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THE EFFECT OF TAPIOCA FLOUR AND MOCAF ADDITION ON THE CHEMICAL CHARACTERISTIC OF SEAWEED CRACKERS

Pengaruh Penambahan Tepung Tapioca dan Tepung Mocaf Terhadap Karakteristik Kimia Kerupuk Rumput Laut

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ABSTRACT

This study evaluated the effect of substituting tapioca flour and *Modified Cassava Flour* (MOCAF) on the chemical characteristics of crackers formulated with *Kappaphycus alvarezii* seaweed. Four treatments were prepared with varying proportions of seaweed, tapioca flour, and MOCAF. Chemical analyses included measurements of moisture, ash, protein, fat, carbohydrate and crude fiber content. Results showed that increasing the proportion of seaweed consistently elevated moisture content (5.32-9.23%), ash content (0.98-2.02%), protein content (2.47-4.04%), fat content (0.29-0.52%), carbohydrate content (84.19-90.95%) and crude fiber (1.57-4.04%) levels in the raw crackers. The highest values across all parameters were observed in treatment KR4 (32% seaweed), whereas the lowest values were recorded in treatment KR1 (without seaweed addition). Moisture, ash, and fat content in all treatments complied with the Indonesian National Standard (SNI) for raw crackers. The enhancement in chemical characteristics were primarily attributed to the naturally high levels of fiber, hydrocolloids, minerals, and protein present in *Kappaphycus alvarezii* seaweed. These findings demonstrate that partial substitution of tapioca and MOCAF flours with seaweed enhances the nutritional profile of crackers, thus potentially yielding products with greater functional value.

Keywords : K. Alvarezii, Mocaf Flour, Tapioca Flour.

ABSTRAK

Penelitian ini bertujuan untuk mengevaluasi pengaruh substitusi tepung tapioka dan tepung mocaf terhadap karakteristik kimia rumput laut berbahan baku *Kappaphycus alvarezii*. Variasi formulasi dilakukan dengan empat perlakuan dengan proposi rumput laut, tepung tapioka, dan tepung mocaf yang berbeda. Analisis kimia meliputi kadar air, kadar abu, kadar protein dan kadar lemak. Hasil penelitian menunjukkan bahwa peningkatan proporsi rumput laut secara konsisten meningkatkan kadar air (5,32-9,23%), kadar abu (0,98-2,02%), kadar protein (2,47-4,04%), kadar lemak (0,29-0,52%), kadar karbohidrat (84,19-90,95) dan kadar serat kasar (1,57-4,04%) pada kerupuk mentah. Nilai tertinggi dari sleuruh parameter kimia diperoleh pada perlakuan KR4 (32% rumput laut), sedangkan nilai terendah terdapat pada perlakuan KR1 tanpa tambahan rumput laut. Seluruh paramater kadar air, kadar abu dan kadar lemak telah memenuhi standar SNI kerupuk mentah. Peningkatan karakteristik kimia terutama dipengaruhi oleh tingginya kandungan serat, hidrokoloid, mineral serta protein alami dari rumput laut *Kappaphycus alvarezii*. Hasil penelitian ini menyatakan bahwa substitusi tepung tapioka dan tepung mocaf dengan rumput laut mampu meningkatkan profil gizi kerupuk sehingga berpotensi menghasilkan produk yang lebih bernilai fungsional.

Kata kunci : *K.alvarezii,* Tepung Mocaf, Tepung Tapioka

INTRODUCTION

Crackers are a dry food product that is generally made from tapioca flour or wheat flour (Wahyuningtyas *et al.,* 2014). Crackers are made by mixing flour dough with other raw materials such as fish, shrimp, or tempe, as well as seasonings and leavening agents (Asikin *et al.,* 2024). Generally, crackers are classified into two types: coarse crackers and fine crackers. Coarse crackers are made with the addition of protein-rich ingredients such as fish and shrimp, while fine crackers consist only of strach and added seasonings (Fauzi *et al.,* 2022). Crackers are very popular in Indonesia as a snack or accompaniment to main meals, but they are often considered less nutritious because the majority of their content is carbohydrates and low in fiber (Bekti & Fitriana, 2022). Therefore, diversification of raw materials is needed to increase the functional nutritional value of the cracker product.

This diversification potential opens up opportunities to utilize seaweed as a raw material in the diversification of cracker products. Considering to potential of seaweed, which is rich in dietary fiber and nutrients, to increase fiber levels and other bioactive components (Dewi *et al.,* 2025). Seaweed contains various essential nutrients such as protein, fiber, vitamins, and minerals that contribute to the nutritional value of crackers and can improve digestive health and provide antioxidant benefits (Roohinejad *et al.,* 2017). Seaweed crackers, as one of the dry light snacks, offer a unique natural savory taste, crispy texture, and nutritional value that supports human health (Ardani & Dan Buwono, 2018). Seaweed crackers are a food category that combines the nutritional benefits of algae with the deliciousness of crackers.

Previous research has shown that the seaweed species Kappaphycus alvarezii contains beneficial bioactive compounds and is known as a major producer of carrageenan, a type of sulfated polysaccharide that acts as a gelling agent, thickener, and stabilizer. This seaweed is also high in fiber, containing protein, fat, and other essential minerals (Mohammad *et al.,* 2019). Some studies show that the protein content of Kappaphycus alvarezii can be higher than that of other seaweeds (Kumar *et al.,* 2015). Therefore, the addition of Kappaphycus alvarezii to crackers can affect physicochemical characteristics such as a moisture content, protein, fat and ash (Putra *et al.,* 2024).

In addition to adding seaweed, using flours like mocaf, which has excellent binding properties and a relatively neutral flavor profile, can also enrich the characteristics of the crackers. This is because mocaf has functional properties similar to tapioca but with greater potential for expansion (Bekti & Fitriana, 2022). Recent studies show that substituting tapioca with mocaf, when combined with seaweed porridge, can significantly alter basic properties including expansion power, moisture content, ash content, and protein content (Lestari *et al.,* 2023). Previous research by Afiyah & Sarbini (2021) stated that there was a significant effect on the fiber content and texture of the final product after the addition of mocaf flour. Integrating the use of tapioca flour and mocaf flour in the grass cracker formulation is considered a potential strategy to improve nutritional quality.

The combination of tapioca flour, mocaf flour, and Kappaphycus alvarezii seaweed can be an excellent source of fiber for food products. This supoorts the potential to develop and create healthier seaweed cracker products (Soewondo *et al.,* 2023). This study examine the effect of substituting tapioca and mocaf flour on the chemical characteristic of seaweed crackers, spesifically on moisture content, ash content, protein content, fat content, carbohydrate content and crude fiber, which are important parameters in determining product quality and shelf life (Hidayat *et al.,* 2020).

RESEARCH METHOD

Time and Location Research

This research was carried out in the analysis technology of fisheries product laboratory, Faculty of Fisheries and Marine Science, Mulawarman University. The crackers using seaweed from Bontang Kuala District, Bontang City, East Borneo.

Tools and Materials

The materials used consisted of Kappaphycus alvarezii as main ingredient with additional fillers tapioca flour (rose brand) and mocaf flour. In addition, sugar (gulaku) was added, eggs, garlic, pepper, salt and flavoring (masako) were also used. Chemical analysis used catalyst tablets, hydrogen peroxide (H_2O_2), concentrated sulfuric acid (H_2SO_4), hydrochloric acid (HCl), NaOH 30%, $Na_2S_2O_3$ 5%, H_3BO_3 , K_2SO_4 10%, etanol 95%, aquadest, Bromocresol Green (BCG), methyl red and other materials (analytical grade).

This research using some tools included a blender, digital scale, plastic trays, beakers, refrigerator, cutting board, knife, pot, frying pan, spatula, gas stove, spoons, and bowls. As for the analysis equipment it includes a muffle furnace, hot plate, stirrer, crubicles, crucible tongs, measuring cylinders, trays, LLDPE plastic, kjeldahl flasks, volumetric pipets, erlenmeyer flasks, desiccator, volumetric flask, electric stove, ruler and HunterLab (Colorflex EZ).

Ingredients	Treatments			
	P1	P2	P3	P4
Main Ingredient				
K. alvarezii	0 g (0%)	200 g (16%)	300 g (24%)	400 g (32%)
Tapioca Flour	600 g (48%)	550 g (44%)	375 g (30%)	250 g (20%)
Mocaf Flour	400 g (32%)	250 g (20%)	325 g (26%)	350 g (28%)
Supporting Ingredients				
Sugar	4,8%	4,8%	4,8%	4,8%
Salt	4,8%	4,8%	4,8%	4,8%
Pepper	1,2%	1,2%	1,2%	1,2%
Flavor enhancer	1,2%	1,2%	1,2%	1,2%
Garlic	3,2%	3,2%	3,2%	3,2%
Egg	4,8%	4,8%	4,8%	4,8%

The research procedure consisted of three main stages: raw material preparation, seaweed pulp production, and the formulation of Kappaphycus alvarezii crackers. The process began with the preparation of 500 grams of dried Kappaphycus alvarezii, which was thoroughly washed to remove any adhering impurities. Seaweed was then siaked in water at a rasio of 1:20 (w/v) for approximately 20 hours. After soaking, seaweed was cut into small pieces and blended until a fine pulp was obtained. This pulp was subsequently used as the base material for cracker preparation. The cracker dough was produced by combining the seaweed pulp with tapioca flour and mocaf flour. The mixture was further enriched with eggs, granulated sugar, garlis, pepper, and flavor enhancers. Four different formulations were prepared based on varying proportions of seaweed, tapioca flour, and mocaf flour, while the additional ingredients and flavor enhancers were kept constant across all treatment.

Once homogenized, the dough was packed into LLDPE plastic and steamed at approximately ± 100°C for 15 minutes before being cooled at room temperature. The cooled dough was then refrigerated for 24 hours to allow the texture to firm slightly. After refrigeration, the dough was removed from the LLDPE packaging and sliced thinly to a thickness of 1-2 mm. The slices were dried under direct sunlight for two days in bright weather, or for 4-5 days under less favorable conditions. Crackers that were completely dry were characterized by their brittleness. The dried slices were then fried over low heat until fully expanded, after which they were ready for futher analysis.

Data Analysis Methods

Comparative analysis of mocaf flour and tapioca flour in the production of raw seaweed crackers was then characterized for moisture content, ash content, protein content, fat, carbohydrate and crude fiber content.

RESULT

Proximate Analysis

Table 1. Proximate Analysis of Raw Crackers Substituted with Tapioca Flour and Mocaf Flour

Treatment	Proximate Analysis					
	Moisture Content (%)	Ash Content (%)	Protein Content (%)	Fat Content (%)	Carbohydrate Content (%)	Crude Fiber (%)
KR1	5.32±0.00^{a}	0.98±0.01^{a}	2.47±0.02^{a}	0.29±0.00^{a}	90.95±0.02^{a}	1.57±0.00^{a}
KR2	8.39±0.01^{b}	1.32±0.00^{b}	3.48±0.02^{b}	0.36±0.00^{b}	86.44±0.01^{b}	3.11±0.01^{b}
KR3	8.96±0.01^{c}	1.78±0.01^{c}	3.68±0.00^{c}	0.43±0.01^{c}	85.16±0.02^{c}	3.57±0.01^{c}
KR4	9.23±0.01^{d}	2.02±0.01^{d}	4.04±0.01^{d}	0.52±0.01^{d}	84.19±0.01^{d}	4.04±0.02^{d}

Note : KR1 = Seaweed 0% : Tapioca flour 48% : Mocaf flour 32%
KR2 = Seaweed 16% : Tapioca flour 44% : Mocaf flour 20%
KR3 = Seaweed 24% : Tapioca flour 30% : Mocaf flour 26%
KR4 = Seaweed 32% : Tapioca flour 20% : Mocaf flour 28%

DISCUSSION

Moisture Content

Moisture content is a crucial element that affects various characteristics of food, including appearance, texture, taste, and shelf life (Rosiani & Widowati, 2015). Moisture content is defined as the percentage of water present in a product or food material. The quality of crackers after the frying process is strongly influenced by the moisture content of the raw crackers, which is associated with the expansion volume of the fried product; the lower the moisture content in the raw crackers, the greater the expansion capacity during frying (Mulyana *et al.,* 2014). Results of the moisture content analysis of raw seaweed crackers with the addition of tapioca flour and mocaf flour showed values ranging from 5.32% to 9.23%. The moisture content values obtained from the analysis are presented in graphical form in Figure 1. Superscript letters in Figure 1 indicate significant differences among treatments ($p<0,05$).

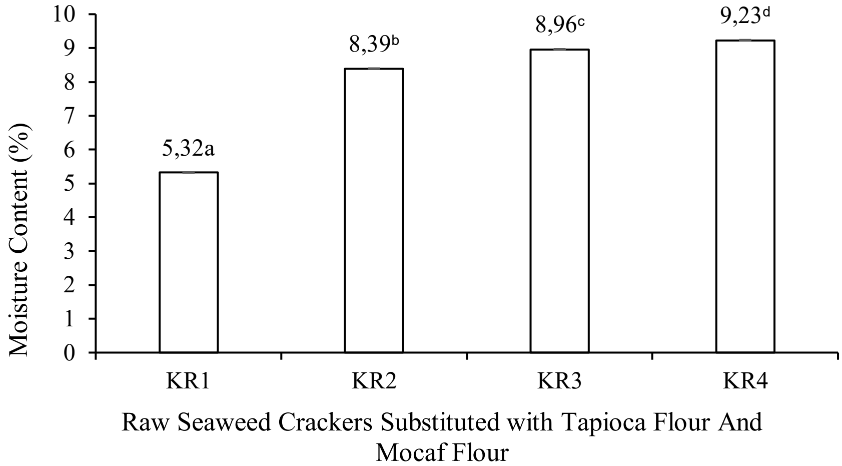

Figure 1. Moisture Content Value of Raw Seaweed Substituted with Tapioca Flour and Mocaf Flour

The highest moisture content in raw seaweed crackers substituted with tapioca and mocaf flour was observed in treatment KR4 was at 9.23%, whereas the lowest was found in treatment KR1 at 5.32%. all treatments complied with the Indonesian National Standard (SNI 0272-2000), which specifies a maximum moisture content of 12% (w/w) for crackers. Moisture content of seaweed crackers substituted with tapioca flour and mocaf flour tended to increase with higher concentrations of seaweed and reduced proportions of tapioca and mocaf flpur. This trend is attributable to the intrinsic water content of seaweed; as the proportion of seaweed in the dough increases, the total water mass also rises. Moreover, Kappaphycus alvarezii contains hydrocolloid polysaccharides and dietary fibers with high water-binding capacity, enabling the retention and entrapment of water molecules (Knudsen *et al.,* 2015). Consequently, the strong water-binding effect of the seaweed fibers and hydrocolloids outweights the reduced absorption capacity of the dough due to lower tapioca and mocaf concentrations, resulting in all overall increase in moisture content (Ardani & Buwono, 2018).

Other factors influencing moisture content include the raw materials used-such as seawweed, tapioca flour, mocaf flour, and water-as well as the drying process. Drying plays a critical role in reducing free water through evaporation by thermal energy (Martiyanti & Erwelda, 2019). Elevated moisture leveks affect both texture and expansion capacity; crackers with high moisture content tend to be softer, less crispy, and have shorter shelf life (Haryati *et al.,* 2019). Controlled moisture content is therefore essential to inhibit microbial growth and preserve crispness after frying. Establishing optimal moisture content in raw crackers contributes significantly to storage stability and prevents product deterioration prior to frying (Asikin *et al.,* 2019).

Ash Content

Ash cintent serves as an indikator of the total mineral composition in processed food materials, obtained through the combustion of organic matter at spesific temperatures (Najib *et al.,* 2017). Based on the analysis, the ash content of raw seaweed crackers prepared with the substitution of tapioca flour and mocaf flour ranged from 0.98% to 2.02%. the ash content values of raw seaweed crackers with tapioca and mocaf flour substitution are presented in Figure 2. Superscript letters in Figure 2 indicates statistically differences among treatments ($p < 0.05$).

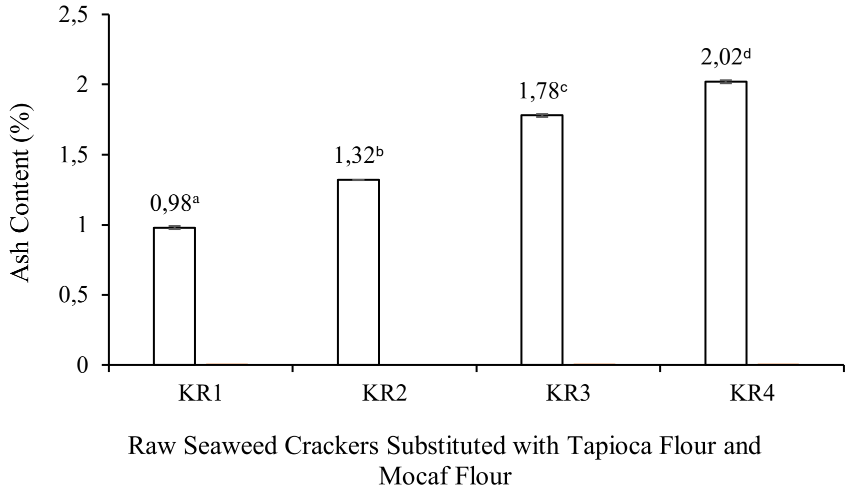

Figure 2. Ash Content Value of Raw Seaweed Substituted with Tapioca Flour and Mocaf Flour

Based on laboratory analysis, the ash content of raw seaweed crackers formulated with tapioca and mocaf flour exhibited variation among treatments. Treatment KR4 produced the highest ash concentration at 2.02%, whereas treatment KR1 showed the lowest ash content at 0.98%. All tested formulations complied with the requirements of the Indonesian National Standard (SNI 0272-2000), which specifies a maximum ash content of 2% for wet-based crackers.

The resukts of this study indicate that the ash content value of raw seaweed crackers increased with the higher proportion of seaweed used in the formulation, in addition to the reduction in tapioca and mocaf flour concentrations also contributes to the increase in ash content value. The elevated levels of inorganic minerals in seaweed are the primary factor driving this increase. Kappaphycus alvarezii is rich in minerals such as sodium, potassium, calcium, and magnesium, which cintribute to the iash content (Premarathna *et al.,* 2022). The high ash content is due to the presence of significant inorganic minerals; these minerals cannot evaporate during burning and remain as ash residue. Kappaphycus alvarezii seaweed contains an ash content of approximately 4.62% so the higher the concentration of seaweed, the higher the ash content (Putra *et al.,* 2024). The ash content in food products is highly influenced by the mineral composition of the raw materials used, where eaach component has a different mineral profile (H. N. Hidayat & Insafitri, 2021). The characteristics of the raw materials indicate that mocaf flour has an ash content of approximately 1.5%, which is significantly higher than tapioca flour, which contains a maximum of only 0.5% ash (Fauzi *et al.,* 2022).

Protein Content

The protein content of food products is a key indicator of nutritional quality. In the case of flour substitution in crackers, protein levels are determined by the composition of the raw material used. Protein provides essential amino acids composed of C, H, O and N elements, with nitrogen being irraplaceable since it cannot be obtained or synthesized from fat or carbohydrate intake (Natsir & Latifa, 2018). As a vital nutrient, protein not otnly supplies energy but also functions as a structural component for tissue formation and as a regulatory agent for enzymes and hormones that govern biochemical processes (Ino Ischak *et al.,* 2025). The use of tapioca and mocaf flours, both strach derivatives, results in very low protein content. However, the incorporation of seaweed, which contains higher protein levels, enhances the nutritional value of crackers. The analysis of raw seaweed crackers substituted with tapioca and mocaf flour revealed protein contents ranging from 2.7-4.04%, as shown in Figure 3. Distinct superscript letters in Figure 3 indicate significant differences among treatments ($p<0.05$), confirming that seaweed addition effectively increases protein levels compared to starch-based formulations.

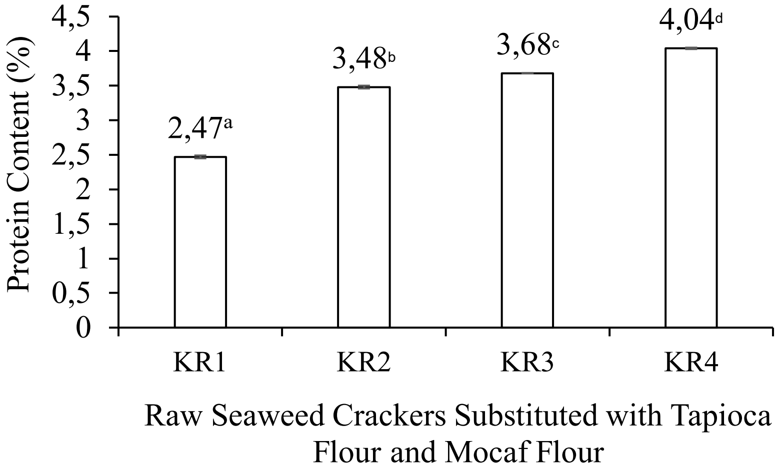

Figure 3. Protein Content Value of Raw Seaweed Substituted with Tapioca and Mocaf Flour

The analysis of raw seaweed crackers substituted with tapioca and mocaf flour showed that the highest protein content was found in treatment KR4 at 4.04%, while the lowest was found in treatment KR1 at 2.47%. protein levels in seaweed-based crackers increased in line with the rising concentration of seaweed and the decreasing proportion of tapioca and mocaf flour (Aganduk *et al.,* 2024). As the concentration of Kappaphycus alvarezii in the cracker formulation was elevated, the use of tapioca and mocaf flour was simultaneously reduced. This shift in the ratio of raw materials resulted in measurable imcrease in total protein content. Seaweed thus acts as a natural fortification agent, enhancing the nutritional value of carckers by raising their protein levels (Islamy *et al.,* 2025).

The addition of tapioca flour, which naturally contains very low protein (0.1-1%), and mocaf flour with protein levels around 2-2.2%, tends to reduce the overall protein content of crackers when used in large amounts. In seaweed-based products, protein not tonly contributes to nutritional value but also affects functional properties such as texture, water-binding capacity, gel formation, and elasticity. Protein levels in food products are strongly influenced by the protein compositions of the raw materials used (Arsyad, 2016). The low protein content observed in treatments with high mocaf substitution is due to its limited protein content, reaching only about 1%. Although both tapioca and mocaf flours are derived from cassava, tapioca contains relatively higher protein compared to mocaf (Sunarsi *et al.,* 2011; Arsyad, 2016; Gusriani *et al.,* 2021).

Fat Content

Fat is a macromolecular organic compound classified as a lipid, characterized by its hydrophobic nature and role as a dense energy source (9 kcal/g) as well as a solvent for vitamins A, D, E, and K. In food system, fat is generally present as triglycerides, phospholipids, and minor lipid compounds. In seaweed-based crackers, fat originates from the seaweed itself, flour, frying oil, and other lipid-containing additives. Therefore, analyzing fat content is essential to accurately determine caloric contribution. The analysis of a raw seaweed crackers substituted with tapioca and mocaf flour showed fat levels ranging from 0.29-0.52%, as presented in Figure 4. Diffent superscript letters in Figure 4 indicate significant differences among treatments ($p<0.05$).

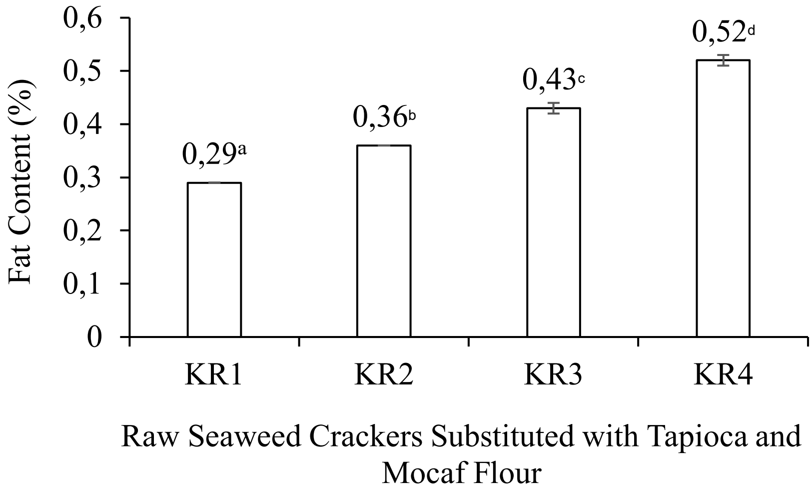

Figure 4. Fat Content Value of Raw Seaweed Crackers Substituted with Tapioca and Mocaf Flour

The fat content of raw seaweed crackers substituted with tapioca and mocaf flour ranged from 0.29% in treatment KR1 to 0.52% in KR4. All treatments met the maximum fat standard for raw crackers set by SNI 01-2713-1999 (≤0.5%). Detected fat levels represent the accumulation of lipids from solid raw materials including seaweed, tapioca flour, mocaf flour, and seasonings. The increase in fat content with higher seaweed concentration is attributed to the intrinsic lipids naturally present in seaweed tissue, generally < 4% of dry weight (Sulistyo *et al.,* 2023). In addition, the lipid contribution from tapioca and mocaf flour also affects total fat levels. The rise in fat percentage with greater seaweed substitution is linked to reduced starch fractions, which weaken the gel matrix that normally restricts lipid penetration. A less compact starch network allows more lipid incorporation, resulting in relatively higher fat values in seaweed-enriched formulations (Zhang *et al.,* 2020). Futhermore, the addition of seaweed as a non-starch component disrupts starch network formation, directly altering dough structure and creating space for lipid penetration (Mamat *et al.,* 2014).

Fat content plays a critical role in determining the shelf life of crackers. Elevated fat levels shorten storage stability by promoting rancidity, which can reduce consumer acceptance and pose negative health effects. In addition, excessive fat decreases cracker expansion, as lipid components form a layer around starch granules that hinders water penetration required for gelatinization (Dewi, 2020; Sari *et al.,* 2021).

Carbohydrate Content

Carbohydrates, alongside fat and protein are major food components and serve as th eprimary energy source for humans, while also functioning widely in the food industry. Carbohydrate content is commonly determined by the *by difference* method, substracting ash, fatm protein and crude fiber values (Nosa *et al.,* 2020). Analysis of raw seaweed crackers substituted with tapioca and mocaf flour showed carbohydrate levels ranging from 84.19-90.95%, with the highest value in KR1 at 90.95% and the lowest in KR4 84.19%.

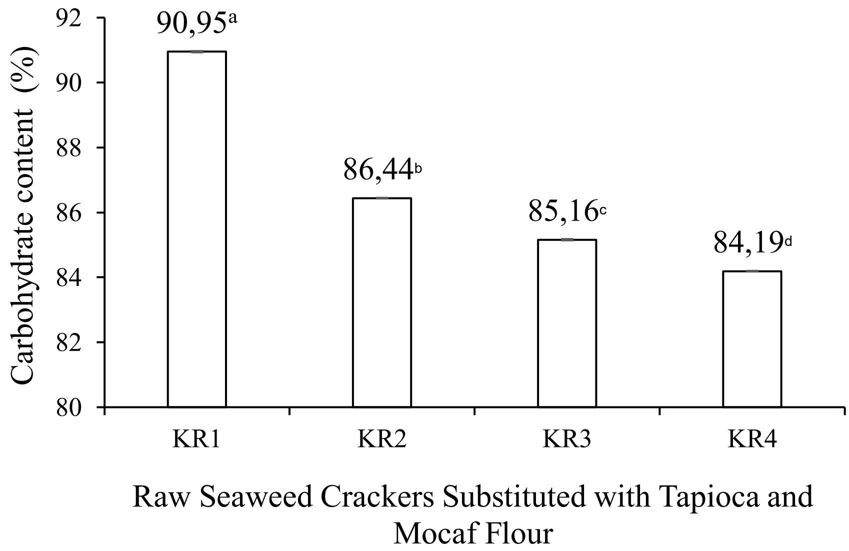

Figure 5. Carbohydrate Content Value of Raw Seaweed Crackers Substituted Tapioca and Mocaf Flour

Carbohydrates in crackers mainly originate from starch-rich ingredients such as tapioca flour, mocaf flour, and seaweed slurry. Increasing the proportion of Kappaphycus alvarezii reduced carbohydrate levels, as seaweed contributes hydrocolloids, fiber, and protein rather than starch. KR1, without Kappaphycus alvarezii exhibited the highest carbohydrate content due to the greater starch contribution from tapioca and mocaf. Carbohydrates in Kappaphycus alvarezii consist of fibrillar forms (cellulose) and amorphous forms (agar and carrageenan) (Harmain *et al.,* 2020) Starch-based raw materials such as tapioca flour contain very high carbohydrate levels (Jamaluddin, 2018). Previous studies reported that reduced mocaf substitution lowers carbohydrate content in crackers, consistent with findings that mocaf is predominantly composed of carbohydrates (Lopulalan *et al.,* 2016; Martiyanti & Erwelda, 2019).

Crude Fiber

Crude fiber is the fraction of food that cannot be hydrolyzed by chemical reagents, typically determined using 1.25% H_2SO_4 and 1.25% NaOH. Fiber content is an important quality index as it contributes to the nutritional value of food (Wang *et al.,* 2022). Beyond nutritional value, dietary fiber significantly influences the technological and sensory properties of foods. Its water-holding capacity, oil absorption, gel-forming ability, and texturizing effects are leveraged to improve product quality, shelf-life, and consumer acceptability (Hamad, 2021). The analysis of raw seaweed cracakers substituted with tapioca and mocaf flour showed crude fiber levels ranging from 1.57-4.04%, with the highest value in KR 4 at 4.04% and the lowest in KR1 at 1.57%.

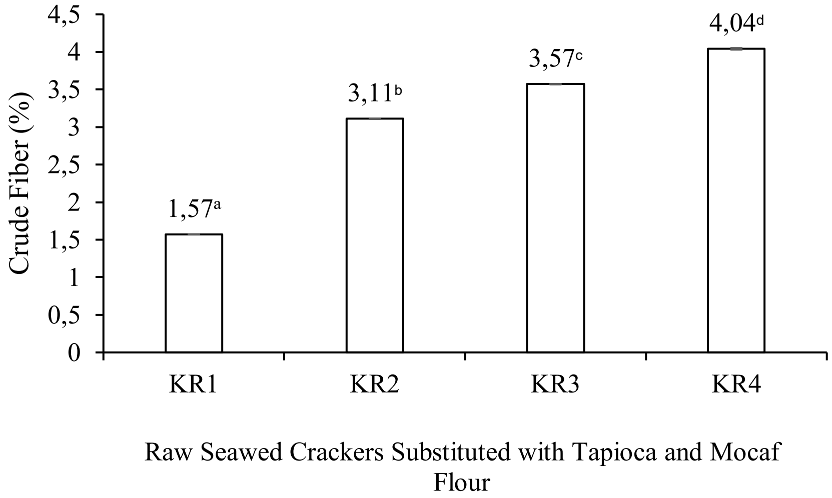

Figure 6. Crude Fiber Value of Raw Seaweed Crackers Substituted Tapioca and Mocaf Flour

The analysis of raw seaweed cracakers substituted with tapioca and mocaf flour showed crude fiber levels ranging from 1.57-4.04%, with the highest value in KR 4 at 4.04% and the lowest in KR1 at 1.57%. Fiber content increased with higher concentration of Kappaphycus alvarezii, which contains up to 3% crude fiber (Ardani & Buwono, 2018). Greater mocaf substitution also elevated fiber levels, as mocaf contains more fiber (2.39 grams/100 grams) compared to tapioca (Jariyah *et al.,* 2022).Elevated fiber levels influence cracker properties by reducing gelatinization, lowering moisture, and limiting expansion capacity (Hakim, 2020).

CONCLUSION

The substitution of tapioca and mocaf flour in seaweed crackers demonstrated that variations in ingredient proportions significantly affected all chemical parameters tested, including moisture, ash, protein, and fat content. Increasing the proportion of *Kappaphycus alvarezii* in the formulation consistently elevated these values, treatment KR4, with the highest seaweed concentration, showed the greatest level of moisture, ash, protein, fat, and crude fiber compared to other treatments. These improvements are associated with the high hydrocolloid, fiber, mineral, and protein content of Kappaphycus alvarezii. Importantly, all moisture, ash, and fat values complied with the quality standards for raw crackers set by SNI, confirming that the product is safe and suitable for consumption.

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