EurAsian Journal of BioSciences
Eurasia J Biosci 14, 287-292 (2020)

The impact of restricted substitution of wheat flour with tannia flour on the physico-chemical and sensory properties of cookies

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Abstract

The feasibility of wheat flour substitution with tannia flour in the production of cookies was investigated. The tannia flour studied were native tannia flour (NTF) and pregelatinized tannia flour (PTF). NTF was made by drying the sliced tannia tuber at 70ºC and then milled and sieved through a 60 mesh sieve. PTF was made using ahydrothermal technique that was by boiling sliced tannia tuber in hot water (95ºC) for 10 minutes before drying. Partial substitution of wheat flour with NTF or PTF was done at the level of 50%. The physical, chemical, sensory, and microstructural properties of the cookies produced were evaluated. Microstructural studies were performed using a scanning electron microscope (SEM). The results showed that substitution of wheat flour with tannia flour had a significant effect on sensory properties (texture); physical properties (hardness, color, and microstructure); and chemical properties (protein, carbohydrate, ash, and curd fiber content). Replacement of 50% wheat flour with PTF produced cookies that compete well with 100% wheat flour cookies (control) in term of sensory, physical, and chemical aspects. The PTF substituted cookies had lower protein level compared to the control cookies, but it had higher crude fiber content. Moreover, the PTF substituted cookies contained 5.94% protein, 24.52% fat, 63.10% carbohydrate, and 1.92% crude fiber, and it was a low-gluten and fiber-rich cookie.

Keywords: tannia tuber, pregelatinized flour, wheat flour substitution, low-gluten cookies

Putra INK, Suparthana IP (2020) The impact of restricted substitution of wheat flour with tannia flour on the physico-chemical and sensory properties of cookies. Eurasia J Biosci 14: 287-292.

INTRODUCTION

Cookies are roasted snacks that have a sweet taste and generally made from wheat flour, sugar, milk, and eggs, which are preferred by both children and adults so that its production and sales are proliferating today. The main ingredient of cookies is wheat flour while, in tropical countries like Indonesia, wheat cannot be produced optimally, so it must be imported from abroad. Throughout 2017, Indonesia imported 11.43 MT of wheat (with a value of US $ 2.65 billion), mostly from Australia (Import of Various Commodities Throughout 2017).

In indonesia, there is abundant stoct of Tannia (*Xanthosoma sagittifolium*), is a tuber plant, that is commonly found in agricultural areas in Indonesia. Tannia has a great potential to produce tubers (10 - 25 tons per hectare), and the tubers are rich in starch (20%) so it suitable to be processed into flour (Moorthy et al. 2018). Tannia tubers contain 2.42 % protein, 0.92% fat, 24.67% carbohydrate, 3.00% crude fiber, 90.92 mg/100g vitamin C, 0.12 µg/g Zn, 0.31 µg/g Ca, and 0.29 µg/g Fe (Sarma et al. 2016). The substitution of wheat flour with tannia flour is an effort that can be done to increase the use of indigenous commodities cultivated in Indonesia. In addition, tannia flour supplementation in cookies can increase the crude fiber and decrease gluten of the cookies. Further, previously reported that tannia flour might be used to substitute a portion of wheat flour in the manufacture of *semprit* cookies, where a 20% substitution still produced satisfactory cookies (Prihatiningrum 2012). Meanwhile, substitution studies above 20% have not been conducted. Moreover, Alflen et al. (2016) stated that substitution of wheat flour with taro flour could cause a decrease in the thickness of cookies. The limitation of tannia flour as a substitute for wheat flour in the production of cookies can be enhanced by modifying its functional properties, where the modification can be done with the pregelatinization

Received: January 2019
Accepted: December 2019
Printed: March 2020

technique. Pregelatinized flour can be prepared by various methods such as steaming method (Khomsatin et al. 2012) and boiling method (Palupi et al. 2011, Padmaja et al. 2002). In the steaming method, the flour material is given a high pressure steaming treatment (121ºC or 1.3 bar pressure) within 10 - 60 minutes, before being further processed into flour (Khomsatin et al. 2012), while in the boiling method, the flour material was boiled at a temperature of 80 - 100ºC for 10 minutes (Palupi et al. 2011). Pregelatinization treatment had a significant effect on amylose content and amylographicproperties of cassava flour (Palupi et al. 2011), and it also changed the pasting profile of corn flour from type B to type C (Khomsatin et al. 2012).

Hence, this study aims to examine the effect of partial substitution of wheat flour with native tannia flour (NTF) and pregelatinized tannia flour (PTF) on the chemical, physical, and sensorial characteristics of cookies. The substitution was done at the level of 50%, and PTF was made by using the parboiling technique.

MATERIALS AND METHODS

Tannia tubers (*Xanthosoma sagittifolium* [L.] Schott) were obtained directly from the farmers' farm in Singaraja, Bali, Indonesia. The tubers were certainly checked before used for free from mechanical and microbiological damage. High protein wheat flour (*Cakra kembar*) was purchased from the supermarket in Denpasar, Indonesia. All the chemicals used in this study were analytical grade. Tannia flour was made according to the procedure of Palupi et al. (2011) with a slightly modification. Tannia tubers were cleaned from dirt, peeled, and sliced with a thickness of ± 2 mm. The sliced tuber was soaked in 2% NaCl solution for 1 hour, washed with clean water, and dried in an oven dryer at 70°C to dry. Subsequently, the dried tuber was ground in a blender and sieved with a 60 mesh sieve, so it was produced the natural tannia flour (NTF). The procedure for making pregelatinized tannia flour (PTF) was the same as the procedure for making NTF except the sliced tubers were boiled at 95ºC for 10 minutes before drying.

Preparation of Cookies

The cookies formulation consist of 100 g wheat flour or composite flour, 45 g margarine, 35 g refined sugar, 15 g egg yolks, 0.4 g salt, 12 g skim milk, and 0.2 g baking powder. The composite flour was made by blending wheat flour and NTF or PTF in the ratio of 50:50. The cookies were made by the creaming method described by Matz and Matz (1978). Margarine, egg yolk, sugar, salt, and skim milk were mixed well, and then the flour and baking powder was slowly added into it and stirred again to form a dough. The dough was flattened with a thickness of 3 mm, shaped, and cooked in the oven at 176°C for 10 minutes.

Chemical Analysis

Proximate composition of the cookies was determined according to the AOAC method (AOAC 2005). The water content was calculated based on the weight loss of the sample after being dried in an oven at 105°C while the ash content was determined based on the weight loss of the sample after been burned in the muffle furnace at a temperature of 550°C. The protein content was calculated by determining total nitrogen by the micro-Kjeldahl method. Subsequently, protein content was calculated as 6.25 × % N. Fat content was determined by the Soxhlet method. Total carbohydrate was calculated by difference (100% - % moisture - % ash - % protein - % fat).

The crude fiber was determined with the procedure mentioned in AACC method No.32-10 (AACC 2000), using a sample that its fat has been previously extracted. The crude fiber was calculated as the residue which left behind after the sample was digested with 1.25% H2SO4 and 1.25% NaOH under specific conditions.

Physical Analysis

The surface color of cookies was measured using a Colorimeter (HH06, Accu Probe, USA). The color parameters measured were L* (lightness/darkness), a* (redness/greenness) and b* (yellowness/blueness). The hardness of cookies was observed with a texture analyzer (TA.XT.plus, Stable Micro Systems, USA), which employed a cylindrical probe P/2 fitted with a 5 kg cell load. Compression was applied at a speed of 1 mm/s until the sample breaks. The maximum force required to break the cookie was considered as a hardness value. Spread ratio was determined with the method described by Walker et al. (2012), where it was calculated as the ratio between the diameter and height of the sample. The cookies thickness and diameter (Cm) were measured with a vernier caliper at three different spots. SEM was used to observe the microstructure of cross-sections of cookies. The sample was cut crosswise using a knife at the thickness of 2 mm, and then it was placed on an aluminum stub where cross-sectional surfaces were facing out. Next, the specimens were overlaid with gold-palladium and photographed with a scanning electron microscope (JSM-6510, Jeol Ltd., Japan) which operated on a 5 kV acceleration potential and 30× magnification.

Sensory Analysis for Acceptance

Sensory evaluation of sample cookies was performed by 20 trained panelists (12 women and eight men, ages ranging from 20 to 30 years old). The panelists were asked to state their level of preference for the sample in a 7-point hedonic scale (1 = dislike very much, 2 = dislike moderately, 3 = dislike slightly, 4 = neither like nor dislike, 5 = like slightly, 6 = like moderately, and 7 = like very much) on the evaluation sheet. The panelists evaluated the sample in terms of

Table 1. Sensory characteristic of cookies with different of flour formulation

Flour formulation	Appearance	Aroma	Texture	Flavor	Overall acceptability
WF	5.8±1.12	5.7±0,61	5.7±1.14^{ab}	6,0±0,96	5.86±1.03
WF+NTF (50:50)	5.5±1.09	6.0±0,78	5.4±1.15^{b}	5,3±1,33	5.64±1.01
WF+PTF (50:50)	5.6±1.08	6.0±0.96	6.1±0.77^{a}	5,6±1,40	5.93±0.73

Values reported are means ± standard deviations (*n* = 20). Mean values with different superscript within the same column are significantly (P<0.05) different. WF: wheat flour; NTF: native tannia flour; PTF: pregelatinized tannia flour.

Table 2. Physical properties of cookies with different of flour formulation

Flour formulation	Hardness (N)	Spread ratio (%)	L*	a*	b*
WF	34.28 ± 2.71^{a}	5.61 ± 0.33^{a}	89.9 ± 0.4	- 4.6 ±0,8	40.4 ± 3.6^{a}
WF+NTF (50:50)	23.49 ± 0.35^{b}	6.70 ± 0.47^{b}	89.8 ± 0.7	- 3.0 ± 0.4	26.2 ± 0.9^{b}
WF+PTF (50:50)	16.62 ± 0.76^{c}	5.75 ± 0.14^{a}	89.3 ±0.5	- 5.1 ± 0.3	41.5 ±3.0^{a}

Values reported are means ± standard deviations (*n* = 3). Mean values with different superscript within the same column are significantly (p<0.05) different. WF: wheat flour; NTF: native tannia flour; PTF: pregelatinized tannia flour.

appearance, flavor, texture, taste, and overall acceptability.

Analytical Statistic

Analysis of variance (ANOVA) was used to determine the significant difference among formulations. Post hoc analysis was performed using Duncan's Multiple Range Test at the level of 5%. Data were expressed as a mean ± standard deviation.

RESULT AND DISCUSSION

Sensory Characteristic

Panelist acceptance scores for cookies made from 100%wheat flour, wheat flour-NTF composites (50:50), and wheat flour-PTF composites (50:50) are shown in **Table 1**. The results of statistical tests showed that substitution of flour with either NTF or PTF did not significantly (P>0.05) affect the appearance, aroma, taste, and overall acceptance score; but the substitution had a significant effect (P<0.05) on the texture score. The overall acceptance score for cookies in this study ranged from 5.64 - 5.93 which meant like moderately. The results of this study indicated the substitution of wheat flour with NTF at the level of 50% could reduce the panelist's acceptance on the texture of cookies; however, substitution using PTF at the same level had no significant effect on the texture of cookies. The texture of PTF substituted cookies was more acceptable by the panelist than NTF substitute cookies, but they were not significantly different from the 100% wheat flourcookies (control). Differences in crispness might cause a difference in panelist's acceptance of the texture of cookies. The PTF substituted cookies was crisper compared to those NTF substituted cookies. A similar study on the cookies made from wheat-taro flour composites by Alflen et al. (2016) showed that the substitution of wheat flour with taro flour caused a decrease in product texture, and the substitution could only be done up to 30%. These results indicated that PTF is more liable to substitute wheat flour compared to NTF and taro flour in producing cookies.

Physical Properties of Cookies

The average values of physical properties (hardness, spread ratio, and color) of cookies prepared from wheat

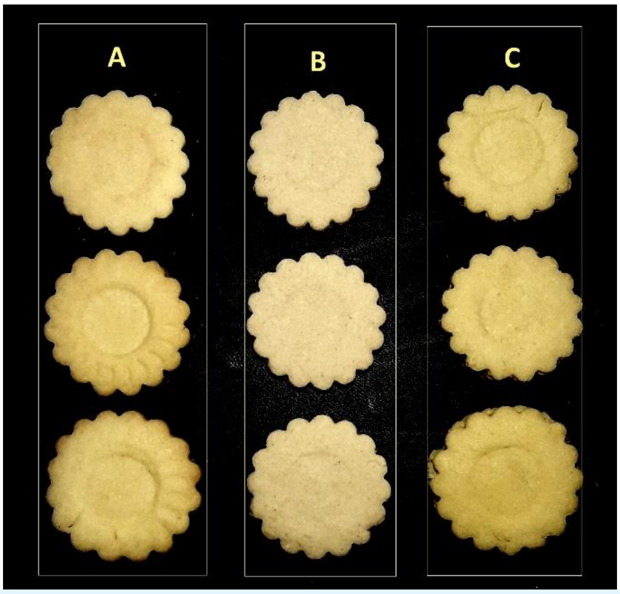

Fig. 1. Appearance of cookies prepared from wheat flour/tannia flour composite. (A) 100%wheat flour; (B) wheat flour-NTF (50:50); (C) wheat flour-PTF (50:50)

flour supplemented with tannia flour are presented in **Table 2**, and the surface appearance photograph of the cookies is presented in **Fig. 1**. Statistical analysis showed that the flour formulation significantly (P<0.05) influenced the hardness value, spread ratio, and b* value of cookies however it did not significantly (P>0.05) influence the L* value and a* value.

Texture is an important physical parameter that determines the quality of cookies (Ostermann-Porcel et al. 2017). Generally, consumers do not like cookies with textures that are too hard or too brittle. In this study, the texture of cookies was observed by measuring the hardness of the cookies using a texture analyzer. The results showed that the substitution of wheat flour either with NTF or PTF could significantly decrease the hardness of cookies, where PTF caused a more considerable decreased in hardness compared to NTF. These results were similar to previous findings, where the substitution of wheat flour with banana flour could decrease the hardness of cookies (Norhidayah et al. 2014). The same was also reported by Singh et al.

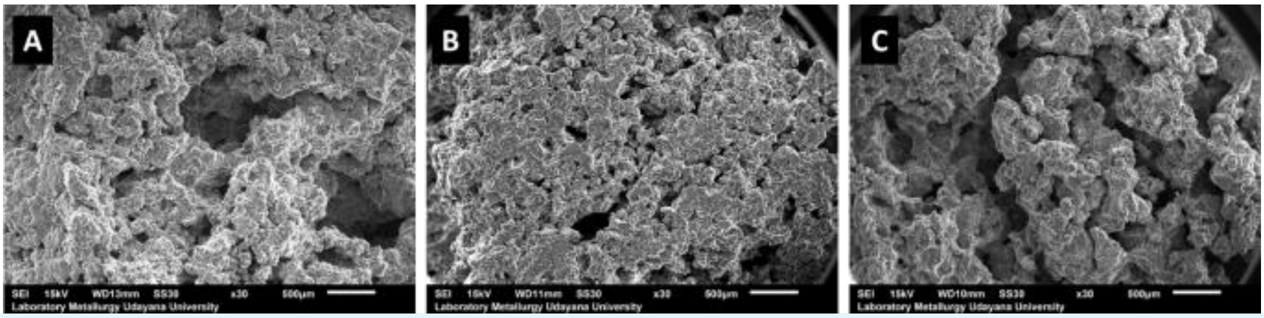

Fig. 2. Cross section SEM image of cookies. (A) 100%wheat flour, (B) wheat flour-NTF (50%:50%);(C) wheat flour- PTF (50%:50%). Magnification: 30×

(2008), where mixing wheat flour with potato flour could reduce the hardness of cookies.

Lowering the hardness of cookies supplemented with tannia flour can be caused by an increase in fiber content and a decrease in gluten content in the cookie dough. Singh et al. (2008) suggested that the fiber content in the dough could reduce the hardness of cookies, while Torbica et al. (2010) stated that gluten, which is the main protein in wheat, is responsible for the texture of bakery products. Furthermore, Chauhan et al. (2016) suggested that gluten plays a role in the formation of a continuous protein matrix in cookies during the baking process; therefore, a decrease in gluten in the dough contributes to the reduction in the hardness of cookies.

Spread ratio is another parameter which determines the quality of cookies. Wheat flour substitution with NTF caused an increase in the spread ratio of cookies. The substitution of wheat flour with NTF significantly increased the cookies' spread ratio. This increase in spread ratio did not occur in substitution with PTF. Spread ratio was calculated based on the ratio between the cookies' diameter and the cookies' thickness. Substitutions with NTF resulted in thinner cookies, which provide a higher spread ratio. These results indicated that substitution with NTF 50% caused the development of cookies did not occur optimally. On the other hand, on substitution with PTF, the development of cookies took place completely, which gave a spread ratio similar to the spread ratio of control cookies (100% wheat flour). A similar study on cookies added with cassava flour done by Oluwamukomi et al. (2011), and on cookies added with yam flour done by Igbabul et al. (2015) showed that substitution of wheat flour with either cassava flour or yam flour could reduce the ratio of cookies spread.

Color is claimed to be an essential attribute of food because it correlates well with the physical, chemical, and sensory properties of food. The brownish color of cookies is developed due to the non-enzymatic browning reactions that take place during the baking process. There are two types of non-enzymatic browning reactions, namely the Maillard reaction (interaction between reducing sugar and amino acids) and the caramelization reaction (not involving amino acids) (Cheftel et al. 1985). The substitution of wheat flour with NTF had a significant effect on the surface color of cookies, while substitution with PTF did not affect it. Substitution with NTF caused a decrease in the value of b*, which indicated a decrease in yellowish intensity. Similar results were reported by Singh et al. (2008), where 60% substitution of wheat flour with sweet potato flour could reduce b* value of the color of cookies from 27.89 to 20.36.

Fig. 1 show that the surface color of NTF substituted cookies is more fade compared to 100% wheat flour cookies (controls). This color difference is likely because the dough of cookies added with NTF contain lower protein than the control cookie dough, so the Maillard reaction occurs when baking process is slow. **Fig. 1** also shows PTF substituted cookies has more intense colors compared to NTF substituted cookies, and also it has a color similar to the color of the control cookies. This happens because the cookies dough added with PTF has a higher simple carbohydrate content so that the rate of browning reaction that occurs during the baking process is faster. The process of pregelatinization in the production of PTF is thought to cause complex carbohydrates in tannia tubers to be degraded to simple carbohydrates.

Microstructure Study

The SEM figure of the cross-section of the cookies made with 100% wheat flour, wheat flour-NTF composite (50:50), and wheat flour-PTF composite (50:50) are presented in **Fig. 2**. The structure shown in **Fig. 2 (A)** (wheat flour cookies) has similarities to the structure shown in **Fig. 2 (C)** (PTF substituted cookies) where the granules of cookies are looser with each other, and they have the larger air cavities. On the other hand, NTF substituted cookies show a compact structure (**Fig. 2B**) where cookies granules are more tightly connected. This result indicated that NTF substituted cookies could not get fluffy well while PTF substituted cookies could be fluffy properly, like 100% wheat flour cookies (controls). This structure is considered to cause the NTF substituted cookies are thinner and harder than the wheat flour cookies or the PTF substituted cookies. It also affects the panelist' preference for the cookies, where they prefer the texture

Table 3. Effect of substitution of wheat flour with PTF on chemical properties of cookies

Flour formulation	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Carbohydrate (%)	Crude fiber (%)
WF	5.27±1.21	7.21±0.06[a]	25.41±0.39	0.87±0.05[b]	61.23±1.38[b]	0.87±0.31[b]
WF+PTF (50:50)	5.20±0.50	5.94±0.24[b]	24.52±0.91	1.19±0.17[a]	63.14±0.66[a]	1.92±0.40[a]

WF: wheat flour; PTF: pregelatinized tannia flour. Values reported are means ± standard deviation of triplicate determinations. Mean values with different superscript within the same column are significantly ($p<0.05$) different.

of PTF substituted cookies and wheat flour cookies compared NTF substituted cookies. A study using SEM conducted by Brites et al. (2019) found that cookies substituted with buckwheat flour, millet flour, and chia seeds had a more compact structure compared to 100% wheat flour cookies. In this case, the protein forming gluten has an essential role in creating the structure of cookies. Porcel et al. (2017), who also conducted SEM study on gluten-free cookies made from a mixture of manioc flour and okara flour, said that the fibers in the dough play a role in the density of cookies.

Chemical Properties

The study of sensory, physical, and SEM properties showed that wheat flour-NTF composite was not able to produce satisfying cookies. Therefore, for the next chemical studies were only carried out on wheat flour-PTF (50:50) cookies and wheat flour cookies (control). Comparison of chemical composition wheat flour cookies and PTF substituted cookies is presented in **Table 3**. The result showed that 50% substitution of Wheat flour by PTF significantly ($P<0.05$) affected protein, ash, carbohydrate and crude fiber content. Substitution of 50% wheat flour with PTF decreased the protein content of cookies from 7.21% to 5.94%. This decrease is due to the protein content of PTF is lower than the protein content of wheat flour. Analysis of the raw material of the cookies used in this study showed that the protein content of wheat flour was 15.60%, whereas the protein content of PTF was 5.50%. The result of this study is similar to the previous findings where the substitution of wheat flour with cassava flour Chauhan et al. (2016) and breadfruit flour (Olaoye et al. 2007) caused a decrease in protein levels of biscuits. The protein content of PTF substituted cookies in this study closes to the protein content of rice-corn flour cookies (5.77%) reported by Rai et al. (2014).

Carbohydrate and the crude fiber content of the PTF substituted cookies were higher than those of wheat flour cookies (**Table 3**). The increase in carbohydrates and crude fiber level is because of the carbohydrate and crude fiber of PTF is higher than those of wheat flour. Chemical analysis of the ingredient for cookies used in this study showed that PTF contained 81.70% carbohydrates and 9.33% crude fiber, while wheat flour contained 69.18 % carbohydrates and 6.10 % crude fiber. Oluwamukomi et al. (2011) found a similar trend in the substitution study of wheat flour with cassava flour in making cookies, where wheat flour cookies contained 68.69% carbohydrates and 0.27% crude fiber, while wheat flour-cassava cookies (60:40) contained 76.81% carbohydrates and 0.33% crude fiber. This study also revealed cookies from wheat flour-PTF composite containing crude fiber (1.92%) higher than the cookies produced from composite cassava flour (0.33%) (Chauhan et al. 2016).

The moisture content of PTF substituted cookies (5.20%) was similar to the moisture content of wheat flour cookies (5.27%) therefore, in terms of water content, the quality of PTF substituted cookies could match the quality of wheat flour cookies. Water content determines the crispness and shelf life of cookies. The moisture level of PTF substituted cookies in the present study was slightly higher than the moisture content of wheat flour cookies which was previously reported (4.08%) by Rai et al. (2014).

CONCLUSION

This study shows that the 50% substitution of wheat flour with NTF decreases physical properties and sensory properties of cookies. On the other hand, 50% substitution of wheat flour with PTF produces cookies that compete well with 100% wheat flour cookies (control) from the aspect of physical, chemical, and sensory properties. The replacement wheat flour with PTF reduces protein levels but increases carbohydrate and crude fiber of the cookies significantly. The microstructure of PTF substituted cookies is hollower than the microstructure of NTF substituted cookies resulting in a more fragile texture of cookies. The PTF substituted cookies contain 5.94% protein, 24.52% fats, 63.1% carbohydrates, and 1.92% crude fiber, and overall acceptance of panelist tothe cookies is “like moderately.”

ACKNOWLEDGMENTS

Udayana University sponsored the current research based on the Letter of Agreement for Research Project (Surat Perjanjian Penugasan Pelaksanaan Penelitian) No. 673-48/UN14.4.A/LT/2017.

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