

Modified Sorghum Flour as a Wheat Substitute in Functional Food Muffin Products

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Abstract. Muffin products have become increasingly popular as a functional food due to its antioxidant activity. Post-Covid-19 consumers have shown particular interest in foods that can boost their immune systems, making muffins a desirable option. This study aims to explore the potential of modified sorghum flour as a substitute for wheat in muffin production to meet the increasing demand for functional foods with antioxidant activity. A completely randomized design was employed to test six different flour combinations in muffin preparation, ranging from 100% wheat flour to 100% modified sorghum flour. The study evaluated the chemical quality, antioxidant activity, and panelist acceptance level of each muffin variant. The results demonstrated that a combination of wheat flour and modified sorghum flour, with 60% modified sorghum flour and 40% wheat flour, produced the most preferred muffin variant among panelists with 5.04% antioxidant activity. Furthermore, the study utilized pre-gelatinization method in processing modified sorghum flour, which is a feasible technology for community-level applications. These findings suggest the potential of modified sorghum flour as a wheat substitute in functional muffin production.

Keywords: Modified sorghum flour, wheat substitution, muffin, functional food, antioxidant activity.

1 Introduction

Sorghum in Indonesia is a food ingredient that has the potential to be developed, including the availability of various varieties both locally and (VUB), sufficient land available, cultivation technology available, postharvest handling to final product processing [1;2]. Sorghum easy cultivated because tolerate to drought and heat [3], even in several countries such as Africa and Southeast Asia around quarter from food consumed originate from sorghum [4] . Thus sorghum has the potential to substitute wheat, thereby reducing dependence on wheat. According to [5], Indonesia on average it imports 11.793 tons of wheat every year.

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Excess sorghum as material food besides contain nutrition adequate basis, containing metabolites such as phenolic compounds which are beneficial for the prevention of chronic diseases, namely diabetes, hypertension, and heart disease [6]. Various sorghum-based nutritious food options such as tortillas, porridge, pop sorghum, muffins, waffles, cookies, and brownies are well-received by both consumers and children in their developmental years [7]. Utilization of sorghum commodities can support this, because it contains polyphenol components that have antioxidant activity [2] .

Based on the physicochemical characteristics of sorghum flour, which is the main basis for determining suitable processed products [8]. One of the processed products that are compatible with sorghum flour is muffins. Muffins are cakes that have a shape like a cup that can be consumed as a heavy meal or snack [9;10], producing processed muffins made from sorghum flour, still requires substitution of wheat as a source of gluten.

Moreover, this study distinguishes itself from previous research by focusing on the modification of sorghum flour specifically for muffin production, similar to the previous approach of substituting it for wheat. Enhancing the physicochemical characteristics of sorghum flour for muffin-based products involves modifications in the food processing techniques. These modifications aim to extend the shelf life, enhance palatability, improve digestibility, and increase the nutritional value of the final product [11].

The selection of the physical pregelatinization method is based on its simplicity, cost-effectiveness, and absence of side effects since no chemicals are involved. Although there might be a decrease in the nutritional composition, this method leads to an improvement in the physicochemical properties, particularly enhancing the smoothness and fluffiness of the flour. The resulting modified sorghum flour can be successfully utilized in muffin production, as confirmed by the high acceptance level among the panelists (who liked it very much), while still retaining its antioxidant activity.

2 Methods

This research was conducted at the International Cereal Research Institute. The material used namely sorghum varieties Soper6 obtained from IP2TP Bontobili Plantation, material chemistry for analysis and materials addition for product processed.

2.1 Activity stages

2.1.1 Manufacturing of Sorghum Flour

As much as 40 kg of Soper6 sorghum seeds were sorted, milled, then processed into flour by soaking method. Milled sorghum is soaked for 6 hours, cleaned, drained, floured, sieved through a 80-90 mesh sieve, dried until the water content is below 12% (referring to flouring technology research results [8]). Furthermore, modification treatment was carried out with the pregelatinization method.

2.1.2 Sorghum Flour Modification

250 g of sorghum flour added to 750 ml of water in a beaker, stirred until homogeneous. Then heated / cooked on a water bath with the temperature of the treatment, stirring for 25-30 minutes. Cooled at room temperature in a container covered with

aluminum foil, then cooled in the refrigerator for 12 hours. Next, the pasta was dried in an oven at 60°C for >12 hours. After cooling, flour and sifted with a 80-90 mesh sieve.

2.1.3 Processed Muffin Products

To determine the quality of each formula will be tested on processed muffin products. The composition of processed ingredients includes 200g flour (according to treatment), 139g eggs, 93g liquid milk, 80g sugar, 30g margarine, 1g baking powder, and 0.5g vanilla. The procedure for making muffins is a) Whisk the eggs and sugar until fluffy using a mixer on low speed for 10-15 minutes until they become airy. Then incorporate the milk and flour substitutes (according to treatment), cocoa powder, vanilla, baking powder until homogeneous; b) margarine that has been melted, put it into the dough until evenly distributed; c) the mixture is poured into the muffin cups $\frac{3}{4}$ of the way so that the volume does not overflow when steamed; d) Then steam the muffin cup dough for 25-30 minutes; d) Remove processed muffins and then serve.

2.2 Experimental design

The study was conducted using a completely randomized design with one factor, namely the proportion of flour which included: 100% wheat flour (S1), 100% sorghum flour (S2), 100% modified sorghum flour (S3), 60% modified sorghum flour: 40% wheat flour (S4), 50% modified sorghum flour: 50% wheat flour (S5), 40% modified sorghum flour: 60% wheat flour (S6). The treatment was repeated 3 times to produce 18 experimental units. Observational variables included physicochemical and functional properties of muffins, including moisture content (oven method 105°C) [12], ash content (furnace method 550°C) [12], protein content (microKjeldahl method) [12], antioxidant activity (DPPH) [13], and organoleptic variables (product *muffins*) which includes color, flavour, texture, taste with a preference level score (1 = dislike, 2 = somewhat dislike, 3 = somewhat like, 4 = like and 5 like very much). The panelists consisted of 25 talented culinary researchers, apprentice students, talented culinary technicians.

2.3 Data analysis

The data obtained were analyzed for variance (F test) at the 5 percent level and if there was variation, it was followed by *Duncan's Multiple Range Test* (DMRT).

3 Result and discussion

3.1 Physicochemical compound of muffins

In making sorghum flour by soaking for 6 hours, it can produce a high flour yield and fine texture compared to the direct method without soaking. Soaking in this case includes spontaneous fermentation [7] , the longer the soaking will produce the aroma of fermentation. [14], soaking barley flour produced better physical-chemical and organoleptic characteristics than flour without soaking. Furthermore, modifications were made to sorghum flour with the pregelatinization method. In gelatinized flour, the drying process causes water to easily escape from the hydroxyl bonds resulting in a decrease in water content. In the drying process, starch granules from pregelatinized modified starch tend to

have larger voids and larger particle sizes so that water evaporates more easily because the hydrogen bonds between amylose and amylopectin become weaker [15] . So there is a physicochemical change that gives added value to the modified sorghum flour

Modified sorghum flour produced by the pregelatinization method is processed into muffin products (Figure 1). Processed muffin products are processed from several substitution compositions of sorghum and wheat flour, as a control for 100% sorghum and wheat flour, the modified sorghum flour substitution for wheat is presented in Table 1.



A

B

Fig. 1 Muffin product a) Sorghum modified 60 % : 40% flour, b) 100% wheat flour

Table 1. Water content, ash, protein and antioxidant activity of processed sorghum flour *muffins* modified flour substitution (Soper6 variety)

Treatment	Water (%)	Ash (%)	Proteins (%)	Antioxidant (%)
S1 (100% Wheat)	31.86b	1.01b	10.55a	62.50a
S2 (Flour Soper6 sorghum 100%)	30.80bc	1.15a	8.57ab	1.15e
S3 (Flour sorghum modified 100%)	31.93ab	1.05ab	6.96d	4.64d
S4 (Sorghum modified 60 % : 40% flour)	32.78a	0.98b	7.48bc	5.04cd
S5 (Sorghum modified 50 % : 50% flour)	30.39cd	1.08ab	7.96b	5.84c
S6 (Sorghum modified 40 % :	27.53d	1.14a	8.49ab	8.65b

60% flour)				
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Note: Column numbers followed by the same letters are not significantly different at the 5% DMRT test level

The results of the analysis of variance showed that the range of water content for all *muffin products* was 27.53 – 32.78%, the highest was S4 (Sorghum modified 60 % : 40% flour) and the lowest was S6 (Sorghum modified 40 % : 60% flour). Like the results of research [10] , the water content of processed sorghum flour *muffins* with the addition of red bean flour still meets the SNI requirements of 40% for sweet bread. Water plays an important role in the damaging effect of cooking, besides that it can affect the formation of disulfide-bound protein polymers, causing changes in protein structure. The content of flour and product ingredients greatly affects the shelf life, the higher the processed water content the lower the shelf life [2;16] .

The average value of muffin ash content ranged from 0.98 – 1.15%, the highest was in 100% unmodified sorghum flour substitution, while the lowest was in 100% wheat flour and S4 treatment. The ash content indicates the mineral content in the product. *Muffin* preparations were not analyzed for minerals, only sorghum flour was processed. The dominant minerals contained in sorghum seeds are Ca (4.1 mg/100g), Mn (4.6 mg/100g), Mg (9.1 mg/100g), K (11.0 mg/100g), P (12.0 mg/100g [17] and specifically the mineral Fe which is relatively high in sorghum seeds (12.50-76.64 mg/kg) [18]. The content of these mineral components depends on the type of variety, soil where it grows, humidity and other environmental factors [2] .

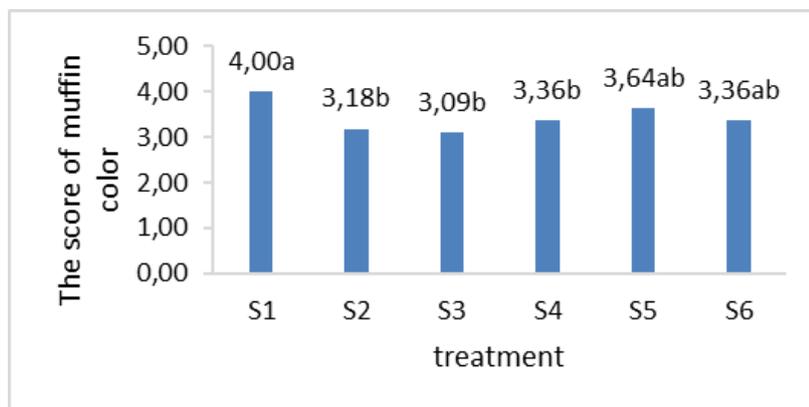
Analysis of variance showed that the protein content of processed *cakes* followed the substitution of flour, the higher the flour concentration, the higher the protein, this was because flour contained higher protein than modified sorghum flour. Processing of *muffins* substitutes sorghum flour with wheat to obtain the gluten required for processing. Apart from gluten, the structure of bakery dough materials such as cakes can also be created by air trapped by the matrix which is formed from bonds between proteins, starches and lipids [19]. This is in accordance with the results of previous studies, substitution of sorghum flour has an effect on the processed protein content [7]. The protein content of flour *muffins* (10.55%) was higher than all substituted flour treatments, namely in the range of 6.96 – 8.57%. To increase the processed protein based on sorghum flour, substitute wheat by adding red bean flour [10].

For all processed treatments, it still contained antioxidant activity in the range of 62.50 – 1.15% . Processed sorghum flour without modification was 100% and the highest antioxidant activity was 1.15%, while the lowest was 100% wheat flour, only 62.50%. The advantage of sorghum-based processed products is that sorghum seeds contain polyphenol components, although there is a decrease in the process to become flour [8]. Phenol has antioxidant, antiatherogenic, and lowers LDL [20]. Antioxidants prevent damage to blood vessel membranes, help optimize blood flow to the heart and brain, fight cancer causing DNA damage, and help lower the risk of heart disease [21]. It was previously informed [22] that the health benefits of sorghum include antioxidant activity as an anticancer and its ability to reduce blood cholesterol.

3.2 Organoleptic test of muffins

The organoleptic properties of food products play an important role in consumer acceptance, as represented by the organoleptic test panel of muffin products . The method used in this test is the hedonic method which aims to determine the value of consumer

preference for *muffins* with a combination of wheat flour and sorghum flour. Increasing the concentration of sorghum flour resulted in a decrease in muffin quality. The seed soaking treatment was not able to increase respondents' preference for the resulting muffins, so modifications had to be made. Modification treatment in the manufacture of sorghum flour can improve the quality of sorghum flour and processed products because it can minimize the decrease in the degree of brightness, fat content and porous nature of cakes and the like. Even though, according to [23], the preference for cakes with 20% substitution of sorghum flour is higher than rice cakes, lower substitution ability for wheat. The physicochemical characteristics of sorghum flour vary depending on the variety, treatment, the process of obtaining the flour ingredients greatly influences the level of substitution for wheat, as well as the processed preparations [8].



Description:

- | | |
|-----------------------------------|--|
| S1 (100% Wheat) | S4 (Sorghum modified 60 % : 40% flour) |
| S2 (Flour Soper6 sorghum 100%) | S5 (Sorghum modified 50 % : 50% flour) |
| S3 (Flour sorghum modified 100%) | S6 (Sorghum modified 40 % : 60% flour) |

Fig. 2 Soper6 sorghum muffin color score diagram

Based on Figure 2, it shows that panelists liked the color of muffins based on 100% flour and muffins substituted with 50% modified sorghum flour (score 3.64). Treatments S5 and S6 were not significantly different from S1 so that the use of modified sorghum flour could be used as an alternative to reduce wheat consumption . The color of the 100% flour-based muffin is yellowish cream, while the 100% sorghum flour is a bit dark cream. The more added sorghum flour, the resulting browner color. This is due to the possibility of tannin compounds contained in sorghum flour. The brown color of the muffins can also be caused by the tannin content in sorghum flour which is still carried away during the milling process [7] .

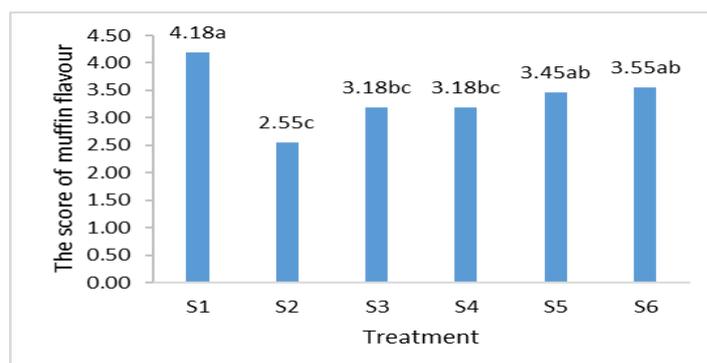


Fig. 3 Soper6 flour muffin flavour score diagram

Analysis of variance for processed S5 (50% substituted modified sorghum flour) showed the panelists' preference level for muffin flavour was not significantly different from that of 100% flour muffin processed (S1). Then followed by S4 treatment (60% sorghum substitution). While treatment S2 (100% sorghum flour) showed the lowest flavour with a score of 2.55. So the process of modifying sorghum flour is important to produce the flavour of muffin products that the panelists prefer. The aroma of a product is one of the initial attractions for consumers to choose and taste it.

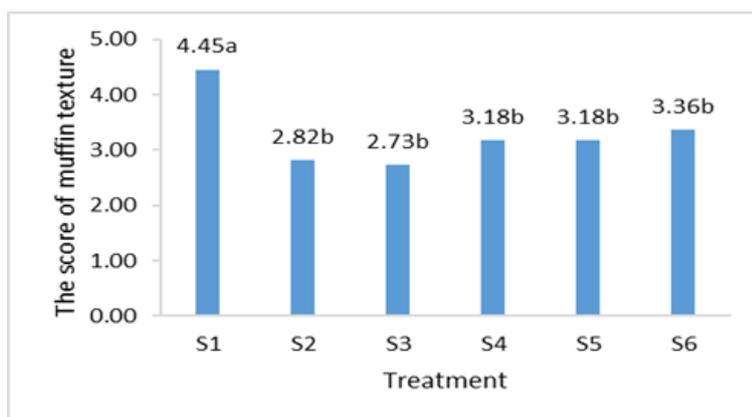


Fig. 4 Soper6 sorghum flour muffin texture score diagram

The results of the panelist assessment showed that the texture of processed (S4) 60% modified sorghum flour: 40% flour, close to the texture value of 100% processed wheat flour. This means that modified sorghum flour can improve the texture of processed muffins. Muffins are characterized by a spongy texture and volume. To obtain this texture requires a stable dough that produces lots of small water bubbles [24]. The use of modified starch in the manufacture of food products can improve the quality and functional value of these food products. This also happened in this study to modify sorghum flour by means of pregelatinization, which can improve the texture of processed products. The high starch content in pregelatinized sorghum flour can cause the muffin texture to become crunchy. The addition of protein from flour to processed muffins causes a decrease in swelling, this is because protein can have a dilution effect which results in the ability to distribute water molecules in the matrix [25], an increase in protein causes a slight swelling of the product so that the product has a more compact texture, the bulk density becomes higher, little air cavity with less porous structure [26], panelist preferred muffin texture.

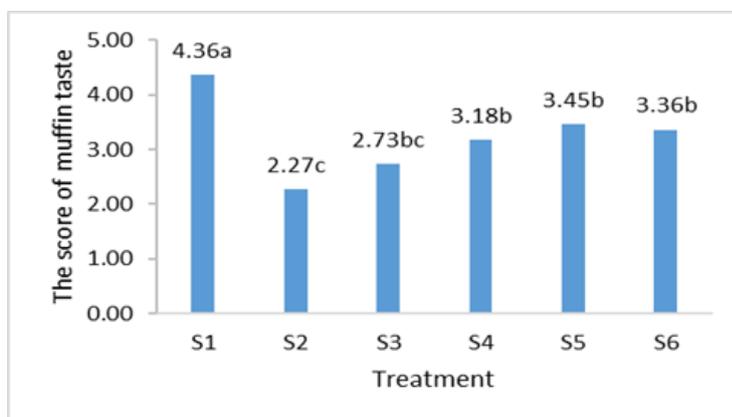


Fig. 5 Soper6 sorghum flour muffin taste score diagram

Muffin taste test can increase the level of substitution of up to 60% for flour with taste test values reaching like to very like. The addition of unmodified sorghum flour caused an astringent taste in the muffins. So that the addition of sorghum flour causes the level of preference for the taste to decrease. It can be seen that the modification of sorghum flour with the pregelatinization method can increase the added value of sorghum flour to processed muffins. The existence of the steaming process in processed muffins causes a level of taste to appear, including hydrolyzed protein into amino acids, giving rise to a delicious savory taste in food and is predicted to produce the amino acid glutamate [27].



Fig. 6 Organoleptic radar diagram of Soper6 sorghum flour muffin preparations

Overall (Figure 6), when viewed from the parameters of taste, flavour, texture and color it shows that the S1 treatment (100% flour) was the most preferred by the panelists with a total score of 17 and an average of 4.25. Then followed by treatments S5 and S4 (60% modified sorghum flour: 40% flour) with a total value of 13.73 and an average of 3.43. The use of sorghum flour must still be added to wheat which aims to obtain gluten for product development. Apart from gluten, the structure of bakery dough materials such as cakes can also be created by air trapped by the matrix which is formed from bonds between proteins, starches and lipids [19]. With the substitution of 60% sorghum flour can minimize the use of wheat. In the future, the use of modified sorghum flour is expected to reduce dependence on the use of wheat. So that wheat imports can be suppressed, and can reduce production costs. In addition, the use of modified sorghum flour can support functional food diversification.

4 Conclusions

Muffin products for all treatments still contained antioxidant activity, although the level of activity followed the high percentage of modified sorghum flour substitution to wheat, including functional food products. Modified sorghum flour can increase the level of substitution of flour for processed muffins with (modified sorghum flour 60% : 40% wheat). Processing technology for modifying sorghum flour using the pregelatinization method, along with the resulting product, can be applied in society because it is cheap and easy to implement.

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