15.71 Kcal per 30 g. Thus, the total energy of the snack bars was almost equivalent to that of a commercial snack bars. So that the total energy of snack bars from CHP and PSPF is equivalent to commercial snack bars and can meet emergency food needs, toppings or additional ingredients can be added such as cereal, oats, wheat germ, lupine, red beans, dates, bananas, and coconut flakes, where these ingredients have been proven to be beneficial for athletes (Szydlowska *et al.*, 2022; Aljaloudi *et al.*, 2024).

In relation to nutritional standards, all snack bars had a protein content that met Indonesian national standards (INS) (INS 2973:2018) for cereal bar biscuits with a minimum protein content of 4.5% (INS, 2018). The protein, lipid, fiber, carbohydrate content, and total energy of snack bars from CHP and PSPF were found to meet the standards for snack bars formulation category (USDA No: 25010) issued by the United States Department of Agriculture (USDA) (protein content: 7.72%; lipid: 14.2%; fiber: 5.2%; carbohydrates: 51.7%; and total energy: 347 Kcal/100 g) (USDA, 2019). However, based on Australian and New Zealand food standards (FSANZ, F000368), the snack bars from CHP and PSPF had protein, lipid, fiber content, and total energy levels that met these standards but carbohydrate content that was lower than the standards. According to FSANZ standards, snack bars generally had 3.9% protein content, 3% lipid, 4.5% fiber, 71.1% carbohydrates, and 323.61 kcal/100 g (FSANZ, 2023).

As emergency food, the snack bars are expected to meet humans' daily energy needs of 2,100 Kcal. The protein content of F2 and F3 was equivalent to 12.97–15.38% of total calories, satisfying the emergency food protein calorie standard of 10–15% of total calories (Hasan *et al.*, 2020; Sayılı *et al.*, 2023). F0, F1, and F2 had lipid and carbohydrate content, which were equal to 40.80–45.76% and 41.99–51.74% of total calories, respectively; these figures likewise met the lipid calorie standards (35–45%) and carbohydrates (40–50%) for emergency food (Hasan *et al.*, 2020; Sayılı *et al.*, 2023). Thus, F2 met the calorie standards for protein, lipid, and carbohydrates for emergency food. The total calories for all snack bars treatments were 414.30–449.70 Kcal/100 g, almost reaching emergency food energy standards (466–500 Kcal/100 g) (Hasan *et al.*, 2020). With one portion of a 50 g snack bars able to fulfil the calorie needs of 207.15–224.85 Kcal, it can be inferred that the snack bars can be consumed at 10-11 pieces (50 g per pc) a day to satisfy the human daily energy needs of 2,100 Kcal. It is suggested that snack bars from CHP and PSPF can be consumed for 3–4 pcs in one meal to meet the range of 828.6–899.4 Kcal.

3.2.2 Antioxidant activity of CHP, PSPF, and snack bars

The antioxidant activity of CHP was higher than that of fillets of common carp (2%) (Kheiri *et al.*, 2022); silver carp (4%) (Kheiri *et al.*, 2022); and snakehead fish skin (11%) (Baehaki *et al.*, 2020). These variations in the antioxidant activity levels in different fish species were influenced by the difference in species, food sources, and seasons (Kheiri *et al.*, 2022). Meanwhile, the high antioxidant activity in PSPF was likely due to the high anthocyanin content found in purple sweet potatoes, further confirming their potential to be used in food product formulation. According to Cheong *et al.* (2022), purple sweet potatoes contain anthocyanins of 0.17 mg/L and antioxidant activity of 42.41%. The antioxidant activity of PSPF in this study was lower than PSPF in previous studies (85.37%) (Curayag *et al.*, 2019). This is due to differences in varieties, harvest age and cultivation environment.

The antioxidant activity of snack bars is similar to research reported by Curayag *et al.* (2019): candy, muffin, and bread products with PSPF had lower antioxidant activity than those made from raw purple sweet potato. Cheong *et al.* (2022) also reported that the processing process can cause changes in the antioxidant activity of purple sweet potatoes. Anthocyanins, one of the compounds contributing to antioxidants, can be damaged because of the influence of temperature and heating time. According to Pérez-Lamela *et al.* (2021), anthocyanin compounds are susceptible to degradation due to light, metal ions and heat treatment, which can further cause changes in antioxidant activity. The matrix in food can as well act as a heat barrier or induce the degradation of antioxidant compounds, possibly leading to an increase or decrease in antioxidant activity (Curayag *et al.*, 2019). The more PSPF that was added, the higher the antioxidant activity of the snack bars. The more phenolic hydroxyl groups in the anthocyanin structure, the higher the antioxidant activity (Han *et al.*, 2017). The antioxidant activity of snack bars in this study (5.34–43.34%) was higher than that of snack bars made from tilapia by-product powder (12.40–26.04%) (Zulaikha *et al.*, 2021). Nevertheless, the antioxidant activity values of all snack bars (5.34-43.34%) were lower than ascorbic acid as standard (65%). According to Poljsak *et al.* (2021), thermal processing processes such as roasting, boiling, steaming, and microwaving can reduce the antioxidant activity of products. Apart from that, during the storage process, it can also cause a loss of antioxidant activity in the product. The findings indicate that the snack bars from CHP and PSPF contain antioxidants and can be used as an alternative to functional food products. However, this needs to be supported by scientific evidence from testing on humans and animals.

3.2.3 Physical properties of snack bars

Color is an important parameter in food products because it contributes to quality and consumer acceptance. The L*, a*, and b* values in snack bars are influenced by the Maillard reaction attributed to the baking process at high temperatures, which refers to a reaction between reducing sugars and amino acids due to heating. As noted by Zulaikha *et al.* (2021), baked snack bars typically had lower L* values and higher a* and b* values than unbaked snack bars. The Maillard reaction will produce brown compounds, such as melanoidin, which might lead to a change in product color (Sun *et al*., 2023).

Hardness is another essential parameter for sensory reception. Siswanti *et al.* (2021) reported that snack bars with black rice bran and PSPF had a softer texture than other snack bars. The texture of the snack bars can be influenced by the composition of the ingredients used, the size of the snack bar, temperature, and baking time. The hardness is also influenced by the amylose content of the material. The PSPF has a high amylose content of 18.2–27.2%, which can increase the hardness value (Yong *et al*., 2018; Zhao *et al*., 2022). The low hardness values can be caused by the lipid content of CHP or other ingredients (e.g., margarine in snack bars), whereby these lipids can form a complex with amylose and amylopectin. This formation of amylose-lipid complex compounds can reduce the degree of product development and the ability to form gels, thereby reducing the hardness value (Azima *et al*., 2020; Marta and Tensiska, 2017).

3.2.4 Sensory evaluation of snack bars

The addition of CHP and PSPF did not affect the panelists' acceptance of the color of the snack bars produced. F3 had a brown color with a higher intensity than F1 due to the high CHP addition ratio, which amounted to 75%. That is in line with the research conducted by Rahmi *et al.* (2021), who studied a snack bars with the addition of purple sweet potatoes and brown soybeans. The brown color of snack bars can be attributed to the Maillard reaction and caramelization of sugar. The addition of CHP up to 50% did not affect the aroma of the resulting snack bars. This resembled the findings of some previous studies: the addition of tilapia, salmon, and tuna protein concentrate up to 10% did not affect the aroma of the cereal bar produced (Vitorino *et al*., 2020), while the addition of 40% bilih fish flour to fish bars still made the aroma acceptable among the panelists (Elnovriza *et al*., 2019). In preparation for snack bars, the addition of cinnamon powder can cover the aroma of fish. Snack bars with CHP and PSPF had a sweet and umami taste. The sweet taste of the snack bars comes from ingredients such as PSPF, powdered milk, powdered sugar, margarine, egg yolks, raisins, and almonds, whereas the umami taste comes from CHP. The umami taste was due to the high content of amino acid glutamate in CHP (30.02 mg/g protein) (Canti *et al*., 2023). Apart from that, CHP also contains histidine, phenylalanine, tryptophan, glycine, alanine, proline, serine, and threonine amino acids, all of which contribute to the sweet taste of snack bars (Bachmanov *et al*., 2016; Canti *et al*., 2023). Furthermore, adding CHP to the snack bar caused a slightly bitter aftertaste, but it was still acceptable among the panelists. This aftertaste arises due to the relatively high content of lysine (12.82 mg/g protein) and valine (9.59 mg/g protein) in CHP (Bachmanov *et al*., 2016; Canti *et al*., 2023). The sensory results on the texture of snack bars are similar to research reported by Vitorino *et al.* (2020) and Elnovriza *et al.* (2019), which found that the addition of concentrate and fish flour did not affect the texture of the snack bars. Rahmi *et al.* (2021) also reported that the texture of snack bars with the addition of 50–90% purple sweet potato and 10–50% soybeans did not show significant differences ($p > 0.05$). Adding CHP up to 50% did not affect the panelists' overall acceptance level. Thus, CHP could be used as an ingredient for food product formulation.

4. Conclusion

The snack bars from CHP and PSPF had protein, lipid, fiber, and total energy that met INS, USDA and FSANZ standards, and their nutritional content, except for the total energy, was higher than that of commercial snack bars. Moreover, the protein, lipid, carbohydrate, and total energy of F2 met emergency food standards. The addition of CHP affected the resulting snack bar's antioxidant activity and hardness value. Regarding all sensory attributes, snack bars with CHP up to 50% were not significantly different from the control snack bars. Of all treatments, F2 was the best treatment based on its chemical, physical and sensory properties, and its compliance with emergency food standards. The utilization of catfish heads for food product development can be further applied to catfish-based industries in Indonesia, such as catfish fillets, floss, minced meat, and surimi. The development of snack bars from catfish head powder and purple sweet potato flour has shown promising results in terms of nutritional content and acceptability. This product has the potential to be used in emergency food relief, particularly in disaster-prone regions such as Indonesia.

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Authors' Contributions

All authors have contributed to the final manuscript. The contribution of each author is as follows: MC; devised the main conceptual ideas, analyzed the data, drafted the manuscript, and designed the figures. NAK; collected and analyzed the data. RAH, L, and MMLWP; critical revision of the article. All authors discussed the results and contributed to the final manuscript.

Conflict of Interest

The authors declare that they have no competing interests.

Declaration of Artificial Intelligence (AI)

The authors affirm that no artificial intelligence (AI) tools, services, or technologies were employed in the creation, editing, or refinement of this manuscript. All content presented is the result of the independent intellectual efforts of the authors, ensuring originality and integrity.

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