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Effect of Sesame Flour Type and Percentation on the Physicochemical and Organoleptic Properties of Combro Chips

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A B S T R A C T

This research aimed to evaluate the application of the three types of sesame flour (white sesame flour, black sesame flour, and mixed sesame flour) and the addition of sesame flour at three different percentages (5%, 10% and 15%) on physicochemical and organoleptic characteristics of combro chips. Sesame flour has a potential functional seasoning alternative that could enhance nutritional value and consumer acceptability of traditional cassava-based snacks. This study uses a Completely Randomized Design (CRD) factorial with 2 factors. All quantitative data were analyzed using ANOVA (Analysis of Variance) with statistical software (α=5%). The study found that the type of sesame flour had no significant effect on the physical and chemical properties of combro chips, while increasing its percentage significantly influenced all attributes except moisture. Higher flour levels raised protein, fat, ash, and breaking force, indicating a firmer texture. Chips with 5% white sesame flour were most preferred for taste, texture, and color, whereas those with black and mixed sesame flour were less favored.

Contribution to Sustainable Development Goals (SDGs):
SDG 2: Zero Hunger
SDG 3: Good Health and Well-being
SDG 12: Responsible Consumption and Production

1. INTRODUCTION

1.1. Research Background

Sesame seeds (*Sesamum indicum L*) emerge as promising candidates due to their rich nutritional profile and the presence of potent antioxidant compounds such as sesamol, sesamin, and sesamolin. Various studies have highlighted sesame seeds as a “nutrient bank” and a valuable fortification agent in food products [1]. The nutrient density includes high levels of unsaturated fatty acids, proteins, vitamins, minerals, and dietary fiber [2], making them suitable for enhancing the nutritional quality of processed foods. Furthermore, black and white sesame varieties, abundant in Indonesia, have already found applications in oils, tahini, and bakery toppings. However, their application in the form of flour remains limited and underutilized. Another key advantage of sesame flour lies in its high protein and lipid content, which contributes positively to the nutritional profile of snack products. According to Ref. [3], white sesame flour possesses superior antioxidant capacity and higher mineral content compared to black sesame flour. Nevertheless, the selection of flour type must consider consumer sensory preferences, as darker flours may impact the visual appeal of the final product.

Combro chips, a product derived from traditional Indonesian culinary heritage, reflect the innovative transformation of local ingredients such as cassava, fermented tempe made from pressed-ground peanuts (*tempe bungkil kacang tanah),* and various spices. The optimisation of seasoning components plays a critical role in enhancing the taste, aroma, and nutritional value of combro chips. Excessive use of spices can alter the taste and aroma profile due to essential oils, even though it increases antioxidant capacity, some spices contain antioxidants. The addition of spices into traditional food is improving health functionality versus preserving product acceptability. A general approach to the problem has focused on modifying the seasoning composition in traditional snacks using functional ingredients derived from plant-based sources, especially for cassava-based products. Several researchers [4][5] have explored natural fortification to boost antioxidant levels in cassava-based products. Within this context, sesame seeds exhibit considerable potential as a functional ingredient suitable for inclusion in combro chip formulation.

Studies have shown that specific processing techniques, such as roasting and milling, can enhance the release of sesame's bioactive compounds [6], further reinforcing their utility in heat-processed snack applications. Specifically, incorporating sesame flour, either from white or black sesame seeds or their mixtures, introduces antioxidant benefits with a neutral or mild flavor profile. Additionally, the high protein and fat content of sesame flour supports nutritional fortification, improving the snack's contribution to daily dietary needs. Significantly, the type and percentage of sesame flour used during production directly affect the chemical and physical characteristics of the final product. These include attributes such as antioxidant activity, protein, and fat content, texture, and visual appearance. The integration of sesame flour into combro chips serves not merely as a nutritional enhancer but as a strategic alternative to traditional seasonings, particularly in formulations requiring stability under thermal processing conditions.

This research extends existing knowledge on the behavior and efficacy of sesame flour in deep-fried snack systems. By investigating its role in combro chip production, the study contributes meaningfully to food diversification efforts and promotes the sustainable use of locally available, nutrient-dense crops. Furthermore, the insights gained may guide future development of functional traditional snacks that are not only healthier but also culturally resonant and acceptable to a broader consumer base.

1.2. Literature Review

Sesame *(Sesamum indicum)* is a widely cultivated oilseed crop valued for its nutritional richness and functional properties. It stands out as a vital plant-based protein source, offering high-quality amino acids essential for human growth and development. As a rich source of bioactive compounds including omega-6 fatty acids, flavonoids, antioxidants, essential vitamins, and dietary fiber, sesame exhibits promising anti-carcinogenic and health-enhancing properties [7]. Various studies have highlighted sesame seeds as a "nutrient bank" and a valuable fortification agent in food products [1]. Black and white sesame seeds offer high levels of unsaturated fatty acids, protein, dietary fiber, vitamins, and essential minerals such as calcium, magnesium, iron, and zinc. Studies also show that processing methods like roasting and germination enhance the bioavailability of bioactive compounds, further improving their antioxidant and therapeutic value.

1.2.1. White Sesame Seed

According to Ref. [3], white sesame flour exhibits greater antioxidant potential and contains more minerals than its black counterpart. Research also indicates that processing techniques such as roasting and germination can increase the availability of bioactive substances, thereby enhancing their efficacy in antioxidant and therapeutic applications. The nutritional composition of white sesame seeds per 100 grams of dry weight includes approximately 595 kcal of energy, 17.6 grams/100 g of protein, 49.7 grams/100 gram of total fat, 9.85 grams/100 gram of carbohydrates, and 14.9 gram/100 grams of dietary fiber [1][8]. In addition to being rich in protein, fiber, and unsaturated fats, sesame seeds also contain sesamin and sesamolin. These compounds belong to a beneficial class of dietary fiber known as lignans, which are associated with various health-promoting properties.

1.2.2. Black Sesame Seed

Black sesame seeds are primarily used for oil extraction, as the full-fat sesame seed exhibits oil and water absorption, bulk density, and stability [2][9]. The black sesame seeds have slightly higher actual density and lower moisture content. In contrast, white seeds are more porous, which may allow them to absorb water more readily, influencing their functional properties in food formulations [10]. The nutritional composition of black sesame seeds includes 18.10% carbohydrates, 48.40% total fat, 20.82% protein, 8.10% ash content, 4.58% moisture, and 6.52% crude fiber [11][12].

1.3. Research Objective

This study aims to examine the effects of sesame flour incorporation derived from different sesame varieties and applied at various concentration levels on the physicochemical characteristics of combro chips.

2. MATERIALS AND METHODS

The materials used in this study include sesame flour made from white sesame seeds (variety Sumberejo-1), black sesame seeds (variety Sumberejo-3), both obtained from BALITTAS, cassava, fermented tempe made from pressed-ground peanuts (*tempe bungkil kacang tanah),* tapioca, sugar, salt and pepper. The materials for chemical analysis include petroleum ether solution, phenolphthalein (PP) indicator, boric acid, methyl red, Kjeldahl tablets, sulfuric acid (H_2SO_4), 30% sodium hydroxide (NaOH), distilled water (aqua dest), ethanol solution, and DPPH solution in ethanol. The equipment used included a steamer, mixer, frying unit, tray oven, siever (40 mesh), spectrophotometer (LaboMed Inc.), Colour reader (Minolta), Tensile strength analyser (IMADA), oven, furnace, digestion and distillation units (Buchi), and Soxhlet system.

2.1. Experimental Design

This study uses a Completely Randomized Design (CRD) factorial with 2 factors. The first factor is the type of sesame flour (T) with three levels: white sesame flour (T1), black sesame flour (T2), and mixed sesame flour (T3). The second factor is the percentage of sesame flour with three levels: 5% (K1), 10% (K2), and 15% (K3). The treatment combination of combro chips show in Table 1.

Table 1. The treatment combination of Combro chips

Type of sesame flour	Percentage of sesame flour		
	K1	K2	K3
T1	T1K1	T1K2	T1K3
T2	T2K1	T2K2	T2K3
T3	T3K1	T3K2	T3K3

2.2. *Sesame Flour Processing*

Sesame seeds were roasted at 80°C for 15 minutes over medium heat. After cooling to 27°C, seeds were milled and sieved through a 40 mesh filter. Mixed flour involved roasting white and black sesame seeds separately, followed by milling, proportional blending (1:1), and sieving.

Mixed sesame seeds were made by mixing both black and white sesame seeds. With the same composition, black and white sesame seeds were roasted over medium heat at a temperature of 80ºC for 15 minutes. The roasted seeds were then allowed to cool until their temperature reached approximately 27ºC. Subsequently, both types of sesame were milled into flour and weighed in a 1:1 ratio by mass. The black and white sesame flours were then thoroughly mixed in a container and sieved using a 40-mesh filter to obtain a uniform particle size.

2.3. *Combro Chip Production*

Cassava was peeled, cleaned, and grated. It was mixed with tapioca, ground tempe, spices (salt, sugar), and water. Sesame flour with different concentrations was added according to the assigned types (black sesame flour (T1), white sesame flour (T2), and mixed sesame flour (T3)) and percentages (5% (K1), 10% (K2), and 15% (K3)). The dough was kneaded until homogeneous, flattened to ±0,9 cm thickness, shaped, and steamed for 15 minutes. Subsequently, chips were oven dried at 60ºC for 24 hours and finally fried (deep frying) at 140ºC.

2.4. *Physicochemical Analyses*

Proximate compositions were determined using AOAC methods. Texture performance of chips was quantified using tensile strength measurements, reported as % deformation. Higher values indicate stronger chips, and lower values reflect better crispness. The expansion rate, indicative gelatinization and air bubble formation, was calculated as the percentage increase in chip volume post-frying.

2.5. *Organoleptic Evaluation of Combro Chips*

The hedonic organoleptic evaluation is used to evaluate the quality of Combro chips with taste, texture, and colour as attributes. A total of 30 panellists were assigned to evaluate the attributes using a 5-point scale ranging from 1 (strongly dislike) to 5 (strongly like). Data analysis included the use of non-parametric tests.

2.6. *Statistical Analysis*

All quantitative data were analyzed using ANOVA (Analysis of Variance) with statistical software. Significant effects of flour type and percentage of sesame flour were determined (α=5%). The organoleptic data were first transformed into interval data before analysis using ANOVA.

3. RESULT AND DISCUSSION

3.1. *Moisture content*

The result of moisture content (Fig.1) in combro chips revealed minimal variation among treatments, with recorded averages ranging between 2.68% to 3.61%. Statistical analysis revealed that neither the type nor the percentage of all sesame flour had a significant effect on moisture levels ($p > 0.05$). The moisture content of Combro chips tends to be low, indicating a reduction in water levels from sesame flour during the frying process. Frying induces moisture loss through the application of heated oil as the thermal medium. As the surface temperature of the material rises rapidly during frying, water within the product evaporates swiftly, contributing to the overall dehydration of the chips [13], [14]. This process aligns with the thermodynamic behavior of fried foods, where high surface temperatures accelerate water migration and vaporization.

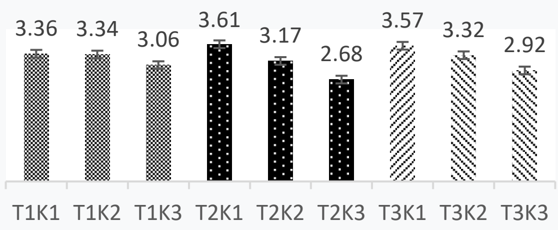

Figure 1: The moisture content of combro chips as affected by sesame flour type and percentage.

3.2. *Protein content*

Figure 2 shows that the average protein content in combro chips ranged from 7.60%-9.53%. Statistical analysis shows that the type of sesame flour had no significant effect on protein content ($p < 0.05$). Meanwhile, the percentage of sesame flour had a significant effect on protein content ($p < 0.05$). Protein is one of the predominant macronutrients found in sesame flour [2]. Consequently, increasing the percentage of sesame flour led to a proportional enhancement in the protein content of combro chips. Previous findings report that white sesame seeds contain approximately 17.6% protein [1], while black sesame seeds contain up to 20.82% [11].

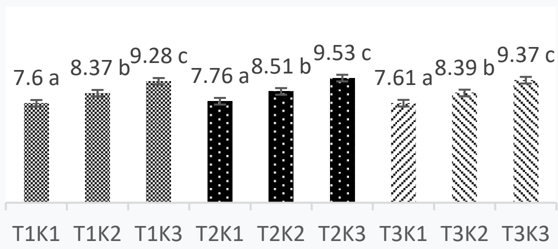

Figure 2. The protein content of Combro chips is affected by the type of sesame flour and its percentage.

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3.3. Fat Content

The fat content of Combro chips ranged from 32.72%-47.08%, as shown in Figure 3. The type of sesame flour doesn't have a statistically significant effect (p>0.05), whereas the percentage of sesame flour significantly influenced the fat content of the combro chips (p< 0.05). Sesame is widely recognised as a valuable biological source of essential fatty acids [15], and it is dominated by unsaturated fatty acids such as oleic and linoleic acid [9]. The application of sesame flour in food products has been shown to increase the lipid content of the final formulation. According to [16]Incorporating sesame flour into protein bars significantly elevated the fat content, reaching up to 11.48%.

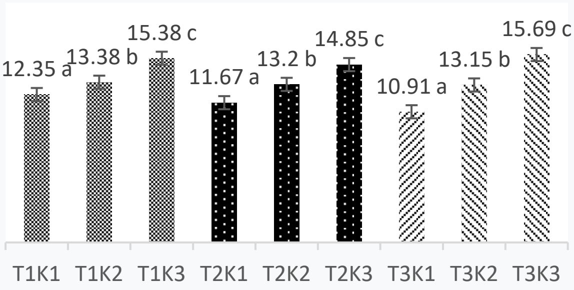

Figure 3. The fat content of Combro chips is affected by the sesame flour type and percentage.

3.4. Ash Content

Figure 4 shows that the ash content in combro chips ranged from 4.40% to 8.22%. Statistically, the type of sesame flour had no significant effect (p>0.05) on the ash content, whereas sesame flour percentage had a significant effect on the ash content of combro chips. Ash content is commonly used as an indirect indicator of the total mineral composition in food materials, as it reflects the inorganic residue remaining after complete combustion of organic matter. A higher ash value typically signifies a greater percentage of essential minerals such as calcium, magnesium, etc. In the context of sesame-based formulations, this parameter becomes particularly relevant due to the naturally high mineral content of sesame seeds. According to [17]Dehusked sesame seeds exhibit an ash content of approximately 34.5%. When sesame flour is incorporated into combro chip formulations, the ash content of the final product increases proportionally with the percentage of sesame flour used. Furthermore, [16] demonstrated that sesame flour fortification in protein bars significantly increased ash content, reflecting improved mineral density in the product. Similarly, [18] reported that roasted sesame seeds retained high ash levels post-processing, further validating sesame's role in boosting mineral composition in functional foods.

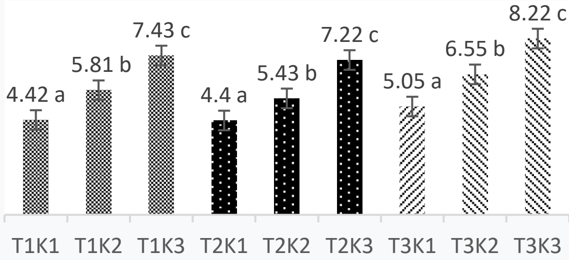

Figure 4. The ash content of Combro chips is affected by the type and percentage of sesame flour.

3.5. Texture of Combro Chips (Crispness)

The texture of combro chips value ranged from 0.14% to 0.82%, as shown in Figure 5. Type of sesame flour had no statistically significant effect (p>0.05) on the combro chip's texture, whereas its percentage had a significant effect on the texture. A lower value of texture indicates greater crispness in the product. The high fat content in sesame seeds may inhibit the formation of air pockets during thermal processing, which plays a critical role in developing a crispy texture [17][18]. Combro chips formulated with 15% sesame flour exhibited the highest fat content, resulting in a firmer texture. Although sesame flour can reduce crispness, its strategic use and combination with other ingredients can enhance the crispy characteristics of food products. According to [19], Gluten-free crackers formulated with 20-30% defatted sesame flour demonstrated improved crispness and sensory acceptability.

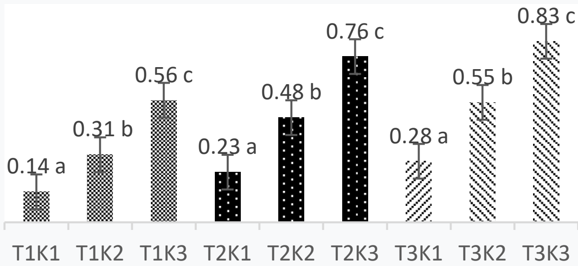

Figure 5. The texture (crispness) of combro chips is affected by the type and percentage of sesame flour.

3.6. Brightness level (L)*

The study showed that the brightness level (L) of combro chips ranged from 40.77 to 50.96, as shown in Figure 6. The type of sesame flour had no statistically significant effect (p>0.05), whereas its percentage had a significant effect on the brightness level of combro chips. According to [20], Sesame seeds contain phenolic compounds such as sesamolin, sesaminol and sesamolinol. Roasting of sesame seeds leads to the hydrolysis of those components. Oxidation of these phenolic compounds contributes to the formation of brown pigments in the product [21]. Thus, higher levels of phenolic compounds result in more intense browning, which in turn reduces the brightness level of combo chips. In chips formulated with black sesame flour and mixed sesame flour, the reduced brightness is not only influenced by phenolic oxidation but also by the inherent dark color of black sesame seeds.

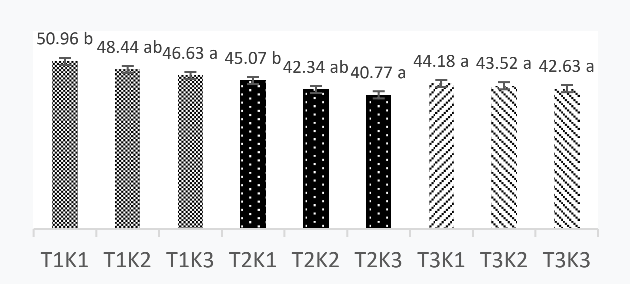

Figure 6. The brightness level of Combro chips is affected by the type and percentage of sesame flour.

3.7. *Organoleptic Evaluation*

The organoleptic evaluation presented in Figure 7 demonstrates variation in panellists' acceptance of taste, texture, and colour attributes of combro chips formulated with different types and percentages of sesame flour. Based on the graphical pattern, white sesame flour prepared with 5% concentration on combro chips displayed relatively high scores in all three parameters. It indicates that panellists prefer products prepared with white sesame flour at lower percentages. The influence of sesame on taste is attributed to its rich composition of flavor-active compounds formed during frying or roasting. These compounds contribute to nutty, roasted, and slightly sweet flavor notes, which can complement starchy or savory matrices such as combro chips. It aligns with [22], which demonstrated that roasting sesame seeds significantly increased pyrazines and furans, which are responsible for the characteristic roasted and nutty flavour of sesame paste. According to [23], substitution of wheat flour with sesame flour in mini croissants significantly affected organoleptic quality, mainly taste and flavor, due to sesame's essential fatty acids and aromatic profile.

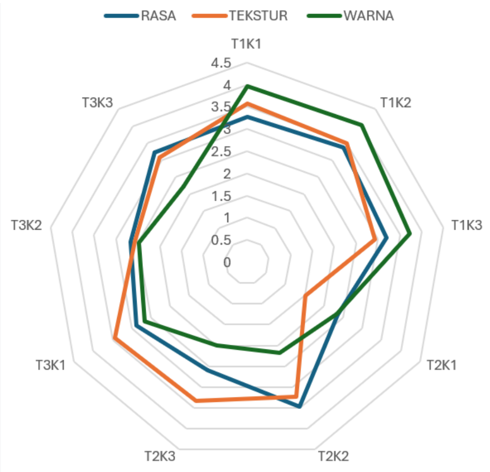

Figure 7. The organoleptic evaluation of combro chips prepared with sesame flour and various percentages.

The higher percentages of sesame flour, particularly in black sesame flour and mixed sesame flour at 15% percentage, show the lowest preferences from panellists in the texture attribute. It's likely attributed to the physicochemical properties of sesame flour, which can alter the structural integrity and mouthfeel of the final product. Sesame flour is rich in fat content and fibre, both of which influence water absorption and gelatinisation behaviour of the sesame flour during processing [16][18].

In terms of colour, lower acceptance was noted in products containing black and mixed sesame flour. This aligns with the brightness value (L*), as the combro chips prepared from black sesame flour and mixed sesame flour have darker colours. Panellists generally favoured chips with lighter colouration over those with darker tones.

4. CONCLUSION

This research provides comprehensive evidence that the application of the three types of sesame flour doesn't have a statistically significant effect on the overall physical and chemical characteristics of combro chips. However, increasing the percentage of sesame flour significantly affected all physical, chemical, and organoleptic attributes of combro chips, except for moisture content. Higher percentages of sesame flour were associated with increased levels of protein, fat, and ash. Additionally, as the percentage of sesame flour increased, the breaking force of the combro chips also became higher, indicating a firmer texture that was more resistant to fracturing. Among the organoleptic attributes assessed, combro chips formulated with 5% white sesame flour were most preferred by the panellists in terms of taste, texture, and colour. In contrast, products containing black sesame flour and mixed sesame flour received lower organoleptic scores and were less favored by the panelists.

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