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Incorporation of defatted coconut flour into purple sweet potato crackers: a study on texture and colour characteristics

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Abstract

The foremost challenge in the development of gluten-free crackers from Indonesian local tubers is their textural properties. In this work, defatted coconut flour was incorporated into purple sweet potato flour in crackers making, which aimed to improve their physical characteristics due to high fibre and protein content. The effect of margarine concentration (15, 20, and 25%) and defatted coconut flour concentration (0, 15, 30%) on hardness, fracturability, lightness (L), redness (a), yellowness (b), and moisture content were studied in a randomized factorial design experiment. Results showed that the concentration of margarine, the concentration of defatted coconut flour, and the interaction between the two factors had a significant effect ($p<0.05$) on hardness, fracturability, lightness, redness, and water content of crackers. Defatted coconut flour increased the hardness and the fracturability of crackers, but margarine concentration reduced both textural properties. Higher concentration of margarine and defatted coconut flour increased values of L and a, but did not affect the b value. There seemed to be a maximum concentration of defatted coconut flour and margarine the in cracker to maintain textural properties.

1. Introduction

Since crackers were introduced in 1885 in Ireland (Sykes and Davidson, 2020), crackers are now well known worldwide as low fat and low sugar, slightly salty, and crisp snacks (Zydenbos and Humphrey-Taylor, 2003). Crackers are now being developed into functional food by incorporation of several raw materials such as chia flour, wheat germ, quinoa or oat (Meriles *et al*., 2021), microalgae (Batista *et al*., 2019), fibers from citrus seeds (Yilmaz and Karaman, 2017), green gram (Venkatachalam and Nagarajan, 2017), *Hibiscus sabdariffa* calyxes residue (Ahmed and Abozed, 2015), brown rice flour (Qadri *et al*., 2018), tempe (fermented soybean) flour (Nicole *et al*., 2021), and sweet potato, its leaves and moringa (Owusu *et al.,* 2011), and also jellyfish (Maisont *et al.,* 2021).

Sweet potato flour is among those raw materials for wheat substitution (Bach *et al.,* 2021) in the making of several bakery products (Hendarto and Siregar, 2010; Hutasoit *et al.,* 2018; Zhu and Sun, 2019; Mu *et al.,* 2019; Morais *et al.,* 2020) including crackers (Owusu *et al.,* 2011), and non-bakery products including probiotic drink (Suhartini, 2009), synbiotic yogurt (Imelda and Ledy, 2017), jelly (Choi and Lee, 2013), and high-fibre noodle (Yolanda *et al.,* 2018). Purple sweet potato exhibits antioxidant activity, contains vitamin C, and beta-carotene which are very good compared to other types of sweet potatoes (Purnomo and Hanny, 2007; Kumalaningsih, 2006), anthocyanins (Ginting *et al.,* 2015), and hypoglycemic activity (Zhu and Sun, 2019). The use of sweet potato flour for product development has been thoroughly reviewed (Dereje *et al.,* 2020) emphasizing its ability to grow worldwide, low price, and functional elements content essential to support health, although it needs starch modification for some applications (Dereje *et al.,* 2020). When incorporated into cracker-making, sweet potatoes decreased elasticity resulting in a harder texture (Mayasari, 2015).

Coconut dregs also known as defatted coconut flour contain high protein around 17 (Dewi, 2015) to 22% (Mihiranie *et al.,* 2017), 6% mineral (Mihiranie *et al.,* 2017), and crude fibre of 17% (Mihiranie *et al.,* 2017), whiter than wheat flour (Putri, 2014). Its content of fibre and complex carbohydrates suggests is suitable for people with diabetes, obesity, and cardiovascular disease (Poli, 2018). Coconut dregs flour had been utilised to make biscuits (Sujirtha and Mahendran, 2015; Pathirana *et al.,* 2020), or crackers (Mihiranie *et al.,* 2017), and

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showed increased protein, fat, fibre and ash content (Sujirtha and Mahendran 2015; Pathirana *et al.,* 2020) as compared to that without coconut dregs. Another health benefit of biscuits added with coconut dregs was a lower glycemic index than that of wheat biscuits (Pathirana *et al.,* 2020). Furthermore, the addition of up to 40% coconut dregs flour into biscuit dough resulted in better sensory acceptance (Sujirtha and Mahendran, 2015). Another study incorporated 20% coconut dregs flour into crackers dough unaltered physical and sensory characteristics of the final product (Mihiranie *et al.,* 2017). Similarly, coconut dregs were added to nixtamalised corn flour (Adebowale and Komolafe, 2018; Adeloye *et al.,* 2020) to give antioxidant activity and bioactive compounds (Adeloye *et al.,* 2020), as well as the protein content of final products (Adebowale and Komolafe, 2018; Adeloye *et al.,* 2020). Coconut dregs added to pastries increase texture and aroma (Poli, 2018).

The main function of margarine in crackers was to improve textural properties (Mamat and Hill, 2014; Ismail *et al*., 2018; Qadri *et al*., 2018), extensibility and spreadability (Mamat and Hill, 2014; Ismail *et al*., 2018; Qadri *et al*., 2018). Shortening influenced the creaming process to retain more air in the cracker dough which in turn would affect leavening properties (Ismail *et al*., 2018). However, too high a concentration of shortening reduces the spread ratio (Qadri *et al*., 2018). Shortening may also have a negative effect on the volume index, density, and puffiness of crackers (Qadri *et al*., 2018), which likely indicates the interaction of shortening with other components in the food matrix. It also determined the external and internal colour of crackers (Ismail *et al*., 2018; Qadri *et al*., 2018; Giuffre *et al*., 2022).

As mentioned previously, sweet potato flour and defatted coconut flour were two potential ingredients for food such as crackers. The addition of margarine into the formula can be useful to improve the texture. Therefore, in this work, we formulated crackers made from sweet potato and defatted coconut flour and examined the physical and chemical properties of the crackers.

2. Materials and methods

The ingredients used for making coconut dregs flour and crackers were coconuts, water, purple sweet potatoes, skimmed milk, yeast, baking powder, salt, sugar, and margarine. Purple sweet potato and mature coconut were obtained from a local market in Socah village, district of Bangkalan, East Java, Indonesia. The equipment used consisted of a waring blender, digital scales, cabinet dryer (TAV), 30 mesh sieve MBT (Sieve Shaker)/AG-515, oven (Cosmos CO-9919), steamer, cake mold, texture analyzer (TA-XT – Plus, Stable Micro System, Surrey, UK); while the color test uses a color reader (CR-10 Konica Minolta), drying oven (DHG -9053A), desiccator and analytical balance (PA413, USA).

2.1 Coconut dregs flour preparation

The stages of making defatted coconut flour referred to previous research (Putri, 2014; Setiawati *et al*., 2015). Coconuts were peeled to remove the testa, washed thoroughly, cut, and grated. The coconut milk was separated by squeezing the grated coconut seven times with the addition of water. The separated coconut dregs were then steamed for three minutes to remove the remaining oil. Subsequently, the coconut dregs were dried using a drying oven for 2 hrs at a temperature of 70°C. After the drying process, the dried coconut dregs were ground and sifted using a 30-mesh sieve.

2.2 Crackers preparation

Margarine (15, 20, 25%), skimmed milk (10%), salt (1%), and sugar (2%) were mixed. The purple sweet potato was washed, cut, and steamed for 30 mins. The steamed purple sweet potato was then cooled, drained, mashed, and added to a mixture of margarine, skimmed milk, salt, and sugar. The even and smooth dough was mixed with defatted coconut flour (0, 15, and 30%), yeast (2%), and baking powder (0.5%). The dough was tightly covered with a wet cloth and let stand for 6 mins. The fermented dough was then flattened to a thickness of approximately 2 mm and cut to a 2 × 2 cm square shape. It was baked in the oven at 110°C for 30 mins and cooled, then kept in an airtight container until use.

2.3 Experimental design

This research used a Factorial Completely Randomized Design consisting of 2 factors, namely margarine concentration and the defatted coconut flour concentration.

2.4 Crackers analysis

2.4.1 Physical properties

The texture was tested using Texture Analyzer (TAXT-Plus, Stable Micro System, UK) with the Texture Profile Analysis (TPA) analysis method using a cylindrical probe of the SMS P/2 type with gF (gram Force) units and a probe diameter of 2 mm. The cracker's samples were measured for thickness and diameter and then placed on the sample table. The resulting data was presented as hardness and fracturability values.

2.4.2 Colour analysis

Colour testing was carried out using Konica Minolta's Colour Reader CR-10 with five replications.

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The sample was placed on a flat surface with lighting that was adjusted to stabilize at a distance of 1 cm. Measurements were expressed as *L* (lightness), *a* (redness), and *b* (yellowness).

2.4.3 Water content analysis

The water content test was carried out using the gravimetric method which was repeated two times. About 2 g of samples were weighed, and then they were dried in an oven at 105±3°C for 1 hr. Samples were then cooled in a desiccator for 30 mins and weighed. The procedure was repeated until constant weight.

2.5 Statistical analysis

Data were analysed statistically by ANOVA using the statistical package SPSS 16.0. If there was a significant difference among treatments, the test was continued with the Duncan Multiple Range Test (DMRT) at a 5% level.

3. Results and discussion

3.1 Textural characteristics of crackers

3.1.1 Hardness

The hardness of crackers decreased as the concentration of margarine or defatted coconut flour increased (Table 1). Shortening improved the elasticity, tenderness, and extensibility of dough (Qadri *et al*., 2018), to reduce hardness (Ong *et al*., 2015; Muhandri *et al*., 2018). However, too high a concentration of shortening negatively affected the puffiness of crackers (Qadri *et al*., 2018), resulting in a less crisp product. Shortening inhibited the evaporation of dough moisture during baking, resulting in a softer texture of the cracker (Muhandri *et al*. 2018; Qadri *et al*., 2018).

Table 1. Hardness and fracturability of cracker as the effect of margarine and defatted coconut flour concentration.

Margarine (%)	Defatted Coconut Flour (%)	Hardness (g)	Fracturability
15	0	60.279[a]	60.037[a]
	15	204.191[b]	225.169[b]
	30	752.689[e]	1109.874[d]
20	0	64.254[a]	69.491[a]
	15	186.857[b]	199.955[b]
	30	616.167[d]	914.612[c]
25	0	31.006[a]	32.079[a]
	15	187.406[b]	214.112[b]
	30	546.334[c]	935.804[c]

Values with different superscripts within the same column are statistically significantly different ($p<0.05$).

On the other hand, the hardness of crackers was increased by the addition of defatted coconut flour (Table 1). Our result was contradictory to the previous result where defatted coconut flour reduced the hardness of crackers (Sujirtha and Mahendran, 2015; Adeloye *et al*., 2020; Nicole *et al*., 2021). Defatted coconut flour in the previous work correlated to the shortening effect of oil content and high moisture (Sujirtha and Mahendran, 2015; Adeloye *et al*., 2020; Nicole *et al*., 2021). This discrepancy was likely due to the use of wheat flour in their work, as compared to non-wheat flour in our work. Sweet potato flour showed low bulk density, resulting in low porosity (Dereje *et al*. 2020; Sabir, 2020). Sweet potato flour also showed low solubility, indicating a low capability to swell (Dereje *et al*. 2020). In this case, the addition of defatted coconut flour seemed to worsen the problem.

In this study, there was a significant effect of interaction between margarine and defatted coconut flour concentration on hardness. The highest hardness (752.689 g) was shown by crackers made with 15% margarine and 30% defatted coconut flour, while the lowest hardness (31.006 to 64.254 g) was shown by crackers without defatted coconut flour (Table 1). This was in accordance with the previous report that too high concentrations of margarine hindered the continuity of the protein matrix which resulted in the reduced spread ratio (Qadri *et al*., 2018).

3.1.2 Fracturability

Fracturability was lowered by the addition of margarine but increased by the addition of defatted coconut flour (Table 1). Fracturability is correlated to hardness and cohesiveness, where low cohesiveness causes products to break easily. In our work, margarine seemed to facilitate low cohesiveness, while defatted coconut flour seemed to affect it in the opposite manner. Fat concentration increased brittleness and gave a crumbly texture to crackers (Fauziyah, 2015), likely due to the softening of dough by coating starch and protein particles preventing them from bonding (Rosida *et al*., 2020). As a result, there were cavities between starch and protein particles, to give porosity (Rosida *et al*., 2020). Defatted coconut flour in our work seemed to reduce this cavity, to give less porous characteristics.

The incapability of defatted coconut flour in our work to lower fracturability seemed due to the higher effect of sweet potato flour in reduced brittleness and increased fracturability, due to low water content (Rosnah and Zulhija, 2018). Sweet potato flour showed low water-binding ability, and its application in bakery products needs some modification to increase water-binding ability (Dereje *et al.,* 2020). High water binding ability was essential to brittleness (Adiningsih and Priatni, 2019).

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There was a significant effect of interaction between factors studied on fracturability. The highest fracturability (1109.874) was shown by a cracker containing 15% margarine and 30% defatted coconut flour, while the lowest fracturability (32.079 to 69.491) was indicated by crackers with no defatted coconut flour (Table 1). High fat-suppressed dough rising (Qadri *et al*., 2018), and sweet potato flour seemed to lack the ability to hold air cells due to lack of gluten, resulting in low puffiness (Qadri *et al*., 2018), and subsequently high fracturability.

3.2 Colour analysis

3.2.1 L value (Lightness)

The L value of the cracker increased as the margarine was higher (Table 2). Natural beta-carotene in margarine caused lighter products (Wijaya, 2004; Ismail *et al*., 2018). More defatted coconut flour in crackers also increased lightness (Table 2), as previously reported (Widarta *et al*., 2013). Since defatted coconut flour was white, its presence in a purple cracker in our work gave a whiter and thus lighter colour. Colour of coconut dregs was influenced by phenol compounds, phenolase or polyphenol oxidase enzyme activity, and the presence of pigments in coconut dregs (Roni, 1993).

There was a significant effect of interaction between factors studied on the *L* value. The highest *L* (26.34) was shown by crackers containing 25% margarine and 30% defatted coconut flour, while the lowest L (16.68 to 17.67) was indicated by crackers with no defatted coconut flour (Table 2).

3.2.2 a value (Redness)

Margarine in crackers increased redness (Table 2), possibly due to the presence of reddish beta-carotene in margarine (Wijaya, 2004). Similarly, defatted coconut flour also increased the redness (Table 2). The higher redness seemed to relate to Maillard's reaction during baking (Winarno, 2008).

There was a significant effect of interaction between factors studied on *a* value. The highest *a* (17.29) was shown by crackers containing 25% margarine and 15% defatted coconut flour, while the lowest *a* value (11.72 to 13.00) was indicated by crackers containing defatted coconut flour at 0 and 15%, and 15 and 20% of margarine (Table 2).

3.2.3 b value (Yellowness)

Yellowness was not influenced significantly by the concentration of margarine or defatted coconut flour (Table 2). Although margarine potentially gave yellowish colour to the product due to its beta-carotene content (Wijaya, 2004), its effect on purple sweet potato crackers seemed to be minor as the purple colour dominated.

3.3 Water content

Margarine concentration and defatted coconut flour concentration, and their interaction significantly affected water content (Table 2). Margarine potentially increased water uptake which was essential in forming the porosity of dough (Muhandri *et al*. 2018; Qadri *et al*., 2018), by shielding protein and starch particles from evaporation (Qadri *et al*., 2018). The water content in margarine (around 20%) (Rosida *et al*., 2020) was due to the presence of an emulsifier in margarine (Nurani and Yuwono, 2014), which also contributed to higher water content in crackers with a high concentration of margarine.

Contrary, coconut dregs flour reduced water content as previously reported (Widarta *et al*., 2013; Ratnasari and Yunianta, 2015). Defatted coconut flour seemed to disrupt the cavity between protein and starch particles, by attaching to the surface of both starch and protein to facilitate binding, and consequently reduced water concentration in the dough (Komah, 2013). At low concentrations of both margarine and defatted coconut flour, however, it was noticed that water content did not differ from that without coconut dreg. This may indicate

Table 1. Hardness and fracturability of cracker as the effect of margarine and defatted coconut flour concentration.

Margarine (%)	Defatted Coconut Flour (%)	*L*	*a*	*b*	Water Content (%)
15	0	17.67^{a}	11.72^{a}	19.92	15.741^{d}
	15	22.53^{d}	12.79^{ab}	18.29	14.146^{d}
	30	21.95^{cd}	15.48^{d}	16.77	3.351^{a}
20	0	16.68^{a}	11.87^{a}	20.14	15.052^{d}
	15	20.86^{c}	13.00^{ab}	18.83	14.092^{d}
	30	22.73^{d}	14.61^{cd}	16.80	4.314^{a}
25	0	19.43^{b}	13.70^{bc}	17.70	20.373^{e}
	15	21.93^{cd}	17.29^{e}	17.58	8.737^{c}
	30	26.34^{e}	15.70^{d}	16.62	6.193^{b}

Values with different superscripts within the same column are statistically significantly different ($p<0.05$).

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that there was a maximum concentration of defatted coconut flour to be added to cracker dough, where a higher concentration beyond the limit would reduce water content. High water content in cracker dough positively correlated to the porosity and crispness of the cracker. Thus, too high a concentration of defatted coconut flour negatively affected the texture of the cracker. This also explained why in previous works (Sujirtha and Mahendran, 2015; Adeloye *et al*., 2020; Nicole *et al*., 2021) defatted coconut flour improved the texture of the product rather than impaired it as shown in our work.

4. Conclusion

The interaction between the concentration of defatted coconut flour and the concentration of margarine had a significant effect on hardness, fracturability, *L* value (lightness), and *a* value (redness) but did not significantly affect the *b* value (yellowness) of crackers.

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