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Changes in Nutritional and Sensory Qualities of Cookies Supplemented with Macadamia Oil Cake

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ABSTRACT

The objective of this study was to investigate effect of the addition with different ratios Macadamia oil cake (MOC) on physical properties (color and texture), nutritional composition (moisture content, protein content, fat content, fiber and energy value) and sensory quality of cookies were investigated. The addition of MOC results in the increases of protein, ash and fat content, while carbohydrate content, by contrast, decreased in the cookies. Regarding the physical properties, the thickness and breaking strength of cookies showed significant differences between the fortified samples and the control while diameter, and spread ratio did not reveal any variations. For the sensory quality, score of color, flavor, texture, taste, except overall acceptability of fortified cookies witnessed a significant difference (p<0,05). The microbiological analyses also confirmed that the fortified cookies satisfy the microbial safety standards. Based on the observed results, the addition with 15% of MOC is recommended for developing cookie products to improve nutritional and sensory qualities The nutritional analysis of the cookies supplemented with 15% macadamia oil cake confirmed that product contains 9.96g protein, 26.50g fat, 55.80g carbohydrate, 3.08g dietary fiber and an estimated energy of 501.58 kcal in each 100 grams.

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1. Introduction

Macadamia oil cake (MOC) is a by-product of macadamia oil production. Because of their high nutritional value, especially protein content (15% to 50%), the seed and nut cakes are commonly utilized as cattle feedstuffs [1]. In addition to the potential nutritional value, the macadamia oil cake can also produce typically attractive flavors so it is suggested to be used as an ingredient to improve sensory quality of food products [2].

MOC was found to contain 24.5% crude protein [3]. MOC crude fiber was also reported to reach the amount of 24.9% [4]. Macadamia oil cake has been successfully studied and applied as an alternative protein source for poultries and ruminants. A study determining the effects of different dietary inclusion levels of MOC showed that he MOC addition positively affected on the growth performance and carcass characteristics of growing lambs [5]. In addition, other studies also reported promising results in the replacement of corn, soymeal, wheat with macadamia oil cake in feedstuff. Macadamia oil cake was reported to be high in fiber, rich in essential nutrients, high lipid residue and positive role of fiber in gut health [6]. Those studies' research subjects are feedstuffs while macadamia oil cake is a potential nutrient source to apply in human foods. These sources can be used to make bakery products such as cake, cookie, bread, etc. Thus, this research focused on producing macadamia oil cake supplemented cookies in order to improve the nutritional and sensory qualities of the products.

2. Material and Methods

2.1. Material

The macadamia oil cake obtained from the cold pressing process was provided by Damaca Nguyen Phuong JSC (No 12 Loc Xuan village, Phu Loc commune, Krong Nang district, Dak Lak province. The

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oil cake was ground and sieved to obtain powder with the size less than 0.25mm. The powder was then preserved at -18°C until used for the experiments.

2.2. Methods

2.2.1. Preparation of cookies supplemented with macadamia oil cake

The formulations of the cookie samples are presented in Table 1.

Table 1. *Composition of cookies*

Ingredients	Formulation			
	M0	**M15**	**M20**	**M25**
Wheat flour (g)	100	100	100	100
Sugar powder (g)	55	55	55	55
Butter (g)	55	55	55	55
Milk powder (g)	7	7	7	7
Baking powder(g)	0.4	0.4	0.4	0.4
Salt (g)	1	1	1	1
Egg (g)	50	50	50	50
Macadamia oil cake (g)	0	15	20	25
Water (ml)	10	13	15	25

Butter and sugar were mixed well until the color turns lighter in a bowl before all other ingredients are added. The mixing process was continued until becoming consistent. The mixture was set the in 10 minutes at room temperature then the dough was spread on a flat tray covered by non-stick paper, and flattened by a rolling pin to the thickness of 0.5cm. A cookie cutter was used to cut dough sheet into circular shape. Put circular cut dough onto a tray covered by baking paper.

The cookies were then baked in an oven which was pre-heated at 190°C in 15 minutes. The baked cookies then removed from the oven and leaved on a cooling rack until reaching room temperature before being packed in an air-tight zipper bag with desiccant bags inside and stored in a dry, cool place, avoiding sunlight.

2.2.2. Evaluation of physical parameters

- Moisture content: Moisture content of samples was determined by using a hot-air oven according to Method 44-15.02 (AACC, 2000) at 105°C until reaching constant weight.

- Size of cookies: Vernier calipers were used to determine the thickness and diameter of cookies according to AACC (2000).

Figure 1. *Demonstration of diameter measuring (left) and thickness measuring (right)*

- Spread ratio: Spread ratio of cookies was calculated by the ratio of the diameter to the thickness of cookies.

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- Specific volume: Each bread was weighed and then measured for volume using a rapeseed displacement volume-meter. Specific volume (cm^3/g) was calculated as the ratio of the volume (cm^3) and the mass of the samples (g) following the AACC Approved Method 10-05.01 (AACC, 2000).

- Texture analysis: The hardness and crispiness of the samples were analyzed using a texture analyzer (CT3, Brookfield Ametek Inc., MA, USA). Each cookie was compressed by a probe and forced to be broken. The maximum force which a sample could bear just before breaking was recorded. The peak force and the slope can estimate hardness and crispiness of cookies [7].

2.2.3. Color analysis

Color values (L*, a* and b*) of the cookies were determined using a colorimeter (CR-400, Konica Minolta, USA). The color difference between a sample with the control sample was calculated as following equation [8]:

$$\Delta E = \sqrt{(L^* - L_0^*)^2 + (a^* - a_0^*)^2 + (b^* - b_0^*)^2}$$

Where

L^*, a^*, b^* are the color values of investigated samples;

L^*_0, a^*_0, b^*_0 are the color values of control sample.

2.2.4. Nutritional composition

- Total crude protein was determined according to AACC 46-10.01 using Kjeldahl method.

- Total ash content was determined according to AACC 08-01.01 standard using an oven at temperature of 600°C in 6 hours,

- Crude fat was determined according to AACC 30-25.01 using a Soxhlet extractor with petroleum ether as the solvent.

- Total carbohydrate was determined according to FAO (2019) [9] using the following equation:

$$Total\ carbohydrate\ \% = 100 - (Protein\% + Fat\% + Ash\% + Moisture\%)$$

- Energy value of samples was calculated based on method of FAO (2019) [9] using the following equation:

$$Energy = (weigh\ of\ Carbohydrate\ \times 4) + (weight\ of\ Protein \times 4) + (weight\ of\ fat \times 9)$$

1g protein: 4kcal energy

1g fat: 9kcal energy

1g carbohydrate: 4 kcal energy

- Other nutritional components such as dietary fiber, mineral content and microbiological criteria were analyzed at Eurofins Hai Dang food testing laboratories (Lot E2b-3, Street D6, Saigon Hightech Park, Tan Phu Ward, District 9, Ho Chi Minh City, Vietnam).

2.2.5. Sensory evaluation

The sensory test was conducted in a form of survey of "9-point hedonic scale". The coded samples were served to 20 random selected judges. The judges were asked to score the cookies samples for color, shape, texture, sweetness, flavor, mouth feel and overall acceptability. The overall acceptability of cookies was evaluated using 9-point hedonic scale ranging from (1, dislike very much to 9, like very much) [7].

2.2.6. Statistical analysis

Each experiment was repeated three times, and the experimental results were presented as the mean ± standard deviation. To analyze differences between the means, an analysis of variance (ANOVA) was performed, followed by the least significant difference (LSD) with $p < 0.05$.

3. Results and Discussion

3.1. Chemical composition of Macadamia oil cake (MOC) powder

MOC is the residue of the manufacturing oil from macadamia nuts, but the nutrients left in oil cake can be utilized to make foods. For example, in the research of Acheampong-Boateng et al. (2008), the crude protein content of MOC was 19.5%, the crude fat content was 10.4%, the ash content was 2.8%, the crude fiber content was 24.9%, the calcium and phosphorus content were respectively 0.24% and 0.29% [4]. Normally, MOC is mostly studied for using as animal feed [10]. The MOC in this research has the protein content is higher than MOC in the research of Mikasi (2018) (14.7%) [11]. The fat of 30.40% in our research is also higher than that in the research (8.5%). The crude fiber content (0.93%) in the research of Mikasi (2018) was much lower than this in our research (6.27%) [11]. In comparison with a research by Rao et al. (2020), the ash content of this research is also higher (3.57% compared to 1.93%, respectively) [12].

3.2. Changes in nutritional composition of MOC cookies supplemented with different MOC ratios

The changes in content of moisture, ash, protein, lipid, carbohydrate contents and energy value of cookiesadded with different ratios of MOC are shown in Table 2.

Table 2. *Chemical composition of MOC cookies*

Sample	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Carbohydrate (%)	Energy value (kcal)
M0	4.14±0.01^{a}	3.20 ± 0.18^{a}	8.66^{b}±0.39^{b}	23.10±0.17^{c}	60.91±0.56^{a}	486.15±1.15^{c}
M15	3.88±0.25^{ab}	3.84±0.37^{a}	9.96^{a}±0.34^{a}	26.50±0.24^{b}	55.80±0.66^{b}	501.58±3.43^{b}
M20	3.55±0.07^{bc}	3.87±0.18^{a}	10.20^{a}±0.11^{a}	27.41±0.11^{a}	54.97±0.11^{b}	507.38±1.06^{a}
M25	3.21±0.28^{c}	3.39±0.66^{a}	10.04^{a}±0.03^{a}	27.60±0.09^{a}	55.76±0.80^{b}	511.61±3.81^{a}

Values are mean ± SD of three replicates. Means of the same column followed by superscript letters are significantly different (p<0.05)

It can be seen that there is a decreasing trend in the moisture content from M0 to M25, the range is from 4.14 to 3.21. A research on lemongrass added cookies showed similar result when low water absorption capacity of lemongrass powder is the reason of moisture content reduction [13]. According to TCVN 5909:1995, the MOC fortified cookies' moisture fit the cookie moisture requirement (below 4%). It was reported that the lower moisture content prevents cookies from microbial spoilage and lengthen shelf life [14]. When Chandra et al. (2015) conducted an experiment on rice flour, green gram flour and potato flour in different ratios, they found out moisture content of composite flours decreased with lower proportions of wheat flour [15].

The ash is generally an indicator of the mineral contents present in foods [16]. In this experiment, the ash content ranged from 3.20 to 3.87%. The highest ash content was found in M20 while the lowest was M0 (the control sample). It can be explained that the increase of MOC level in composite flour goes with the increase of ash content [13]. However, the ash content of 4 samples are insignificantly different (p>0.05)

Protein is essential to human health; cookies could be potential carriers of proteins because they are widely accepted by consumers. Wheat flour contains less protein than MOC do. It can be seen that protein content present in cookie samples ranged from 8.66 to 10.20%, which shows an upward trend with the increase of MOC level. With the increasing proportion of MOC and the protein content in cookies, the carbohydrate content obviously decreased, which reduced from 60.91% to 55.71%. Similar result was reported in a research of soya cookies [7].

The fat content in foods is linked with textural characteristics, water holding ability and provides product a mechanism to distribute and transfer heat at high temperatures [17]. Wheat flour used in this experiment has a fat content of 3.00% while MOC fat content stands at 30.40%. The fat content present in cookies increase with the increase of MOC level. M25 was the sample contains the highest fat level while the control sample M0 was the lowest at fat content. The similar result was found in a study by Ghosha et al. (2020) when they conduct a research on soymeal cookies [7].

The energy value ranged from 486.16 to 511.61 kcal, the difference in energy value may come mostly from fat content of MOC. A similar result was reported by Ndife et al. (2014) when they evaluated the substitution of soymeal in cookies [18].

3.3. Effect of MOC addition on physical properties of cookies

The physical properties of cookies added with various amounts of MOC are shown in Table 3. The diameter of control sample M0 was the largest, while the diameter of other samples decreased when the level of added to cookies increased. This phenomenon can be explained by a research [19] which claimed that there is inverse correlation between protein content and diameter of cookies. However, there is no statistically significant difference in terms of the diameter of cookies (p>0.05).

Table 3. *The data of physical properties of MOC fortified cookies*

Sample	Diameter (mm)	Thickness (mm)	Spread ratio (D/T)	Breaking strength (g)
M0	49.62±0.45^a	7.98±0.16^a	6.22±0.06^a	3007.8±128.1^c
M15	49.02±0.20^a	7.55±0.39^b	6.51±0.36^a	3096.5±45.3^c
M20	46.36±1.03^a	7.12±0.11^c	6.51±0.06^a	3278.2±112.4^b
M25	44.68±1.07^a	7.11±0.13^c	6.28±0.08^a	4006.5±50.6^a

Values are mean ± SD of three replicates. Means of the same column followed by superscript letters are significantly different (p<0.05)

The thickness of MOC cookies also showed a downward trend among samples. A statistically significant difference can be seen in case of thickness of cookies (p<0.05). A similar result can be found in a previous study [20], when thickness and diameter, spread ratio of bamboo powder fortified cookies all decrease.

Spread ratio can be used as a quality indicator for cookies, higher spread ratio is desirable for better cookies [21]. Spread ratio of control sample (M0) was the slowest, while the sample M15 and M20 almost had the similar spread ratio value (6.51), which was slightly higher than the control sample. Some researches show the similar decrease in spread ratio when the non-wheat flour used for cookies is high in fiber [14, 22, 23]. Overall, spread ratio of 4 different ratio cookies are insignificantly different (p>0.05).

The hardness of the cookies is influenced by air space formation, gluten network, andother ingredients present in flour composite, and especially the moisture content [24]. Breaking strength is a factor shows that how cookies work when put in mouth and pressedby teeth. The moderate crackling strength and crispy mouthfeel affect the consumers' acceptability [25]. The breaking strength is the force required to break the cookies, which increases from 3007.8 g Force to 4006.5 g Force with the increase of MOC level, the similar result was reported in moringa leaves fortified cookies [26].The breaking strength of 4 samples are significantly different (p<0.05).

3.4. Changes in color values of cookies added with different ratios of MOC

The color of the cookies surface is one of important factors besides texture and taste, to evaluate the initial consumer acceptability of the products [27]. The color of the cookies' surface was produced during baking and may have been caused by non-enzymatic browning (Maillard reactions) between reducing sugars and amino acids, it may be the result of starch dextrinization and sugar caramelization.

The result of surface color of cookies was evaluated by CIE L*a*b* system and shown in the Table4.

As shown in the Table 4, L* value of the control sample (M0) was significantly different (p<0.05) from fortified samples. An increase was observed for sample M15 while samples M20 and M25 showed decreases in L* value compared to the control. This suggests that the color tends to be darker with higher the added amount of MOC.

Table 4. *Color parameters of MOC supplemented cookies*

Sample	L*	a*	b*	∆E*
M0	75.14±0.62^{b}	-0.49±0.39^{b}	34.27±2.70^{b}	-
M15	78.30±0.48^{a}	1.50±0.26^{b}	34.83±0.53^{b}	4.65±0.51^{b}
M20	72.62±1.41^{bc}	6.28±2.96^{a}	39.59±0.24^{a}	9.28±3.53^{ab}
M25	71.17±2.36^{c}	8.38±1.61^{a}	40.06±0.73^{a}	11.41±2.51^{a}

Values are means ± SDs of three replicates. Means of the same column followed by superscript letters are significantly different (p<0.05)

a* value is relative to the green–red opponent colors, with negative values toward green and positive values toward red. An upward trend shown in the Table 4 suggests that the higherthe amount of MOC is added, the more reddish the cookies will be. M0 surface color is slightly green, the surface color of other samples turns red when more amount MOC is added. As a result, the surface color of M20 and M25 are significantly more reddish than M0 and M15 andthey are insignificantly different (p>0.05). Insignificant difference in value a* between M0 andM15 was recorded (p>0.05).

b* value represents the blue–yellow opponents, with negative numbers toward blue and positive toward yellow. The notable increase in this study shows that the higher the amount ofMOC is added into cookies dough, the more yellow color will appear on the surface. It can be seen that M20 and M25 were yellower and significantly different from M0 and M15 (p<0.05). However, insignificant differences were recorded between M0 and M15 or M20 and M25 (p>0.05).

The value ∆E shows the difference in color of investigated sample compared to the control sample regarding CIE L*a*b* color space. ∆E value of M15 was 4.65, which falls between 3.5-5.0, this means there is clear difference in color between M0 and M15. Because ∆E value of bothM20 and M25 are above 5, the observer can notice different colors between M0 and M20; M0 and M25. With the decrease of brightness and the reddish color and yellowish color, the appearance of MOC cookies is not highly preferred. The similar result was found in chestnut cookies in a previous study [14].

3.5. Sensory evaluation of MOC added cookies

The sensory scores for color, flavor, taste, texture and overall acceptance of the MOC added cookies are presented in Table 5.

Table 5. *Sensory evaluation of MOC cookies*

Sample	Color	Flavor	Taste	Texture	Overall aceptance
M0	6.45±1.54^{a}	7.05±1.32^{a}	5.70±1.84^{ab}	5.45±1.39^{b}	5.95±1.43^{a}
M15	4.60±2.11^{b}	5.80±1.67^{b}	6.50±1.10^{a}	6.60±1.64^{a}	6.50±1.43^{a}
M20	5.30±2.11^{ab}	5.75±2.07^{b}	5.30±1.72^{b}	5.30±2.05^{b}	5.55±2.01^{a}
M25	4.80±1.88^{b}	5.60±1.19^{b}	5.85±1.93^{ab}	4.65±2.06^{b}	5.75±1.11^{a}

Values are means ± SDs of three replicates. Means of the same column followed by superscript letters are significantly different (p<0.05)

The color of the cookies plays an important role in determining consumer liking and their acceptability of the products [14]. In terms of color, M0 is the most accepted sample due to its golden butter-like color, while scores of M25 and M15 fall between "neither dislike or like" and "dislike slightly", M20 is above "neither dislike or like" and under "like slightly". This result matches with color analysis result because M20 and M25 get darker. M15 may not widely be accepted because of its brown edge. As the MOC substitution levels increase, the color scores declines. The color changes come from Maillard, caramelization and dextrinization reactions, the natural color of MOC partly affects the color of cookies [14].

The flavor scores decrease with the increase of MOC content. M0 sample and 3 MOC samples are statistically insignificantly different (p<0.05). The flavor highest score belongs to control sample M0 which is evaluated at 7.05 (like moderately), the lowest score goes with M25 which stands at 5.60 (between "neither like or dislike" and "like slightly". Panelists are used to with buttery smell instead of MOC flavor, this may be the reason why control sample is scored highly and other MOC cookies are not well accepted.

In terms of taste, the M15 become the most favorite among all samples. Panelists seem to like creamy taste of MOC than buttery taste in moderate MOC level. The score for M15 is 6.50, which falls between "Like slightly" and "Like moderately" while other samples are between "Neither like or dislike" and "Like slightly".

The most preferred texture sample is M15. In hardness determination, the M15 hardness was the lowest one. This can be explained that the M15 sample has moderate hardness, crispy enough to eat. Whereas the M20 and M25 cookies are reported to be harder and difficult to bite because of further fortification of MOC. Same result was found in soy and water chestnut cookies of [28], with the addition of soy and water chestnut blends, this made the cookies become crispier and less preferable.

Overall, the panelists widely accepted M15 and scored this sample 6.50. While other samples, including control samples have medium score from 5.55 to 5.95. After M15 (15%), the acceptability score of M20 and M25 reduced as cookies became too crispy and have strong taste of MOC. Same trend was found in a previous research on cookies added with soybean and water chestnut [28].

In this study, the M15 sample (15% MOC fortified) is selected based on the improvement in the taste and texture compared to the other formulations. However, the improvement in color and flavor of the MOC fortified cookies should be further studied.

Furthermore, the nutritional parameters of 15% MOC fortified cookies (M15) are optimal, with protein content 9.96%, fat content 26.5%, carbohydrate content 55.80%, dietary fiber content 3.08% and energy value 501.58 kcal.

3.6. Microbiological quality of the selected MOC cookies (M15)

Microbial spoilage of bakery products primarily comes from mold and yeast development which is a reflection of high solids content and low moisture content present in bakery products [29]. The high sugar content in cookies can immobilize water content within, which is not appropriate for microbial growth. Understanding the nature of microorganisms is a good way to control microbial growth or outbreak in bakery plants [30].

Table 6. *Microbiological parameters of MOC cookies (M15)*

Tested microorganisms	Unit	Results	Evaluation
Clostridium perfringens	CFU/g	Not detected (LOD=10)	Meets
Coliforms	CFU/g	Not detected (LOD=10)	Meets
Escherichia coli	CFU/g	Not detected (LOD=10)	Meets
Aerobic plate count	CFU/g	Not detected (LOD=10)	Meets
Total spores of yeast and moulds	CFU/g	Not detected (LOD=10)	Meets

The microbiological parameters of 15% MOC fortified cookie sample (M15) were analyzed at Eurofins Sắc Ký Hải Đăng food testing laboratories.

Clostridium perfringens (*C. perfringens*) is a gram-positive spore-forming anaerobic. *C. perfringens* can produce heat-resistant spores that can survive at cooking temperature [31]. Food poisoning by *C. perfringens* is caused by a heat labile enterotoxin which is cytotoxic, this disrupts the epithelial cells' membrane, causing diarrhoea [32]. According to TCVN 5909-1995, *C. perfringens* is not allowed to present in cookies, so theMOC cookies sample (M15) are safe based on microbial standards.

Coliforms are Gram-negative non-spore-forming bacilli, which have ability to degrade lactose into acids and gas within 48 hours. The coliforms can be considered as hygiene indicator, they are mostly found in case of insufficient heating or secondary contamination after heating [33]. According to TCVN

5909-1995, *Coliforms* must not be more than 10^2 CFU/g; therefore. Based on the microbial standards, the data showed that the cookies samples are safe for microbiological quality.

Escherichia Coli (E. coli) is non-spore-forming, Gram-negative bacterium [34]. *E. coli* is an indication of unhealthy conditions, which can be poor quality of water used [34]. According to TCVN 5909-1995, the *E. coli* must not exist in cookies. Therefore, the cookies sample (M15) is safe for microbiological quality with no *E. coli* found in the sample.

Aerobic plate count is commonly used to indicate the level of microorganism present in food product [36]. TCVN 5909-1995 allows the amount of APC no more than 5×10^3 CFU/g. Hence, the M15 sample met the microbial standards.

Total spores of yeast and molds are also an important microbial indicator because the growth ofmold and yeast shortens the shelf life of bakery products. The production of mycotoxins on those products may result in acidification. Mycotoxins are secondary metabolites and toxicto human consumption [37]. Yeast can be allowed with the amount no more than 10^2 CFU/g while molds that produce mycotoxins must not exist in product. MOC can adapt both specifications of yeast and molds because no spores of yeast and molds were found in M15 sample.

In conclusion, the cookie sample with 15% macadamia oil cake fortified (M15) are safe for microbial quality.

4. Conclusions

This study revealed that the fortification of MOC significantly improved the nutritional quality and sensory quality of cookies. The cookies produced from MOC were more nutritional than basic cookies and basic bread in terms of ash, protein and fat. The diameter and thickness of MOC cookies decreased with the increase of MOC addition, while the spread ratio increased. The hardness of 15% MOC fortified cookie was the lowest but this sample was the most preferred in terms of texture and the crispy mouthfeel of M15 was evaluated as good level. The optimum ratio for MOC fortification in cookies was 15% of MOC although the sample still had some definite disadvantages of color and flavor. In addition, the selected MOC supplemented cookies satisfied standard microbial safety requirements of TCVN 5909-1995. Based on the obtained results, it can be concluded that the MOC (a waste from macadamia processing) supplementation can help improving nutritional and sensory of cookies. Findings of this study also suggest the use of macadamia oil cake for producing other types of bakery products such as cracker, muffin and sponge cake.

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Conflict of Interest

The authors declare no conflict of interest.

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