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Chemical and sensory characteristics of sweet potato crackers containing various starch types

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ABSTRACT

White sweet potato is a local Indonesian food ingredient that can be processed into various products, including nonflaky crackers. Adding different types of starch to the cracker formulation can improve product characteristics, enhancing sensory acceptability. This study aims to determine the effects of the proportion of white sweet potato flour to wheat flour and the type of added starch on the chemical and sensory characteristics of crackers. A completely randomized design (CRD) was used. The factors studied were the addition of various types of starch (P; P1, white sweet potato starch; P2, cornstarch; and P3, tapioca) and the white sweet potato starch: wheat flour ratio (% w/b, T) (T1, 1:3; T2, 1:1; T3, 3:1; and T4, 4:0). The chemical characteristics evaluated were the moisture, ash, fat, protein, and carbohydrate contents. The sensory characteristics evaluated were the taste, texture, color, and degree of liking (preference). The chemical variables were analyzed using ANOVA and DMRT at the α = 5% level. The Friedman test was used for sensory evaluation. The results showed that the type of added starch (P) significantly affected the fat content. Furthermore, the proportion of white sweet potato flour to wheat flour (T) significantly influenced the fat and protein contents. In addition, the treatment combination (PT) significantly affected texture, color, and preference. The best treatment (P1T1) resulted in crackers with 4.40% moisture, 18.06% fat, and 74.86% carbohydrates, along with favorable sensory attributes like slightly salty taste, crunchy texture, and light brown color.

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INTRODUCTION

Crackers are a type of biscuit made by fermentation, with a porous and crunchy texture (Ramadhani et al. 2022). In general, crackers are made using wheat flour, fat, salt, and yeast (Batista et al. 2019). Wheat flour is generally used as a raw material for crackers because it contains gluten, which can hold the gas formed during the fermentation, so that the dough expands. How the dough expands during baking determines the structure of the biscuits/crackers (Hatmi et al. 2021). Indonesia imports large amounts of wheat flour. In 2023, wheat imports amounted to 10.58 thousand tonnes, valued at US$3.66 billion. Therefore, flour made from local ingredients is needed as an alternative raw material to make crackers. Crackers are a type of biscuit made using a fermentation method, with a layered and crunchy texture that many consumers prefer (Muhammad et al. 2022).

Bima-Pasru honey sweet potato is a new variety of white sweet potato rich in carbohydrates (as much as 84.83%). This carbohydrate percentage is higher than that of yellow (83.19%) and purple (83.81%) sweet potato flour (Muhammad et al. 2022). Thus, white sweet potato flour may be used to manufacture various food products. However, the absence of gluten is one of the main obstacles that hinder the use of sweet potato flour as a raw material for bakery products (Amelia et al. 2020). The lack of gluten impedes the dough from holding gas, so the dough has small pores and does not expand properly (Subandoro et al. 2013). As a result, a baked product with a hard texture is obtained. Thus, adding starch is needed to achieve a crunchy texture (Xu et al. 2020).

According to Utomo et al. (2017), cornstarch is added to generate a firmer texture in cracker-like products like biscuits because it has a fairly high amylopectin content. Amylopectin has a branched chain that causes puffing; thus, flour with a high amylopectin content results in crispy, light, hollow, and crunchy products (Reyniers et al. 2020). Different types of starch have different amounts of amylopectin; for instance, tapioca, cornstarch, and white sweet potato starch have 91.94% (Choi et al. 2022), 65.025% (Utomo et al. 2017), and 45.163% (Yuliansar et al. 2020) amylopectin, respectively. The difference in the amylopectin content can affect the quality of the final product. Thus, this study aimed to determine the effects of the ratio of white sweet potato flour to wheat flour and variations in the type of starch added on the chemical and sensory characteristics of crackers.

METHODS

Materials

The main ingredients were white sweet potato (Bima-Pasru variety) flour (from Pasrujambe Distric, Lumajang, West Java, Indonesia), low-protein wheat flour (Kunci Biru brand, PT Indofood Sukses Makmur, Indonesia), butter (Plamia brand, PT Indofood Sukses Makmur, Indonesia), sweet potato starch (Kalibendo Agro Forestry, Banyuwangi, East Java), cornstarch (PT Aneka Boga Nusantara, Karawang, Indonesia), cassava starch (PT Tirta Kencana, Bogor, Indonesia), skim milk (PT Global Perkasa Jaya, Indonesia), powdered sugar, instant yeast, baking powder (Koepoe-Koepoe brand, Indonesia), water, and salt.

Table 1 Ingredient composition for each cracker product

Composition (g)	Product			
	P1	P2	P3	P4
Sweet potato flour	12.5	25	37.5	50
Wheat flour	37.5	25	12.5	0
Starch (sweet potato/corn/cassava)	10	10	10	10
Yeast	0.75	0.75	0.75	0.75
Baking powder	0.25	0.25	0.25	0.25
Butter	12	12	12	12
Fine granulated sugar	1	1	1	1
Skim milk	2	2	2	2
Water	25	25	25	25
Vanilla	0.2	0.2	0.2	0.2
Salt	1	1	1	1

Sample Preparation

Crackers were made by mixing all the ingredients presented in **Error! Reference source not found.**. The dough was kneaded until smooth and left to stand at room temperature (30°C) for 20 minutes, covered. Next, the dough was flattened to a thickness of 0.2–0.3 mm, molded into a square shape with a size of 5 × 5 cm, and holes were poked. Crackers were baked at 160°C for 20 minutes.

Experimental Design

The study used a factorial completely randomized design (CRD) with two factors. The first factor, the proportion of white sweet potato flour to wheat flour (T), comprised the ratios of 1:3 (T1), 1:1 (T2), 3:1 (T3), and 4:1 (T4). The second factor was the type of starch added, namely sweet potato starch (P1), cornstarch (P2), or tapioca (P3). Each combination was repeated in triplicate.

Analysis

Cracker samples were analyzed for moisture (AOAC 2005), ash (AOAC 2005), fat (AOAC 2005), protein (AOAC 2005), and carbohydrate content (by the difference method). A sensory analysis (taste, texture, and color) was conducted by 15 trained panelists. A rating test using a 5-point scale was employed. Saltiness was assessed on a 5-point scale: 1 (not salty at all), 2 (not salty), 3 (slightly salty), 4 (slightly salty), and 5 (salty). The texture was assessed on a 5-point scale: 1 (not crispy at all), 2 (not crispy), 3 (slightly crispy), 4 (slightly crispy), and 5 (crispy). The color was also assessed on a 5-point scale: 1 (dark brown), 2 (brown), 3 (light brown), 4 (yellowish brown), and 5 (brownish yellow). The preference test was conducted by 50 untrained panelists, using a 5-point preference scale: 1 (dislike a lot), 2 (dislike), 3 (neutral), 4 (like), and 5 (like a lot).

Data Analysis

The chemical characterization data were analyzed using the analysis of variance (ANOVA) test with a confidence level of 95%. If the ANOVA test showed a significant effect, Duncan's multiple range test (DMRT) was conducted with $\alpha = 5\%$. The data from the sensory analysis and preference test were analyzed using the Friedman test and the effectiveness index test to identify the optimal cracker formula.

RESULTS AND DISSCUSION

Chemical Characteristics

Moisture Content

The moisture content was not significantly affected by the proportion of flour, starch type, or their interaction. The lowest moisture content (2.32%) corresponded to P3T4 crackers (tapioca added and 100% sweet potato flour). By contrast, the highest moisture content (4.69%) corresponded to P2T4 crackers (cornstarch added and 100% sweet potato flour). All formulations in this study met the quality requirements for crackers, based on SNI 2973: 2011, namely, a maximum of 5% moisture (BSN, 2011). According to Putri et al. (2020), the higher the amount of purple sweet potato flour added to biscuits, the more water needs to be incorporated, thus increasing the water content. In addition, according to Jayanthi et al. (2021), starch granules can absorb water because of the presence of large hydroxyl groups, so that more starch added needs more water added. However, in the current study, the same water and starch proportion was used in all formulations, so that the moisture content of the product was not significantly different. The duration of fermentation is another factor that affects the water content of crackers. The longer the fermentation time, the lower the water content of a product (Aini et al. 2024). The moisture content of crackers can also be affected by the temperature and time used for baking because of water evaporation. Furthermore, starch can affect the water content of crackers because it binds water; thus, more starch results in higher water binding. Starch granules can absorb water because of their large hydroxyl groups (Tô et al. 2020). In the current study, the fermentation time, baking temperature and time, and amount of starch in all treatment combinations were the same; thus, they did not significantly affect the water content of crackers.

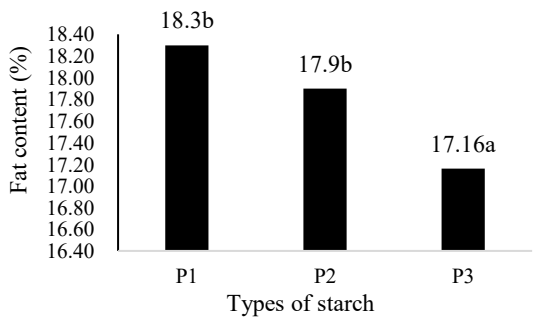
Ash Content

The ash content of the sweet potato crackers was not significantly affected by variations in the starch type, proportion of sweet potato flour, or their interaction. The lowest ash content (1.77%) corresponded to P2T4 crackers (made with 100% sweet potato flour with cornstarch added). By contrast, the highest ash content (2.36%) corresponded to P3T4 crackers (made with 100% sweet potato flour with tapioca added). This result is due to the similar ash content of the white sweet

potato flour (0.61%) (Rahmawati et al. 2015) and high-protein wheat flour (0.56%) (Pangestuti and Darmawan 2021). In addition, the different types of starch have a similar ash content: white sweet potato starch has <1% ash (Sigüenza-Andrés et al. 2021); tapioca starch, 0.58% ash (Katunzi-Kilewela et al. 2022); and cornstarch, 0.3% ash. Thus, adding starch in small amounts did not affect the ash content of the crackers. Notwithstanding, several treatments did not meet the quality requirements of SNI 012973-1992, namely, a maximum of 2% ash (BSN, 2011). A higher ash content indicates a higher inorganic material content in food products (Ogunmolasuyi et al., 2017). An ash content that exceeds the standard can also be due to the incomplete oxidation of organic substances during combustion (Ahmed and Abozed 2015). The more minerals in the food, the darker its color (Muhammad et al. 2022). In addition, consuming an excess of minerals may have detrimental effects on health. Excessive iron deposition can result in oxidative stress and organ/tissue damage, whereas hypercalcemia can cause kidney stones, cardiac arrhythmias, and soft-tissue calcification (Zhang et al. 2020).

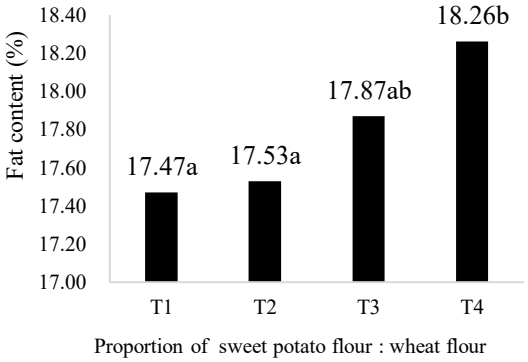
Fat Content

The fat content of crackers was significantly affected by the type of starch added (P) and the proportion of white sweet potato flour to wheat flour (T). Figure 1 shows that crackers with tapioca added had a significantly lower fat content (17.16%) than those with white sweet potato starch (18.30%) or cornstarch (17.90%) added. This result may be due to the higher fat content of cornstarch (0.05 g), compared to tapioca (0.02 g) (United States Department of Agriculture, 2019).



Notes: Different letters indicate significant differences; P1 = white sweet potato starch; P2 = cornstarch; P3 = tapioca.

Figure 1 Fat content of crackers with various types of starch added (P)



Notes: Different letters indicate significant differences; T1 = 1:3, T2 = 1:1, T3 = 3:1, T4 = 4:0.

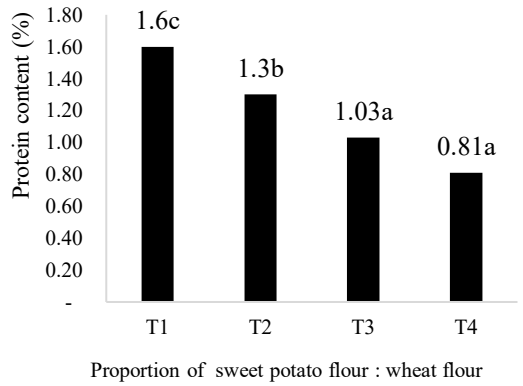
Figure 2 Fat content of crackers with varying proportions of white sweet potato flour: wheat flour (T)

The fat content of T1 crackers (17.47%) was not significantly different from that of T2 (17.53%) or T3 (17.87%) crackers but was significantly different from that of T4 (18.26%) crackers. On the other hand, T3 and T4 crackers did not have a significantly different fat content. Figure 2 shows that the higher the proportion of white sweet potato flour, the higher the fat content. This outcome contrasts with a previous study (Olorunsogo et al. 2019), which reported that white sweet potato dry noodles made using 75% white sweet potato flour and 25% wheat flour had a low fat content of 0.575%. Moreover, the fat content of white sweet potato flour is lower (0.26%) than that of wheat flour (1.13%) (Ji et al. 2015).

Protein content

The protein content of crackers was significantly affected by the proportion of white sweet potato flour: wheat flour (T). T1 crackers had a significantly different protein content from T2, T3, and T4 crackers. On the other hand, T3 and T4 crackers did not differ significantly in their protein content. Figure 3 shows that the highest protein content (1.6%) corresponded to T1 crackers. By contrast, the lowest protein content (0.81%) corresponded to T4 crackers. The higher the proportion of wheat flour, the higher the protein content. Our results are in line with several other studies. For example, the higher the yellow sweet potato flour content in nastar (Suarningsih et al. 2022), the lower the protein content. Notably, the protein content in purple sweet (2.36%), yellow (2.85%), and white sweet potato

flour (2.35%) is much lower than that in wheat flour (12.37%) (Ernayanti et al. 2021).



Notes: Different letters indicate significant differences; T1 = 1:3, T2 = 1:1, T3 = 3:1, T4 = 4:0.

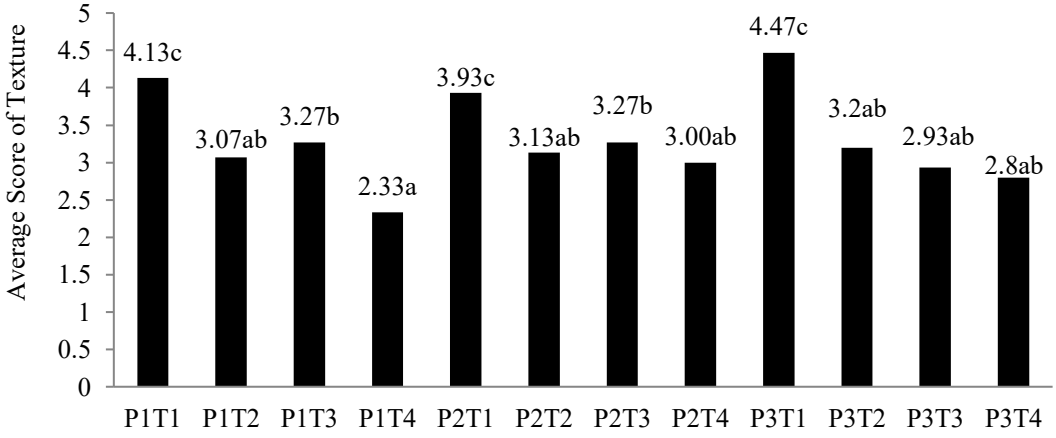
Figure 3 Protein content of crackers with varying proportions of white sweet potato flour: wheat flour (T)

Carbohydrate content

The carbohydrate content of sweet potato crackers was not influenced by the addition of various types of starch (P), the proportion of white sweet potato flour to wheat flour (T), or the interaction between P and T (PT). The carbohydrate content of the crackers ranged from 72.54% to 75.5%, with the lowest carbohydrate content corresponding to P1T1 (72.54%), and the highest, to P2T4 (75.5%). The carbohydrate content was high in all samples because the raw materials used are rich in carbohydrates. Sweet potato flour contains 84.83% carbohydrate (Santosa et al. 2019), whereas wheat flour has 84.32% carbohydrate (Prasetyo and Winardi 2022). Both types of flour have similar carbohydrate contents; thus, the variation in the proportion of white sweet potato flour to wheat flour does not significantly affect the carbohydrate content of the crackers. In addition, the various types of starch were added in the same amounts; thus, they did not significantly influence the carbohydrate content of the crackers. Baking results in water evaporation. Nonetheless, here, crackers were baked under the same conditions, so the water content of all samples was similar and did not affect the carbohydrate content (Manzocco et al. 2020).

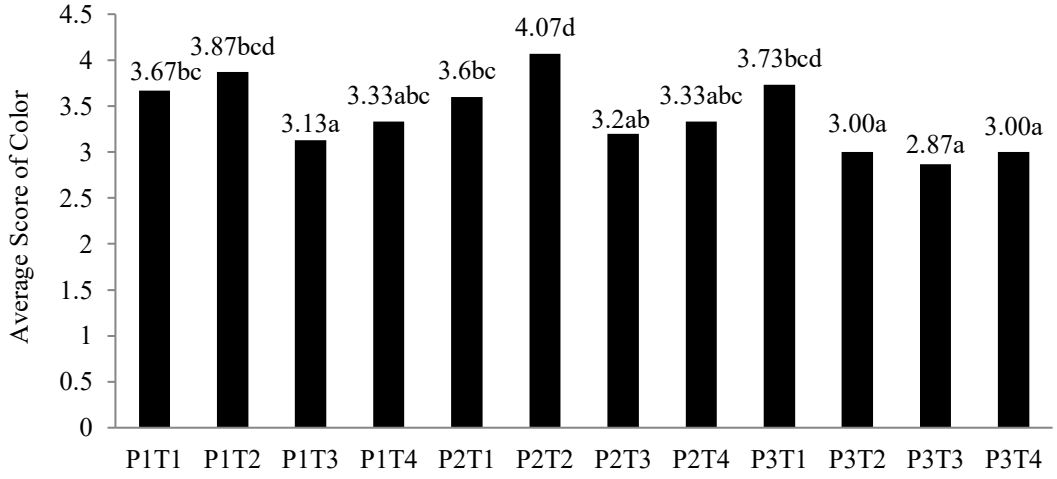
Sensory Characteristics

The combination of the type of starch added and the proportion of sweet potato flour to wheat flour did not affect the chemical variables, but did affect the sensory characteristics of the crackers. This is likely because the human senses are better able to detect differences in taste, texture, color, and preference, although the chemical parameters of the sample do not change significantly.



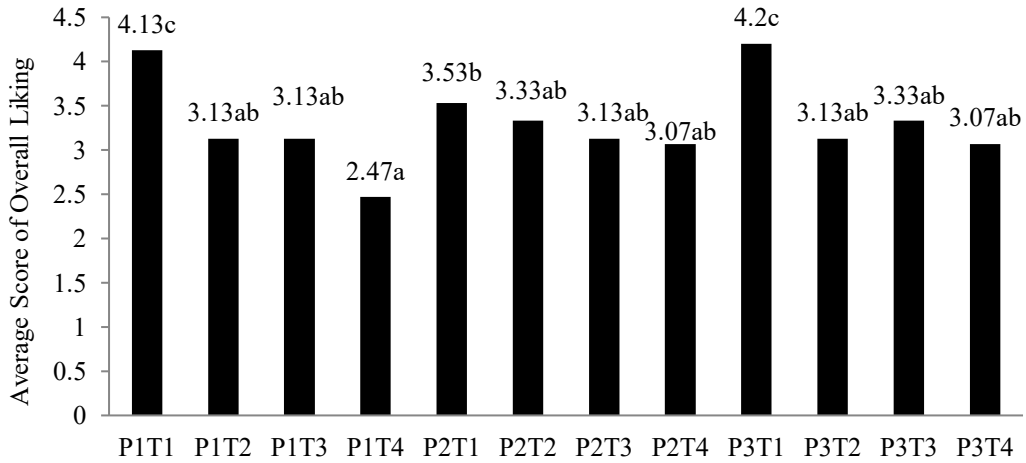
Notes: Different letters indicate significant differences. P1 = white sweet potato starch; P2 = cornstarch, P3 = tapioca. T1 = 1:3; T2 = 1:1; T3 = 3:1; T4 = 4:0

Figure 4 Average texture scores of the crackers



Notes: Different letters indicate significant differences. P1 = white sweet potato starch; P2 = cornstarch; P3 = tapioca. T1 = 1:3; T2 = 1:1; T3 = 3:1; T4 = 4:0.

Figure 5 Average color scores of the crackers.



Notes: Different letters indicate significant differences. P1 = white sweet potato starch; P2 = cornstarch; P3 = tapioca. T1 = 1:3; T2 = 1:1; T3 = 3:1; T4 = 4:0.

Figure 6 Average preference scores of the crackers

Taste

The taste attributes of crackers are focused on the salty taste that characterizes them. The results of the Friedman test showed that the treatment combinations did not have a significant effect on the salty taste of the crackers. All samples had average taste scores of 2.93–3.73, implying that they had a slightly salty taste. This is due to the use of salt in the cracker formulation. Salt acts as a flavor enhancer (Venkatachalam and Nagarajan 2017). In this study, salt was added at the same rate for all treatment combinations (PT); thus, the saltiness of crackers was not affected.

Texture

Crackers have a characteristic crunchy texture. Based on the results of the Friedman test, the treatment combinations (PT) significantly affected the texture of the crackers. As shown in **Error! Reference source not found.**, the highest t exture score corresponded to P3T1 (4.47 = crispy). Adding tapioca resulted in the crunchiest crackers because tapioca has a higher amylopectin content

(91.94%) (Mohamed 2021) than cornstarch (65.025%) (Utomo et al. 2017) and white sweet potato starch (45.1634%) (Yuliansar et al. 2020). Wheat flour plays a role in the formation of texture because of its gluten content, which affects the cohesiveness and extensibility of the dough, so it can retain the gas formed during the fermentation and expand (Mir et al. 2017). Therefore, the more wheat flour is used, the crisper the texture of the crackers. The P1T1 (4.133), P2T1 (3.922), and P3T1 (4.467) samples did not have significantly different textures and obtained the highest texture scores. However, these samples were significantly different from other treatments.

Color

Crackers are expected to have a yellow-brown color. Based on the results of the Friedman test, the treatment combinations (PT) resulted in significant differences in the color of the crackers. As shown in **Error! Reference source not f ound.**, the highest average score corresponded to the P2T2 sample (4.07 = brownish yellow) and was significantly different from other treatments. On the other hand, the lowest average score corresponded to P3T3 (2.87 = brown). The highest score indicates that the color is in accordance with the expected (yellow-brown) for crackers. By contrast, the lowest score implies that the color is unappealing (dark brown). The proportion of white sweet potato flour to wheat flour influenced the color of the crackers. Wheat flour is white, whereas white sweet potato flour is slightly brownish. Thus, a greater proportion of white sweet potato flour results in crackers with a darker color. In addition, the brownish color of crackers is also due to the Maillard and caramelization reactions (Faccioli et al. 2021). Caramelization is a reaction that occurs when sugar is heated in the absence of water (Winarno 2008). On the other hand, the Maillard reaction occurs between amino acids and reducing sugars that are heated simultaneously (Sutrisno and Susanto 2019).

Preference

Overall preference was significantly influenced by the treatment combinations (PT). As shown in **Error! Reference source not found.**, t he highest average score corresponded to P3T1 (4.2 = preferred). The preference for crackers can be influenced by several attributes, especially texture, a crucial attribute in crackers. Crackers should have a crunchy texture and be light and soft when bitten (Indrianingsih et al. 2019). Therefore, the crunchier the texture, the greater the preference for crackers. Here, P3T1 had the highest crunchiness score (4.41) and the highest preference score (4.2). In addition, P3T1 had a slightly salty taste (3.53) and did not significantly differ from other samples. The color attribute of sample P3T1 received the third-highest score (3.73), reflecting its light brown color. The aroma may have also influenced the preference for these crackers. The higher the sweet potato flour content, the lower the preference (Figure 6). The appearance of the crackers can also influence consumer preference, with crackers containing more sweet potato flour having a less attractive appearance because of the darker color.

Optimal treatment

The optimal treatment was identified based on the highest productivity value in the effectiveness index test (Table 2). The results of the effectiveness index test revealed that P1T1 crackers made with white sweet potato starch (P1) and a proportion of sweet potato flour: wheat flour of 1:3 (T1) were the optimal based on their sensory characteristics. The P1T1 crackers were made by adding P1 starch (white sweet potato starch and a proportion of sweet potato flour to wheat flour of 25:75). This treatment resulted in crackers with a slightly salty taste (score = 4.13), crunchy texture (score = 4.13), and light brown color (score = 3.67), and were thus preferred (score = 4.13) over other samples.

Table 2 Effectiveness index test results for the crackers

Variable	Productivity value											
	P1T1	P1T2	P1T3	P1T4	P2T1	P2T2	P2T3	P2T4	P3T1	P3T2	P3T3	P3T4
Taste	0,31	0,26	0,26	0,23	0,26	0,18	0,18	0,28	0,23	0,31	0	0,23
Texture	0,18	0,08	0,1	0	0,16	0,08	0,1	0,07	0,22	0,09	0,06	0,05
Color	0,06	0,08	0,01	0,03	0,06	0,1	0,02	0,03	0,07	0	-0,01	0
Preference	0,36	0,14	0,14	0	0,23	0,19	0,14	0,13	0,37	0,39	0,19	0,13
Sum	**0,91**	0,56	0,51	0,26	0,71	0,55	0,44	0,51	0,89	0,79	0,48	0,41

CONCLUSION

Adding various types of starch affected the fat content of crackers. Moreover, the proportion of white sweet potato flour to wheat flour affected the fat and protein content of crackers. The combination of the two factors did not significantly affect all chemical characteristics, but significantly affected the sensory characteristics of texture, color, and liking. The optimal treatment based on the sensory characteristics involved adding white sweet potato starch and a proportion of sweet potato flour: wheat flour of 1:3 (P1T1). P1T1 crackers had 4.40% moisture, 1.81% ash, 18.06% fat, 1.55% protein, and 74.86% carbohydrate. This sample received a taste score of 4.13 (slightly salty), a texture score of 4.13 (crunchy), a color score of 3.67 (light brown), and a preference score of 4.13 (like). Thus, crackers made using sweet potato flour and added with sweet potato starch can be an alternative for utilizing sweet potatoes in the food industry.

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