Influence of the supplementation of macadamia oil cake powder on nutritional and sensory qualities of bread

Chuyen V. Hoang*, & Duy L. A. Do

Faculty of Chemical and Food Technology, HCMC University of Technology and Education, Ho Chi Minh City, Vietnam

ARTICLE INFO

Research Paper

Received: March 21, 2024

Revised: April 25, 2024

Accepted: May 10, 2024

Keywords

Bread

Macadamia oil cake

Nutritional quality

Physical property

Sensory quality

***Corresponding author**

Hoang Van Chuyen

Email:

chuyenhv@hcmute.edu.vn

ABSTRACT

Although macadamia oil cake (MOC) is a by-product of macadamia oil processing, this material still has high nutritional value, making it a promising ingredient for food products. This study aimed to investigate effects of the MOC supplementation at different ratios on physical properties, nutritional composition and sensory quality of bread. The results show that the addition of MOC led to increases in protein, ash and fat content, while carbohydrate content was lower in the supplemented bread. The specific volume and springiness of the bread were significantly affected by the MOC supplementation while no significant change in hardness and spread ratio was observed ($P < 0.05$). For the sensory quality of fortified bread, the differences in color, flavor, texture and overall acceptability among 4 levels of MOC addition were insignificant, except for the taste score. Microbiological analyses also confirmed that the MOC supplemented bread product met microbial safety standards. The obtained results suggest that the bread sample with 20% MOC addition (9.35 g protein, 12.32 g fat, 46.13 g carbohydrate, 4.29 g dietary fiber and 332.77 kcal per 100 g) should be selected for developing high nutritional bread products.

Cited as: Hoang, C. V., & Do, D. L. A. (2024). Influence of the supplementation of macadamia oil cake powder on nutritional and sensory qualities of bread. *The Journal of Agriculture and Development* 23(3), 79-89.

1. Introduction

Macadamia nut is known as the Australia's only commercial food crop indigenous and the world's finest nuts due to its unique, delicate flavor, crunchy texture. Macadamia nuts are an abundant source of nutrition including unsaturated fats, plant protein, and vital minerals with and exceptional lipid content that varies from 69.1% to 78.4%. Macadamia nuts contain 77.4% MUFA per 100 g of fat, of which 58.5% is oleic acid (18:1ω9) and 18.7% is palmitoleic acid (16:1) (Munro & Garg, 2008).

The extraction of macadamia oil normally uses cold pressing method (Navarro & Rodrigues, 2016). Because of their high nutritional value and protein content (15% to 50%), the seed and nut cakes are commonly utilized as feedstuffs for poultry and cattle (Acheampong-Boateng et al., 2017). In addition to the potential nutritional value, the macadamia oil cake (MOC) can also produce typically attractive flavors so it is suggested to be used as an ingredient to improve sensory quality of food products (Sarkis et al., 2014).

Different types of oil cake and nuts are utilized to make food products. The addition of oil cakes into food products could be a great way to increase the consumption of oil industry by-products to solve malnourishment (Behera et al., 2013; Szydłowska-Czerniak et al., 2021). A research on bread fortified with walnut oil cake and walnut oil showed positive results, especially the high amount of antioxidants and health aspects. However, some definite disadvantages in that research were recorded, such as the increase of hardness, dark crumb, reduction in bread volume (Pycia et al., 2020). Another research on hemp cake bread also showed a decrease in volume and negative effects on structural and textural characteristics of bread crumb. Nevertheless, the addition of hemp cake in bread helps to improve nutritional quality, especially proteins and some macro-elements, micro-elements such as iron (Pojić et al., 2015).

Thus, this research focused on producing bread supplemented with different ratios of MOC to improve the nutritional and sensory qualities of the products.

2. Material and Methods

2.1. Materials

Macadamia oil cake (from the cold pressing process) was provided by Damaca Nguyen Phuong Company (Dak Lak, Vietnam). The oil cake was dried, ground and sieved to obtain powder with the size less than 0.25 mm and then stored at -18^{o}C until used.

The MOC was analyzed and confirmed to have a moisture content of 6.83%, crude protein content of 21.6%, crude fat content of 30.4%, ash content of 3.57%, and crude fiber content of 6.27%.

2.1. Preparation of bread supplemented with macadamia oil cake

Table 1. Composition of bread

Ingredients	Samples			
	S0	S15	S20	S25
Wheat flour (g)	200	170	160	150
Macadamia oil cake (g)	0	30	40	50
Sugar powder (g)	15	15	15	15
Butter (g)	25	25	25	25
Non-sugar fresh milk (g)	130	130	130	130
Yeast (g)	3	3	3	3
Condensed milk	30	30	30	30
Salt (g)	1	1	1	1

Procedure of bread making:

All the ingredients were put and mixed well in a mixing bowl until becoming consistent. After that, the mixture was rested for 15 min at room temperature for 4 resting cycles. The rested dough was then folded the outer edge to the middle about 10 - 12 times. The obtained dough was divided the dough into 6 equal parts, about 60 g each. The edge of the dough was folded in the middle until the surface was smooth before the rolling and shaping to form pillow bread. The shaped dough was placed in the mold with 3 parts on each mold. The mold was then covered with a towel to be prevented from drying out for incubating until the bread has doubled in size (about 30 min).

Before baking process, the oven was preheated to 160°C in 10 min and then the trays were put into the oven and bake at 160°C in 30 min. After baking, the bread samples were placed on a cooling rack for cooling to room temperature and kept zip-top bags with desiccant packs in a cool and dry location.

2.3. Evaluation of physical parameters

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

- 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 Method (AACC, 2000).

- Texture analysis: The texture characteristics of the bread were analyzed using a texture analyzer (CT3, Brookfield Ametek Inc., MA, USA). TA-AACC3 type probe with trigger load of 4.0 g and test speed of 1 mm/s was employed for texture profile analysis (TPA). The hardness, elasticity, cohesiveness, and stalling rate of the TPA curve were analyzed.

2.4. Color analysis

L*, a* and b* values of the bread were determined using the CR-400 colorimeter (Konica Minolta, USA). The color differences between fortified samples with the control were calculated based on following equation (Mokrzycki & Tatol, 2011).

$$\Delta E = \sqrt{(L^* + L^*_0)^2 + (a^* + a^*_0)^2 + (b^* + b^*_0)^2}$$

Where

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

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

2.5. Nutritional composition

- Crude protein was determined by Kjeldahl method according to AACC 46-10.01.

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

- Total ash content was determined by heating in an oven at temperature of 600⁰ in 6 h according to AACC 08-01.01 standard.

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

Total carbohydrate% = 100 - (Protein% + Fat% + Ash% + Moisture%) (1 g protein: 4 kcal energy; 1 g fat: 9 kcal energy; 1 g carbohydrate: 4 kcal energy)

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

Energy = (weight of Carbohydrate × 4) + (weight of Protein × 4) (weight of fat × 9)

- Other indexes including dietary fiber, mineral content and microbiological criteria were analyzed by Eurofins Hai Dang food testing laboratories (Ho Chi Minh City, Vietnam).

2.6. Sensory evaluation

The sensory test was conducted using 9-point hedonic scale ranging from (1, dislike very much to 9, like very much) (Ghoshal et al., 2020). The coded bread samples were served to 20 untrained panelists including 10 males and 10 females (their age was from 20 to 50 years old). The panelists were asked to score the samples for color, shape, texture, sweetness, flavor, mouth feel and overall acceptability.

2.7. Data analysis

All experiments were performed in triplicate, and the results were expressed as the mean ± standard deviation. Comparisons amongst values were based on the LSD tests. Differences were considered to be significantly different at *P* < 0.05.

3. Results and Discussion

3.1. Effect of MOC substitution on physical properties of MOC bread

The analysis of physical properties of MOC supplemented bread (Table 2) showed that the addition of MOC caused significant variation in the specific volume of the bread samples. This change may be due to the ability to absorb water of the dough which is impacted by the uneven kneading process among the samples thereby leading to the unstable expansion during baking (Plazzotta et al., 2018).

Table 2. Physical properties of macadamia oil cake-supplemented bread

Samples	Specific volume (cm^3/g)	Hardness cycle 1 (N)	Hardness cycle 2 (N)	Springiness (mm)
S0	2.33 ± 0.01^c	2003.83 ± 16.28^a	2005.08 ± 13.32^a	17.00 ± 2.37^b
S15	2.65 ± 0.02^a	1994.67 ± 12.21^a	1982.50 ± 12.13^a	11.31 ± 0.48^c
S20	2.49 ± 0.03^b	1987.00 ± 22.10^a	1995.67 ± 15.75^a	21.51 ± 2.42^{ab}
S25	2.67 ± 0.04^a	1990.00 ± 11.26^x	2007.00 ± 10.58^a	26.00 ± 1.42^a

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

The hardness cycle 1 of S0 (2003.8 N) was the highest among the four samples, followed by S15 (1994.7 N). But when compressing the second time, the hardness cycle 2 of 3 samples S0, S20, S25 increased, the highest was S25 (2007N), only sample S15 decreased and gave the lowest value (1982.5N). Bread hardness is usually affected by airspace formation, gluten networks, other components present in the flour mixture and especially moisture content. In this study, when increasing the amount of MOC added, the moisture content decreased in sample S15 (29.65%), then increased in turn in samples S20 (31.12%), S25 (32.23%).

Regarding the springiness of MOC-fortified bread, it can be seen in Table 2 that the springiness decreased in sample S15 (11.3 mm), then gradually increased in samples S20 (21.5 mm), S25 (26.0 mm). Because the protein in the MOC is higher than the protein in the wheat flour (11% < 21.6%), it helps the gluten network to grow stronger, helping to increase the bread's flexibility, springiness, structure and shape. The reduced springiness in sample S15 can be attributed to the uneven mixing of the samples affecting the water absorption ability, causing the dough to not expand properly and having a low springiness value (Kumala & Sutrisno, 2020).

3.2. Effect of MOC substitution ratio on color of bread

The color analysis showed that when replacing wheat flour with MOC at the ratios of 15%, 20%, 25%, the L*, a*, b* values were significantly different to the control sample 0% (Table 3). Value of a* was directly proportional to the ratio of MOC addition and conversely the L* value and b* value were inversely proportional. As the amount of additional MOC is increased, L* and b* decreased while the value of a* increased.

Table 3. Color parameters of macadamia oil cake-added bread

Samples	L*	a*	b*	ΔE*
S0	59.71 ± 1.56[a]	5.49 ± 1.77[c]	28.57 ± 1.36[a]	-
S15	51.04 ± 1.43[b]	8.97 ± 2.47[b]	23.96 ± 1.69[b]	10.80 ± 2.04[b]
S20	49.28 ± 1.00[b]	12.28 ± 0.76[a]	24.42 ± 0.77[b]	13.31 ± 2.18[b]
S25	44.62 ± 1.90[c]	13.46 ± 0.49[a]	19.18 ± 2.22[c]	19,71 ± 2.71[a]

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

The more MOC is added, the darker the color tends to be and the control is the brightest bread sample. For the value of a*, an uptrend can be seen in the Table 3, which means that the more MOC is added, the redder the sample will be. As a result, the surface color of S20 and S25 is significantly redder than that of S0 and S15, and they are not significantly different ($P >$ 0.05). A significant difference in a* value at S0 and S15 was noted ($P > 0.05$). The value of b* decreases significantly. The higher the amount of MOC added to the bread dough, the lighter the yellow color of the surface will be. A significant difference was noted between M0 and all other 3 samples ($P < 0.05$).

Figure 1. Color of 4 different supplemented ratios of macadamia oil cake bread samples.

The ΔE* value of all three samples was greater than 5, indicating that the observer can see the color difference between the samples, the larger the ΔE* value, the greater the color difference. In addition to the analyzed color values, the obvious variation in color of the bread samples is also illustrated via the visual observation as shown in Figure 1.

3.3. Chemical composition of MOC added bread

The changes in contents of moisture, ash, protein, lipid, carbohydrate and energy value of bread added with different ratios of MOC are shown in the Table 4. The moisture content of the bread significantly increased with the high level supplementation of MOC, which were 31.12% for S20 and 32.23% for S25. In contrast, the moisture content of S15 (29.65%) was lower than that of the control (30.73%). The lower moisture content can prevent microbial spoilage and prolong the shelf life of the products (Demirkesen, 2016). Therefore, bread sample S15 has the longest shelf life, followed by reference sample (S0) due to its relatively low moisture content.

Table 4. Chemical composition of macadamia oil cake bread

Samples	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Carbohydrate (%)	Energy value (kcal)
S0	30.73 ± 0.03b	0.90 ± 0.04^{b}	7.78 ± 0.13^{b}	8.79 ± 0.19^{c}	51.81 ± 0.34^{a}	317.44 ± 0.86^{c}
S15	29.65 ± 0.11c	0.97 ± 0.01^{b}	9.19 ± 0.11^{a}	11.90 ± 0.23^{b}	48.29 ± 0.44^{b}	336.99 ± 0.86^{a}
S20	31.12 ± 0.39b	1.08 ± 0.02^{a}	9.35 ± 0.12^{a}	12.32 ± 0.17^{b}	46.13 ± 0.53^{c}	332.77 ± 1.72^{b}
S25	32.23 ± 0.59a	1.17 ± 0.04^{a}	9.47 ± 0.23^{a}	10.3 ± 0.12^{a}	44.03 ± 0.90^{d}	331.88 ± 1.69^{b}

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

The ash is generally the indication of mineral content in foods (Oguntoyinbo et al., 2021). In this experiment, the ash content in MOC bread increased with the addition of MOC, respectively, S0 (0.90%), S15 (0.97%), S20 (1.08%) and sample S25 (1.17%) had the highest value. This increase may be due to the effect of higher ash content in MOC (3.57%) than in wheat flour (0.8%). Macadamia nuts are also one of the nuts that can be considered as a source of essential and beneficial minerals for human health such as calcium, iron, magnesium (Munro & Garg, 2008).

Protein content in the bread samples ranged from 7.78 to 9.47% along with the increase in the MOC addition level. Because protein content in wheat flour is lower than in MOC (11% to 21.6%), the increase in protein content of the MOC added bread may be caused by the higher protein in the supplemented MOC. A previous study on bread supplemented with moringa seed powder also revealed similar results with the present research (Bolarinwa et al., 2019).

The amount of fat in the wheat flour used in this experiment is 3%, whereas the amount of fat in MOC is 30.4%. With an increase in MOC level, bread's fat content also greatly elevated. The sample with the highest fat content was S25, while the control sample with the least fat content was S0. The same outcome was discovered in (Bolarinwa et al., 2019) when they conduct a research on bread fortified with moringa seed powder. As a result of the change in nutritional composition, the energy value ranged from 317.44 to 331.88 kcal, which may be primarily attributable to MOC's fat content.

3.4. Effect of MOC on mineral content of MOC bread

It can be claimed that the mineral content of the sample will be lower the smaller the amount of ash contained in the flour sample (Bilge et al., 2016). S0 and S25, however, have ash contents of 0.9% and 1.08%, respectively (Table 5). The samples S0 (control sample) and S20 (the sample that received the most positive feedback) were selected to examine the mineral content present and explain the change of each element.

Table 5. Mineral content of macadamia oil cake bread

Samples	Ca (mg/kg)	Fe (mg/kg)	Mg (mg/kg)
S0	504	13.9	159s
S20	626	19.5	440

Overall, all minerals increased between the two samples of bread. In two samples of bread, calcium is the element that is most prevalent. Iron is the least dominant element, followed by magnesium. The calcium content in this study ranged from 504 to 626 mg/kg, increasing the calcium in S20 by 122 mg/kg. The amount of calcium the body needs each day is roughly 450 mg.

3.5. Sensory evaluation of MOC bread

Table 6. Sensory evaluation of macadamia oil cake-added bread samples

Samples	Color	Flavor	Taste	Texture	Overall acceptability
S0	6.33 ± 1.88^{a}	6.22 ± 1.56^{a}	6.33 ± 1.46^{ab}	6.89 ± 1.41^{a}	6.44 ± 1.82^{a}
S15	6.61 ± 1.94^{a}	6.22 ± 1.52^{a}	5.72 ± 1.93^{ab}	6.00 ± 1.61^{a}	5.72 ± 1.67
S20	6.33 ± 1.71^{a}	6.50 ± 1.58^{a}	6.83 ± 1.42^{a}	6.83 ± 1.62^{a}	6.22 ± 1.66^{a}
S25	6.83 ± 1.42^{a}	5.83 ± 2.04^{a}	5.33 ± 1.94^{b}	5.67 ± 1.94^{a}	5.44 ± 1.42^{a}

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

The sensory scores of the bread samples are presented in Table 6. In terms of color, All samples were evaluated with "like slightly" and "like moderately" scores. S20 sample got the same score as the control sample, while S25 had the highest acceptance for its eye-catching golden brown color. The Maillard, caramelization, and dextrinization reactions cause the color changes, and the natural color of MOC contributes to some of the bread color variations (Demirkesen, 2016). The flavor score of sample S15 is comparable to the flavor of the control. The highest score belongs to the S20 sample, which shows that this is the sample most accepted by the panelists. The lowest score belongs to S25 below "like slightly" (5.83). In terms of taste, there are only 2 samples scored between "like slightly" and "like moderately" namely S0 and S20, the remaining 2 samples were between "neither like or dislike" and "like slightly". The S20 became the most popular sample with the highest score of 6.83 of all samples, which indicates that panelists liked MOC's creamy in moderation. The most preferred texture samples can be said to be S0 and S20 because the difference is not significant (6.89 and 6.83). This can be explained in structural measurements, both of which have moderate hardness and springiness.

Overall, panelists widely accepted the S20 and gave this sample a score of 6.22, slightly lower than the control sample (6.44). Therefore, S20 sample (20% MOC fortified) is the selected sample for publication. Furthermore, the nutritional parameters of 20% MOC fortified breads (S20) are optimal, with protein content 9.35%, fat content 12.32%, carbohydrate content 46.13%, dietary fiber content 4.29% and energy value 332.77 kcal.

3.6. Microbiological quality of MOC added bread (S20)

The microbiological parameters of 20% MOC fortified bread sample (S20) were analyzed at Eurofins Hai Dang food testing laboratories and shown in Table 7. The results indicate that the microbial quality of selected bread sample satisfies all the microbiological requirements according to TCVN 5909-1995.

Mold and yeast growth are the main sources of microbial spoilage in confectionery products, which are characterized by high solids content and low moisture level (Loureiro & Querol, 1999). Controlling microbial growth or outbreak in confectionery plants requires an understanding of microorganism nature (Kačániová, 2011).

Table 7. Microbiological parameters of macadamia oil cake-added bread (S20)

Microbial indexes	Unit	Results	TCVN 5909-1995
Clostridium perfringens	CFU/g	Not detected (LOD=10)	Satisfy
Coliforms	CFU/g	Not detected (LOD=10)	Satisfy
Escherichia coli	CFU/g	Not detected (LOD=10)	Satisfy
Aerobic plate count	CFU/g	Not detected (LOD=10)	Satisfy
Total spores of yeast and mold	CFU/g	Not detected (LOD=10)	Satisfy

Clostridium perfringens is a gram-positive, anaerobic spore-forming organism. Heat-resistant spores that can live at cooking temperatures are produced by *C. perfringens* (Lee, 2016). A heat labile enterotoxin produced by *C. perfringens*, which is cytotoxic and responsible for food poisoning, damages the membrane of epithelial cells and causes diarrhea (Andersson et al., 1995). Macadamia oil cake bread adheres to the TCVN 5909-1995 standard for *C. perfringens*, which forbids its presence in bread, so the MOC bread sample (S20) are safe based on microbial standards.

Coliforms are non-spore-forming gram-negative bacteria that can break down lactose into acids and gas within 48 h. The presence of coliforms, which are regarded hygienic indicators and are typically detected when heating is insufficient or secondary contamination results from heating (Tominaga & Ishii, 2020). Coliforms shall not exceed 10^2 bacteria/g in accordance with TCVN 5909-1995; consequently, MOC bread satisfies this requirement. The statistics indicated that the bread sample is safe for microbiological quality based on the microbial standards. *Escherichia coli* is a gram-negative, non-spore-forming bacteria, a sign of unhealthy conditions, which may include using water that is of poor quality (Al-Nasiry, 2020). As a result, the bread sample (S20) is free of *E. coli*, making it safe for microbiological quality. An indicator of the amount of microorganisms contained in a food product is the aerobic plate count (Maturin & Peeler, 2001). The maximum amount of aerobic plate count allowed by TCVN 5909-1995 is 5 x 10^3 bacteria/g. The S20 sample thus met the microbiological requirements.

Total yeast and mold spores: Products made of confectionery have a shorter shelf life because to mold and yeast growth. the potential for acidification caused by the mycotoxin formation on those items. Secondary metabolites known as mycotoxins are harmful for human intake (Oranusi et al., 2013). PọMolds that create mycotoxins must not be present in the product, although yeast is permitted with a concentration of no more than 102 bacteria/g. MOC is capable of adjusting to both yeast and mold parameters. In summary, the bread sample fortified with 20% macadamia oil (S20) is safe for microbiological quality.

4. Conclusions

This study revealed that the fortification of MOC significantly improved the nutritional quality and sensory quality of bread. The optimum ratio for MOC fortification was 20% for the bread. The bread produced from MOC were higher nutritional than basic bread in terms of ash, protein, fat and mineral content, especially magnesium content. The hardness of 20% MOC was moderate and this and the control sample were the most preferred samples in terms of texture. All sensory criteria of the S20 bread samples were above 6 which fall between "Like slightly" and "Like moderately". Besides, the developed bread samples satisfied standard microbial safety requirements of TCVN 5909-1995. Based on the obtained results, it can be concluded that the MOC (a food processing waste) supplementation can help improving nutritional and sensory of bread. The promising results of this study suggest that MOC may also be used as a nutritional supplement ingredient for producing other bakery products instead of being regarded as a waste of food processing.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

This research is supported by Ho Chi Minh City University of Technology and Education (HCMUTE), Vietnam. The authors also acknowledge Damaca Nguyen Phuong Company for providing macadamia oil cake.

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