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The Effect of Sago (*Metroxylon sagu* Rottb.) Flour and Sorghum (*Sorghum bicolor* L. *Moench*) Flour Proportion on Resistant Starch, Nutrient, and Organoleptic Properties of Cookies for Type 2 Diabetes Mellitus

Pengaruh Proporsi Tepung Sagu (*Metroxylon sagu* Rottb.) *dan Tepung Sorgum* (*Sorghum bicolor* L. Moench) *terhadap Pati Resistan, Kandungan Gizi, dan Sifat Organoleptik Kukis untuk Diabetes Melitus Tipe 2*

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ABSTRACT

Background: Basic Health Research (2018) reported that the prevalence of diabetes mellitus (DM) among individuals aged 15 years and older is 8.5%, with 90–95% of them being type 2 diabetes mellitus (DMT2). Therefore, corrective action through food modification is needed to control blood glucose. Sago and sorghum contain resistant starches that can enhance glycemic and insulin response.

Objectives: To analyse the effect of the proportion of sago flour and sorghum flour on resistant starch, nutritional content, and organoleptic properties of cookies designated for T2DM.

Methods: This study employed a Complete Randomised Design with 5 variations of sago flour and sorghum flour treatment, namely F1 (100%:0%), F2 (75%:25%), F3 (50%:50%), F4 (25%:75%), and F5 (0%:100%), each replicated twice. The analysis of resistant starch and nutritional content utilised a one-way ANOVA test, followed by the Duncan test for significant differences. Organoleptic properties were assessed using the Kruskal Wallis test. The best formulations were determined based on the De Garmo method.

Results: The results revealed significant differences in resistant starch (p-value=0.002), protein (p-value<0.001), carbohydrate (p-value=0.012), and ash content (p-value=0.005). No significant differences were observed in fat (p-value=0.514), moisture content (p-value=0.881), colour (p-value=0.891), aroma (p-value=0.061), texture (p-value=0.164), and taste (p-value=0.421). The F2 formulation emerged as the best, containing 6.31% resistant starch, 7.34% protein, 23.69% fat, 50.95% carbohydrates, 16.19% moisture content, and 1.84% ash content.

Conclusions: The proportion of sago flour and sorghum flour significantly affected the content of resistant starch, protein, carbohydrates, and ash content, but not fat, moisture content, and organoleptic properties.

INTRODUCTION

The International Diabetes Federation (IDF) reported in 2021 that 536.6 million adults aged 20–79 years were diagnosed with diabetes mellitus (DM)[1]. Indonesia ranked fifth among countries with the highest prevalence of diabetes mellitus in 2021. Basic Health Research (2018) records that 8.5% of Indonesian population aged from 15 years old are suffering from diabetes mellitus[2]. The prevalence has shown an upward trend since 2013, increasing from 6.9%. The majority of diagnosed DM cases are type 2 diabetes mellitus, constituting 90–95% of all diagnosed cases[3].

Type 2 diabetes mellitus (T2DM) is caused by impaired insulin production and decreased cellular responsiveness to insulin[4]. The progressive nature of this condition ultimately leads to a chronic disruption of blood glucose homeostasis. The function and production of insulin are led by lifestyle transformation, especially dietary imbalance[5]. Simple carbohydrate and sugar consumption in long term can increase T2DM risk[6].

Resistant starch offers a potential approach to managing blood glucose. Resistant starch is a complex carbohydrate that is indigestible in the small intestine and, therefore, fermented in the large intestine[7]. Resistant starch positively influences blood glucose

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metabolism by improving glucose response and insulin secretion, modulating the gut microbiota, and regulating lipid metabolism[8]. A meta-analysis found that resistant starch supplementation significantly improved fasting glucose, fasting insulin, and insulin sensitivity in obese diabetic patients[9]. Fermentation of resistant starch produces Short-Chain Fatty Acids (SCFA), which can maintain blood glucose homeostasis through enhancing Glucagon-Like Peptide-1 (GLP-1) secretion[10]. Consequently, Food Agriculture Organization (FAO) recommends consuming resistant starch in 15–20 grams per day[11].

Sago (*Metroxylon sagu* Rottb.) is a local food with more resistant starch than rice[12]. The resistant starch content of natural sago is 31.26%[13]. The research conducted by Wahjuningsih et al. revealed that the resistant starch content of analogue sago rice (12.25%) was higher than mentik wangi rice (10.72%)[14]. In another study, Hariyanto (2017) showed that intervention with sago starch and red bean rice significantly reduced postprandial blood glucose, total cholesterol, and triglyceride[15].

Sago processing into flour can add value by extending shelf life. Sago flour has a high amylose content, ranging from 27% to 39,69%[16,17]. Food with high amylose has solid bonds, resulting in slower digestion and preventing glucose spikes[18]. However, protein and fat content tend to be low, necessitating other foods.

Sorghum (*Sorghum bicolor* L. Moench) is a cerealia containing 21.89% resistant starch[19]. That amount is higher than resistant starch in wheat flour, which is 15.1%[20]. Additionally, sorghum has been shown to process superior nutritional qualities compared to rice and corn. The nutritional composition of sorghum grain comprises 4.4–21.1% protein, 2.1–7.6% fat, 57–80.6% carbohydrate, 75–90% insoluble fiber, 10–25% soluble fiber, and 1.3–3.5 total minerals[21,22]. Sorghum has been demonstrated to exert a hypoglycemic effect, leading to controlled blood glucose levels[23]. A preceding study revealed a reduction in fasting blood glucose levels among obese adult males following a 28-day dietary intervention involving sorghum cookies[24].

The benefit of resistant starch in regulating blood glucose levels emphasizes the importance of food modification to increase resistant starch content. One of the food modifications is cookies. Many people have shown a great interest in cookies. Food Consumption Statistics (2020) stated that the level of pastry consumption in Indonesia, including cookies, was 0.438 ons per week[25]. Meanwhile, a study by Fernández-Carrión *et al.* (2021) found that subjects with T2DM had a slightly higher preference for sweet tastes, such as sugary drinks, cookies, and cakes, compared to non-T2DM subjects[26]. Cookies are commonly consumed as snacks, typically made from wheat flour and characterized by their crispy texture and sweet taste[27]. Using wheat flour and sugar causes cookies to have high glycemic index and low resistant starch. According to research by Giuberty et al. (2016), the resistant starch content of cookies made with wheat flour was 1.6%[28]. Therefore, food modification using sago and sorghum as substitutes for wheat flour is predicted to increase the resistant starch content of cookies.

A previous study discovered that black rice snack bars fortified with sago starch and tempeh resulted in a high resistant starch content of 6.29–8.8%[29]. A separate study demonstrated that white sorghum snack bars yielded a high resistant starch content, reaching 7.19%[30]. Therefore, the development of innovative resistant starch cookies using a combination of sago and sorghum flour is needed to control blood glucose. This research investigated the effects of varying proportions of sago and sorghum flour on the resistant starch content, nutritional value, and sensory properties of cookies.

METHODS

Research Design

The research design was approved by Health Research Ethics Committee of Universitas Pembangunan Nasional "Veteran" Jakarta, as evidenced by Letter Number 103/III/2024/KEP, issued on March 28, 2024. The method employed is a Completely Randomized Design with 5 treatment levels and 2 replications. The treatment used includes F1 (100% sago flour:0% sorghum flour), F2 (75% sago flour:25% sorghum flour), F3 (50% sago flour:50% sorghum flour), F4 (25% sago flour: 75% sorghum flour), and F5 (0% sago flour:100% sorghum flour). These treatments were formulated to meet the daily requirement of resistant starch in snacks.

Table 1. Formulation of Sago Flour and Sorghum Flour Cookies

Ingredients (grams)	F1	F2	F3	F4	F5
Sago Flour	50	37.5	25	12.5	0
Sorghum Flour	0	12.5	25	37.5	50
Margarine	20	20	20	20	20
Egg yolk	19	19	19	19	19
Skim Milk	10	10	10	10	10
Baking Powder	0.5	0.5	0.5	0.5	0.5
Vanilla Powder	0.5	0.5	0.5	0.5	0.5
Total	**100**	**100**	**100**	**100**	**100**

Time and Place

The research was undertaken from January to July 2024. Cookies production occurred in the Food Technology Laboratory at Universitas Pembangunan Nasional "Veteran" Jakarta. The analysis of resistant starch was performed at the CV Chem-Mix Pratama Laboratory. Lastly, the proximate analysis was carried out at the Saraswanti Indo Genetech Laboratory.

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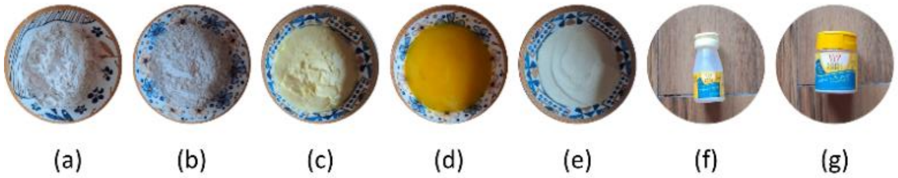
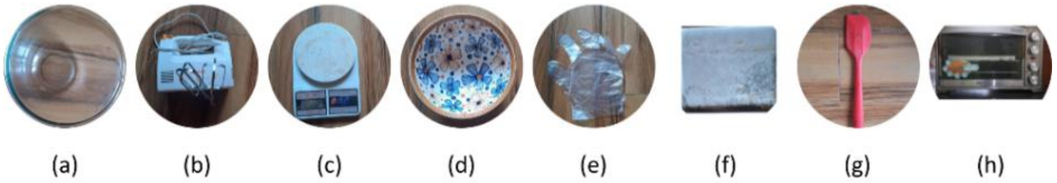


(a) Sago Flour, (b) Sorghum Flour, (c) Margarine, (d) Egg Yolk, (e) Skim Milk, (f) Vanilla Powder, (g) *Baking Powder*
Figure 1. Ingredients Used in Making Sago Flour and Sorghum Flour Cookies



(a) Big Bowl, (b) Mixer, (c) Food Scale, (d) Bowl/Plate, (e) Plastic Glove, (f) Baking Tray, (g) Spatula, (h) Oven
Figure 2. Tools for Making Sago Flour and Sorghum Flour Cookies

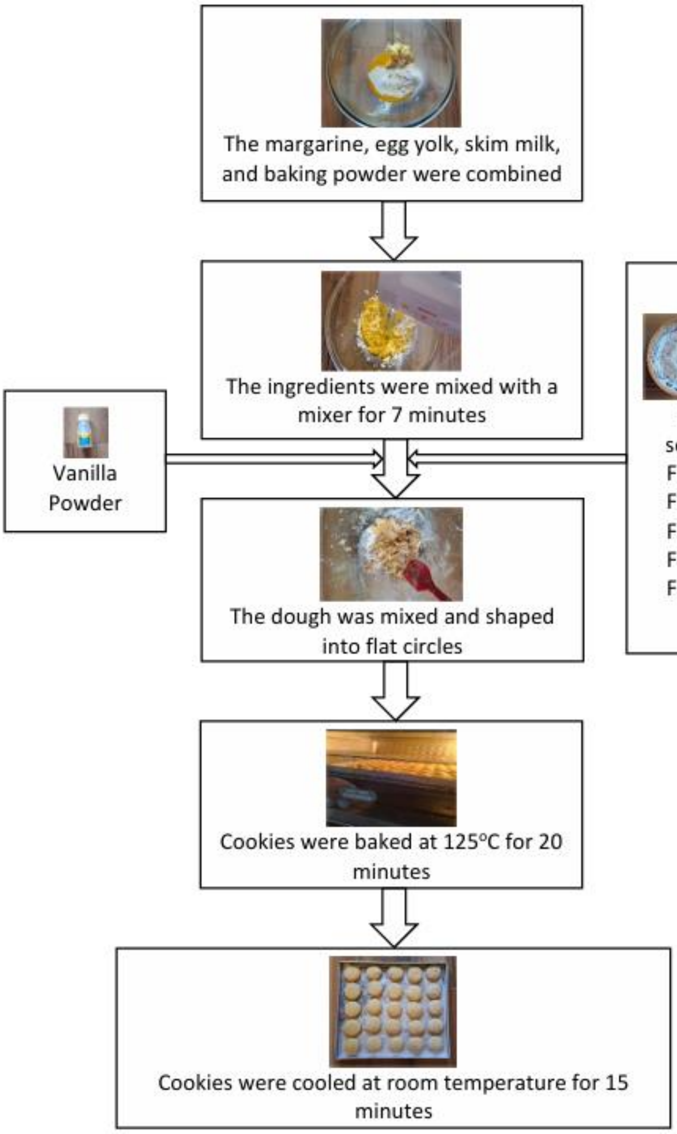


Figure 3. Flowchart for Making Sago and Sorghum Cookies

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Apparatus and Materials

The apparatus used were categorized based on the steps of the process, namely tools for making cookies, chemical analysis, and organoleptic properties test. Cookies were made using a big bowl, mixer, food scale, bowl/plate, plastic glove, baking tray, spatula, and oven. The chemical analysis utilized a UV-Vis λ spectrophotometer at 500 nm, test tubes, an incubator, porcelain crucible, furnace, oven, desiccator, analytical balance, bunsen burner, kjeldahl flask, heating device, kieltec system, volumetric flask, erlenmeyer flask, burette, soxhlet extractor, filter paper, fat-free cotton, fat flask, soxhlet tube, beaker, incubator, aluminum foil, and fume hood. The organoleptic properties test was conducted using evaluation sheets and pens.

The production of cookies required raw materials, including sago flour, sorghum flour, margarine, egg yolk, skim milk, baking powder, and vanilla powder. Meanwhile, several chemicals were used for resistant starch and nutritional content analysis, such as 50 mL of 0.08 M phosphate buffer solution, 10 µL of α-amylase enzyme, 1 N HCl, 20 µL of amiloglucosidase enzyme mixture, 1 mL of FS glucose oxidase, HgO, K2SO4, H2SO4, boiling stones, distilled water, 5% NaOH-Na2S2O3, H3BO3, 0.02 N HCl, 0.2 N HCl, and a fat solvent (hexane).

Cookies Making

The flowchart for making sago and sorghum flour cookies is presented in Figure 3. The process began by mixing margarine, egg yolk, skim milk, and baking powder. The process continued by mixing all the ingredients using a mixer for 7 minutes. Then, sago flour, sorghum flour, and vanilla powder were added according to each treatment. Next, the dough was mixed until smooth and shaped with a thickness of approximately 5-7 mm. After that, the dough was baked at 125°C for 20 minutes in an oven. The process ended with cooling the cookies at room temperature for 15 minutes.

Chemical Analysis

Resistant Starch Analysis with the Enzymatic Method

Resistant starch was analysed by the enzymatic method. A 1-gram sample was suspended in 50 mL phosphate buffer at pH 5.5. Subsequently, the sample was heated at 100^{o}C for starch gel formation. Then, the sample was cooled at room temperature (27^{o}C) until it reached 65^{O}C. Afterwards, 10 µL of α-amylase enzyme (Megazyme, USA) was added and incubated at 65^{o}C for 30 minutes. Next, the suspension was acidified with 1N HCl (Merck, Germany) to pH 4.5, 20 µL of a mixture of amyloglucosidase enzyme (Megazyme, USA) was added, and it was incubated at 60°C for 60 minutes. Subsequently, 10 µL of the sample was mixed with 1 mL of glucose oxidase FS (Diagnostic System International, Holzhein, Germany). Then, the mixture was incubated at 20-25°C for 20 minutes. Analysis was performed using a UV-Vis spectrophotometer at λ 500 nm. The percentage of resistant starch was calculated based on the following formula.

$$\text{Resistant Starch (\%)} = \frac{1 - G \text{ x } 0.9}{\text{Sample Weight}} \text{ x } 100\%$$

Protein Analysis with the Kjedahl Method

Protein analysis was carried out in three stages: destruction, distillation, and titration. The destruction stage began with 50 grams of the sample placed in a kjeldahl flask and added with 40 mg HgO, 1.9 K$_2$SO$_4$, and 2-3 boiling stones. Then, the solution was heated gradually over 1-1,5 hours until the solution became clear, then cooled. The next stage was distillation. This stage involved transferring the sample from the destruction process to the kjeltec system. The kjedahl flask was rinsed with 1-2 mL of distilled water, repeated 5-6 times, and the rinse water was mixed with 8-10 mL of 60% NaOH-5% Na$_2$S$_2$O$_3$ solution. This solution was distilled with an erlenmeyer flask containing 5 mL H$_3$BO$_3$ solution and 2-4 drops of indicator (a mixture of methyl red and methylene blue) until 15 mL of distillate was obtained. Next, the distillate was diluted with distilled water to a volume of 50 mL. In the titration stage, the distillate was titrated with 0.02 N HCl until it turned grey. Then, the volume of HCl required for titration was recorded as the basis for calculation.

$$\text{N Content (\%)} = \frac{\text{(Sample Titration} - \text{Blanko Titration) x N HCl x 14}}{\text{Sample Weight (mg)}}\ x\ 100\%$$

$$\text{Protein Content (\%)} = \text{\%N x Conversion Factor (6.25)}$$

Fat Analysis with the Soxhlet Method

The soxhlet method was used to calculate fat content through several steps. The analysis procedure began with drying the flask at 150^{o}C for 30 minutes. Then, 2 grams of the sample were wrapped in filter paper and covered with fat-free cotton. Next, the sample was placed in the soxhlet extractor chamber. After that, the sample was flushed with hexane solution and refluxed for 5 hours, indicated by a change in the solution colour to clear. Then, the extraction result was dried at 150^{o}C for 1 hour. The purpose of this drying was to evaporate the solution mixed with the fat in the sample. In the final steps, the sample was cooled in a desiccator and weighed. The following formula was used to calculate the fat content.

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$$\text{Fat Content (\%)} = \frac{\text{Fat Weight (g)}}{\text{Initial Sample Weight (g)}} \times 100\%$$

Carbohydrate Analysis with the by-Different Method

Carbohydrate analysis was calculated based on the by-different method. Carbohydrates were obtained from the difference between 100% and the water, ash, fat, and protein content percentage. The following formula was used to calculate the carbohydrate content.

$$\text{Carbohydrate Content (\%)} = 100\% - (\text{Water} + \text{Ash} + \text{Protein} + \text{Fat})\%$$

Water Content with the Gravimetric Method

The water content calculation in food products employed the gravimetric method by measuring the weight of the sample before and after the heating process. The first step in this method was heating the porcelain crucible at a temperature of 103-104°C for 30 minutes, cooling in a desiccator for 30 minutes, and initial weighing. After that, 2-gram samples were placed in the porcelain crucible to be dried at 130°C for 1 hour. Then, the sample was cooled in the desiccator for 30 minutes. The process was completed by weighing the sample. The following formula is used to calculate the percentage of water content.

$$\text{Water Content (\%)} = \frac{\text{Final Sample Weight (g)} - \text{Initial Sample Weight (g)}}{\text{Initial Sample Weight (g)}} \times 100\%$$

Ash Content with Dry Ashing

The ash content was determined by the dry ashing method. Initially, a porcelain crucible was placed in a furnace and heated at 600°C for 30 minutes. This was followed by cooling in a desiccator for 30 minutes. Subsequently, 3 grams of the sample were placed in the crucible and ashed in a furnace at temperatures ranging from 450-500°C for 2-3 hours. Cooling was then carried out in a desiccator for 30 minutes. Finally, the sample was weighed and calculated. The percentage of ash content using the following formula.

$$\text{Ash Content (\%)} = \frac{\text{Sample Weigh after Ashing (g)}}{\text{Initial Sample Weigh (g)}} \times 100\%$$

Organoleptic Properties Test

An organoleptic property test was conducted to evaluate the sensory attributes of cookies made from sago and sorghum flour. The sensory attributes assessed were colour, aroma, texture, and flavour. This study aimed to determine the acceptability of the cookies among 30 undergraduate Nutrition students from the University of Pembangunan Nasional "Veteran" Jakarta as panellists. Inclusion criteria were: good health, no visual, olfactory, or tactile impairments, no psychological disorders, no allergies, no food consumption at least 1 hour prior to the test, no smoking or snacking for at least 20 minutes prior to the test, and willingness to participate as a panellist. Exclusion criteria were panellists who did not complete the entire test. A 5-point hedonic scale ranged from 1 (dislike extremely) to 5 (like extremely).

Data Analysis

The data were analyzed using Microsoft Excel 2019 and IBM SPSS Statistic 23. For normally distributed data, one-way ANOVA was employed, followed by Duncan's test if p-value<0.05. The Kruskal Wallis test was used for non-normally distributed data, followed by the Mann-Whitney test if p-value<0.05. The best formulation was determined using the De Garmo method.

RESULTS AND DISCUSSIONS

Resistant Starch

Resistant starch is defined as starch that resists breakdown by amylase enzymes in the small intestine and, thus, is fermented by the microbiota in the large intestine[31]. Resistant starch can prevent blood glucose spikes[32]. Several researches have demonstrated that resistant starch plays a role in enhancing insulin sensitivity, reducing fat oxidation, and promoting satiety[33]. These studies align with the research of Nugraheni et al. (2017), which found that crackers fortified with type 3 resistant starch in diabetic rats significantly reduced blood glucose, total cholesterol, triglycerides, and Low-Density Lipoprotein (LDL), while increasing High-Density Lipoprotein (HDL)[34].

The resistant starches of sago flour and sorghum flour cookies are presented in Table 2. The highest resistant starch was obtained by F1 cookies at 7.31% with a proportion of 100% sago flour:0% sorghum flour, while F5 cookies obtained the lowest resistant starch at 1.89% with a proportion of 0% sago flour:100% sorghum flour. Statistical analysis using the ANOVA test indicated significant differences among the pairs of cookie formulations (p-value=0.002).

The decrease in sago flour proportion directly led to reduced resistant starch content across all formulations since sago flour inherently contains more resistant starch than sorghum flour. Sago flour contains 18.31% resistant starch, while sorghum flour contains

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5.6% resistant starch[35,36]. These findings are corroborated by prior studies demonstrating an increase in resistant starch content of mocaf noodles as the level of sago flour substitution was elevated[37].

Resistant starch formation is modulated by amylose content and thermal processing involving heating and cooling cycles. Amylose content can induce the formation of resistant starch. Sagor flour contains 27%–39,69% amylose content, while sorghum flour contains 10%–18,72% amylose content[16,17,38]. The linear and unbranched configuration of amylose contributes to its resistance to enzymatic degradation, whereas heating promotes hydration and swelling of starch granules, thereby disrupting hydrogen bonding[39]. This transformation is called gelatinization. Post-cookies temperature reduction induces recrystallization of the starch structure, resulting in a more compact polymeric arrangement[40]. That recrystallization can form resistant starch type 3.

Table 2. Resistant Starch of Sago Flour and Sorghum Flour Cookies

Parameter	F1	F2	F3	F4	F5	p-value
Resistant Starch (%)	7.31 ± 0.232^{a}	6.31 ± 0.619^{ab}	5.51 ± 0.117^{bc}	4.09 ± 1.202^{c}	1.89 ± 0.319^{d}	0.002*

F1 (100% sago flour:0 % sorghum flour), F2 (75% sago flour:25% sorghum flour), F3 (50% sago flour:50% sorghum flour), F4 (25% sago flour:75% sorghum flour), F5 (0% sago flour:100% sorghum flour)

$^{a, b, c, d}$ = identical letter notations within the same row suggest that there are no substantial differences among the groups (p-value>0.05)

*An ANOVA test is statistically significant when the p-value<0.05

Nutritional Content

Protein

Proteins are complex macromolecules within organisms that serve as energy sources, structural components, and regulatory substances. Protein structures are formed by chains of amino acid monomers covalently linked by peptide bonds. Protein consumption has been demonstrated to delay gastric emptying, suppress ghrelin secretion, and stimulate the release of cholecystokinin (CCK) and Glucagon-Like Peptide-1 (GLP-1)[41].

Proteins of sago flour and sorghum flour cookies are presented in Table 3. The highest protein was obtained by F5 cookies at 10.41% with a proportion of 0% sago flour:100% sorghum flour, while F1 cookies obtained the lowest protein at 6.34% with 100% sago flour:0% sorghum flour. The pairs were significantly different based on the ANOVA results (p-value<0.001).

There was a positive correlation between the protein content of the cookies and the proportion of sorghum flour in each formulation. Consequently, a higher proportion of sorghum flour in the formulation resulted in a higher protein content in the cookies due to sorghum flour's inherently higher protein content than sago flour. The protein content of 100 grams of sorghum flour is 8.43%, significantly higher than the 1.11% protein content of 100 grams of sago flour[42,43]. A previous study has substantiated this claim by demonstrating that a 50% substitution of wheat flour with sorghum flour resulted in a significant increase in the protein content of cookies[44]. Another study has shown that the higher proportion of sorghum flour in mocaf dry noodles could increase protein content[45].

Indonesian National Standard (SNI) 01-2973-1992 stipulates that cookies must contain a minimum of 6% protein to meet the quality standards. The protein content of cookies in this research ranges from 6.34% to 10.41%. Therefore, the protein of sago flour and sorghum flour cookies has met the prescribed minimum requirements.

Table 3. Nutritional Content of Sago Flour and Sorghum Flour Cookies

Parameters	Results of Nutritional Content Analysis					p-value
	F1	F2	F3	F4	F5	
Protein (%)	6.34 ± 0.226^{a}	7.34 ± 0.120^{b}	8.71 ± 0.190^{c}	9.38 ± 0.000^{d}	10.41 ± 0.445^{e}	<0.001*
Fat (%)	22.98 ± 0.289^{a}	23.69 ± 0.728^{a}	23.82 ± 0.862^{a}	23.28 ± 0.113^{a}	23.79 ± 0.297^{a}	0.514
CH (%)	52.96 ± 1.032^{a}	50.95 ± 0.064^{ab}	50.01 ± 0.771^{b}	48.83 ± 1.329^{bc}	47.52 ± 0.806^{c}	0.012*
Water (%)	16.02 ± 0.530^{a}	16.19 ± 0.685^{a}	15.55 ± 0.289^{a}	16.56 ± 1.470^{a}	16.30 ± 1.463^{a}	0.881
Ash (%)	1.71 ± 0.021^{a}	1.84 ± 0.000^{b}	1.91 ± 0.014^{bc}	1.94 ± 0.021^{bc}	1.98 ± 0.777^{c}	0.005*

F1 (100% sago flour:0 % sorghum flour), F2 (75% sago flour:25% sorghum flour), F3 (50% sago flour:50% sorghum flour), F4 (25% sago flour:75% sorghum flour), F5 (0% sago flour:100% sorghum flour)

$^{a, b, c, d, e}$ = identical letter notations within the same row suggest that there are no substantial differences among the groups (p-value>0.05)

*An ANOVA test is statistically significant when the p-value<0.05

Fat

Adequate consumption of fats can prolong satiety due to their slower rate of digestion[46]. Food products with high fat content generally exhibit a lower glycemic index[47]. Fat content of sago flour and sorghum flour cookies is presented in Table 3. Cookie F3 exhibited the highest fat content at 23.82%, with a 50:50 ratio of sago flour to sorghum flour. In contrast, cookie F1, composed entirely of sago flour, had the lowest fat content at 22.98%. As the ANOVA test revealed no significant pairwise differences (p-value=0.514), the Duncan test is deemed unnecessary.

Cookie fat tends to increase with the addition of sorghum flour proportion. The substantial difference in fat content between sorghum flour (3.34%) and sago flour (0.27%) is the primary factor contributing to the

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increased fat levels[42,43]. Incorporating additional ingredients, such as margarine with an approximate fat content of 80%, is a primary contributor to the cookies' elevated fat levels in the cookies[48].

Indonesian National Standard (SNI) 01-2973-1992 stipulates that cookies must have a minimum fat content of 9.5% to be considered acceptable. The fat content of cookies in this research is 22,98%–23,82%. Consequently, the fat content of cookies made from both sago flour and sorghum flour has fulfilled the stipulated minimum requirements.

Carbohydrate

The carbohydrate content of sago flour and sorghum flour cookies is presented in Table 3. The highest carbohydrate content was obtained by F1 cookies at 52.96% with a proportion of 100% sago flour:0% sorghum flour, while F5 cookies obtained the lowest carbohydrate content at 47.52% with a proportion of 0% sago flour:100% sorghum flour. The ANOVA results indicated a statistically significant difference among groups (p-value=0.012).

The decrease in carbohydrate content is directly proportional to the reduction in sago flour composition in each formulation. This means that a lower proportion of sago flour can reduce the carbohydrate content of cookies. Sago flour exhibits a higher carbohydrate content compared to sorghum flour. The carbohydrate level in sago flour is 84.03%, while the carbohydrate level in sorghum flour is 76.64%[42,43]. These findings are consistent with the research of Alhadi et al. (2023), who demonstrated a significant increase in the carbohydrate content of beef burger patties following the addition of palm sago flour[49]. Previous research has shown that the carbohydrate content of bagea cookies decreases as the amount of sago flour decreases[50].

Indonesian National Standard (SNI) 01-2973-1992 stipulates that cookies must contain a minimum of 70% carbohydrates to meet quality standards. The carbohydrate content of cookies made from sago and sorghum flour ranged from 47.52% to 52.96%. Consequently, these cookies did not meet the established quality standards.

Water Content

Water content is the percentage of water in a food product. Water content significantly impacts the appearance, flavour, texture, and shelf life of food products. Water content can be considered a determinant of shelf life due to its influence on physicochemical properties, chemical changes, and microbiological activity[51]. Excessive water content can expedite microbial proliferation and hydrolysis of chemical compounds, thereby compromising the quality attributes of food substances[52].

The water content of sago flour and sorghum flour cookies is presented in Table 3. The highest water content was found in F4 cookies (16.56%) with a proportion of 25% sago flour:75% sorghum flour, while the lowest water content was found in F3 cookies (15.55%) with a proportion of 50% sago flour:50% sorghum flour. ANOVA test gave non-significant results (p=value=0.881), and the Duncan test was deemed unnecessary.

Indonesian National Standard (SNI) 01-2973-1992 stipulates that cookies must have a maximum water content of 5% to be considered acceptable. None of the cookie formulations made from sago and sorghum flour met the specified requirements, as their water content ranged from 15.55% to 16.56%. The water content of cookies can be influenced by the components and characteristics of the ingredients, baking temperature and duration, as well as the humidity level of the storage environment

The water content of sago flour is 13.90%, while the water content of sorghum flour is 10.26%[42,43]. Both of the ingredients have a high starch. Heating can weaken the hydrogen bonds in starch, leading to water absorption and swelling, causing the starch granules to rupture once they exceed their maximum swelling point[53]. The rupture of starch granules results in evaporation of water content[54].

The elevated water levels in the sago and sorghum flour cookies are attributed to inadequate baking temperatures, which failed to achieve the desired level of water reduction. It is hypothesized that the baking temperature in this study was insufficient to evaporate all moisture content throughout the 5-7 mm thick cookies, even though the cookies appeared to be fully baked. Polii's research (2017) corroborates this hypothesis, indicating that cookies with a thickness of 3-4 mm baked at 160°C have a relatively high water content, ranging from 11.46% to 12.09%[55].

Ash Content

Ash content represents the quantity of inorganic residues obtained from the combustion or oxidation of a food item's organic matter. Ash content can be used to identify the mineral content of food products. The Ash content of sago flour and sorghum flour is presented in Table 3. The F5 cookies have the highest ash content (1.98%) with a proportion of 0% sago flour:100% sorghum flour, while the F1 cookies have the lowest ash content (1.71%) with a proportion of 100% sago flour:0% sorghum flour. Based on the ANOVA test, a significant pairwise difference was found (p-value=0.005).

A positive linear relationship was observed between ash content and the proportion of sorghum flour in the formulations. A higher proportion of sorghum flour resulted in a higher ash content. The increase in ash content can be attributed to the raw ingredients used. The ash content of sorghum flour is higher at 1.32%, compared to the 0.41% found in sago flour[42,43].

Indonesian National Standard (SNI) 01-2973-1992 stipulates that cookies must have a maximum ash content of 2% to be considered acceptable. The ash content of sago flour and sorghum flour cookies is 1.71%–1.98%. Therefore, the sago and sorghum flour cookies have met the established standards.

Organoleptic Properties

Data analysis was commenced with a normality test to determine the data distribution. The Kruskal Wallis test was employed for analysis as the organoleptic data did not meet the normality assumption. The Kruskal

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Wallis revealed no significant pairwise differences among the groups for colour (p-value=0.891), aroma (p-value=0.061), texture (p-value=0.164), and taste (p-value=0.421). Consequently, Mann-Whitney tests were deemed unnecessary.

Colour

The sago and sorghum flour cookies have a light brown colour. The increased proportion of sorghum flour resulted in a slightly darker colour. This is attributed to the higher whiteness index of sago flour (87.93%) compared to sorghum flour (71.40%)[56,57]. The color of the cookies is determined by various factors, including egg yolks. The carotenoid pigments in egg yolks contribute to the orange, yellow, and red colours observed in the cookies[58]. Heat triggers the Maillard reaction in the ingredients, resulting in the brown colour of the cookies. This reaction involves the interaction of sugars and proteins in the food[59].

Aroma

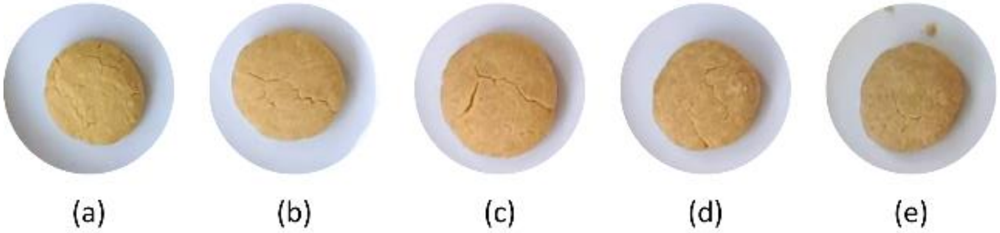
Aroma is the sensation perceived when volatile compounds from a product stimulate the olfactory receptors in the nasal cavity[60]. The aroma of food products is influenced by factors such as baking temperature, duration, and the combination of fats, amino acids, and sugars[61]. The sago and sorghum flour cookies have a savoury aroma. The aroma originates from the flour, margarine, egg yolk, and milk. Budiyanto et al. (2019) described that the aroma of sago starch is mild and not pungent[62]. The aroma of sorghum is characterized by notes of dustiness, woodiness, and a hint of graininess[63]. The higher proportion of sorghum flour in F4 and F5 resulted in a slightly more pronounced sorghum aroma. However, this was generally acceptable to the panellists as the aroma of other ingredients masked the sorghum flavour, leading to no significant differences.

Table 4. The Median Value of Hedonic Test for Sago Flour and Sorghum Flour Cookies

Parameters	The Median Value of Hedonic Test for Sago Flour and Sorghum Flour Cookies					p-value
	F1	F2	F3	F4	F5	
Colour	4 (2–5)^a	4 (2–5)^a	4 (2–5)^a	4 (2–5)^a	4 (2–5)^a	0.891
Aroma	4 (3–5)^a	4 (3–5)^a	4 (3–5)^a	4 (3–5)^a	4 (1–5)^a	0.061
Texture	3 (2–5)^a	4 (2–5)^a	4 (2–5)^a	4 (2–5)^a	3 (1–5)^a	0.164
Taste	3 (2–4)^a	3 (2–4)^a	3 (2–5)^a	3 (1–5)^a	3 (1–5)^a	0.421

F1 (100% sago flour:0 % sorghum flour), F2 (75% sago flour:25% sorghum flour), F3 (50% sago flour:50% sorghum flour), F4 (25% sago flour:75% sorghum flour), F5 (0% sago flour:100% sorghum flour)

^{a} = identical letter notations within the same row suggest that there are no substantial differences among the groups (p-value>0.05)



(a) F1=100% sago flour:0% sorghum flour, (b) F2= 75% sago flour:25% sorghum flour, (c) F3= 50% sago flour:50% sorghum flour, (d) F4= 25% sago flour:75% sorghum flour, (e) F5= 0% sago flour:100% sorghum flour

Figure 4. Sago Flour and Sorghum Flour Cookies

Texture

Food texture refers to the tactile sensation of contact between the oral cavity and a food item. Sago flour and sorghum flour cookies have a crumbly texture. Gluten is a protein that can influence the cookie's texture. Gluten can bind and form dough into an elastic state, making it easily shaped. Gluten-free ingredients, such as sago flour and sorghum flour, result in a dough that can not bind water optimally, leading to a crumbly texture[64]. Other components, such as fat, can also influence the texture of cookies. Fat can contribute to a porous texture, thereby increasing water absorption and softening the cookie texture[65].

Taste

The flavour is a sensory experience created by the interaction between the taste buds and the specific combination of ingredients in a food[66]. Based on Table 4, the tastes of sago flour and sorghum flour cookies are not significantly different. The mild flavour of sago and sorghum flour could be a factor in this result. White sorghum flour was used in this particular research. White sorghum flour contains less tannin than red and brown sorghum flour, which can impact a bitter taste[16,17].

The Best Formulation

The best formulation was determined by the De Garmo Method. The formulation resulting in the highest productivity score of cookies was deemed the best. Cookies with a 75% sago flour: 25% sorghum flour proportion (F2) exhibited the highest productivity score. Therefore, formulation F2 was selected as the best formulation in this study.

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A key strength of this research is using sago and sorghum flour, local grains with a low glycemic index, to produce cookies with higher levels of resistant starch than wheat flour cookies. Furthermore, these cookies do not contain added sugar, making them suitable for people with T2DM. Despite its strengths, this research has certain limitations. The water content of the cookies exceeded the maximum allowed by SNI 01-2973-1992, and the study did not assess the cookies' impact on blood glucose levels.

CONCLUSIONS

The proportions of sago flour and sorghum flour significantly impacted the resistant starch content, protein, carbohydrate, and ash content. However, no significant differences were observed in terms of fat content, water content, and organoleptic properties. The optimal formulation was determined using the De Garmo method, considering the highest productivity score. Cookies F2, exhibiting the highest productivity score based on parameters such as resistant starch content, nutritional value, and organoleptic properties, were determined to be the optimal formulation in this study.

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CONFLICT OF INTEREST AND FUNDING DISCLOSURE

All authors declare that they have no conflict of interest regarding this article. This research was self-funded.

AUTHOR CONTRIBUTIONS

HTL: conceptualization, investigation, methodology, supervision, writing–original draft, editing, funding acquisition; AF: writing–review, project administration, supervision, editing; NN: writing-review, supervision, editing.

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