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Research Article

Antioxidant Activity, Texture Attributes, and Hedonic Properties of Fortified Cheese with Moringa Leaf Extract

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Abstract | The aim of this research was to evaluate the antioxidant activity, textural attributes and hedonic properties of cheese resulting from Moringa leaf extract fortification. Moringa leaf extract was fortified in the five treatment groups, 1000 ml each with different concentrations, namely 0% (P0); 2% (P1); 4%(P2); 6%(P3) and 8%(P4). The research method used one-way analysis of diversity (at $p<0.05$) and continued with the Duncan test using the SPSS version 25 system. The results showed that increasing the level of Moringa leaf extract had no effect on pH, water content, and fat but significantly affected protein and ash content ($p<0.05$). In the color aspect, the L* and a* values significantly decreased ($p<0.05$), but the b* values significantly increased. Texture profile analysis showed a significant increase in hardness, guminess, cohesiveness, springiness, and chewiness ($p<0.05$). The antioxidant capacity of cheese (mg/L Gallic Acid Equivalent Antioxidant Capacity (GAEAC)) significantly increased, namely 33.60 ± 0.49; 48.07±0.33; 52.71±0.51; 59.18 ± 0.54 and 65.73 ± 0.34. The results of the hedonic analysis showed that the color, aroma, and taste of cheese were preferred up to the level of 2%-4%. Still, their preference significantly decreased above that concentration level ($p<0.05$). Finally, increasing the concentration of Moringa leaf extract in cow's milk cheese products can provide positive functional value, especially in increasing the antioxidant activity of cheese.

Keywords | Antioxidant effect, Cow's milk cheese, Fortified, Hedonic properties, Moringa leaf extract, Texture analysis

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INTRODUCTION

The development of downstream processed livestock products with functional value is currently a consumer demand. This results from increasing public knowledge and awareness about processed livestock products that provide health values (Swensson et al., 2017). Consumer awareness about the importance of consuming functional food is both an opportunity and a challenge to diversify processed livestock products, especially processed milk, into cheese. As a livestock product, milk is a popular animal protein source. The health benefits of dairy products have been known for a long time. Naturally, these processed livestock products contain bioactive components related to health factors, such as cheese which has an antioxidant effect because it contains polyphenolic compounds (Branciari et al., 2015; Hilario et al., 2010).

The antioxidant effect on dairy products occurs due to the complexation between phenolics and milk protein (Park et al., 2018). However, this antioxidant activity is relatively weak due to the low concentration of polyphenolic

compounds in cheese products. This is because the polyphenol molecules' pH and nature limit the interaction of phenolic compounds and milk proteins (Gad and El-Salam, 2010). Therefore, the fortification of bioactive components from various plants has been developed to enrich functional properties in cheese products, such as the fortification of *Inula britannica* L (Lee et al., 2016); red ginseng extract (Jung et al., 2016), grape extract (Da Silva et al., 2015), purple cassava extract (Miwada et al., 2019) and so on, all of which provide antioxidant values to cheese.

In this study, the fortification effect of Moringa leaf extract powder was examined to increase the functional values of cheese products. Moringa leaves (*Moringa oleifera*) belonging to the Moringaceae family have been used as a source of antioxidants. This plant contains lots of protein, vitamins (β-carotene, vitamin C, and vitamin E), contains phytochemical compounds with high amounts of antioxidant potential, such as flavonoids, carotenoids, terpenoids, phenolic acids, and alkaloids (El-Massry et al., 2013; Kou et al., 2018; Ahmadifar et al., 2020). In this research, efforts were made to utilize Moringa leaves to enrich the antioxidant potential of cheese to produce functional cheese products with antioxidant values. This study analyzed the antioxidant capacity, physico-chemical analysis, texture, and hedonic properties of cow's milk cheese products given fortification from Moringa leaf extract.

MATERIALS AND METHODS

Research materials

The raw material for cheese is cow's milk whose chemical composition has been tested by Lactoscan SL60, serial number 3680 and calibration 1/cow and the characteristics of the fresh milk used are fat content (3.89%); SNF (8.36%); density (28.27%); lactose (4.59%); salt (0.69%); protein (3.05%); total solids (12.25%) and temperature (14.3oC). Other ingredients are Moringa leaf powder, 0.2 mL/L rennet enzyme and 0.5% citric acid (1.5%).

Cheese production with fortified moringa leaf extract

The cheese was produced according to the method of Jeong et al. (2017). Fresh milk (5 L) and concentrations of Moringa leaf extract (0%; 2%; 4%; 6% and 8%) were pasteurized at 83oC for 10 minutes and added 0.5% citric acid (1.5%). Stirring was carried out consistently for 15 minutes. Cooling is carried out to a temperature of 30°C. Inoculate 0.2 mL/L) of the rennet enzyme into the prepared material and incubate at 28-30°C for 24 hours for coagulation. Separation of solids from whey continued with the addition of salt (5%) and cheese ripening. Furthermore, each treatment sample was vacuum packed and repeated 3 times and ready to be tested for quality.

Physico-chemical analysis and Antioxidant Capacity of Cheese

The pH test was determined with a pH meter. At the same time, the proximate analysis, which included water content (105°C drying oven method for 4 hours), protein (Kjeldahl method), fat (Gerber method), and ash, was carried out by the AOAC Method (2005). Meanwhile, the antioxidant capacity test was carried out using the DPPH method (Lee and Bae, 2018).

Texture and color profile analysis of cheese

Texture profile analysis was performed using a TA-XT2 texture analyzer. The cheese was prepared in cubes (30 x 30 x 30 mm) and determined with a pre-test speed value of 2.0 mm/s, a post-test speed of 5.0 mm/s, a maximum load of 2.0 kg, and a distance threshold of 8 mm and force of 5 g. Texture profile tests include hardness, guminess, cohesiveness, springiness, resilience, and chewiness according to the method of Bozkurt and Bayram (2006). At the same time, the cheese color test was carried out with a chroma meter with measurements of L*, a*, and b* values according to the method of Yoo et al. (2019).

Cheese hedonic evaluation

The hedonic evaluation was conducted with 25 semi-trained panelists from the Faculty of Animal Husbandry, Udayana University, Bali, Indonesia. Cheese samples with fortified moringa leaf extract were prepared on a white plastic plate @ 15 g by adding a 3-digit code mark according to the treatment. Before the test, the panelists cleaned the palate with sterile water. Each sample was subjected to an organoleptic assessment, including a preference for color, aroma, texture, taste, and overall acceptance. Panelists were instructed to provide an assessment with a descriptive scale with a score of 1 (dislike very much) to a score of 5 (very like), and this analysis was carried out according to the method of Choi et al. (2015).

Statistical analysis

The research data is expressed as mean±SD data. To compare the results, a one-way analysis of variance was carried out (at $p<0.05$) and continued with Duncan's test using the SPSS version 25 system.

RESULTS AND DISCUSSION

Physico-chemical of cheese

The composition of cheese with fortified moringa leaf extract (0%; 2%; 4%; 6%, and 8%) is presented in Table 1. Increasing the concentration of moringa leaf extract in the fortification process of cow's milk cheese did not significantly affect changes in the pH of the cheese and cheese water content. This may be due to the bioactive components in Moringa leaf extract not interfering with the water-holding

capacity of the bioactive components in cheese (Lee et al., 2016). Meanwhile, fortification of moringa leaf extract in the cheese making process significantly increased ($p<0.05$) the protein and ash content of the cheese. Moringa leaves contain bioactive components, especially polyphenols, and their binding to milk proteins forms cross-links (Lee et al., 2016) and this is thought to contribute significantly to the protein content and ash content of the cheese produced. The phenol content functions as an antibacterial so that it can inhibit pathogenic bacteria from degrading protein, thereby causing protein levels in the product to increase (Salsabila et al., 2023). The highest protein content was found in P1 with the fortification of Moringa leaf extract as much as 2% compared to the control treatment. The results of the study by Zuldin et al. (2021) showed that the highest protein content in sweet bread was found in adding 7% Moringa leaf flour, and the lowest protein content was found in the control. The protein content of Moringa leaf flour is 28.25%. El-Massry et al. (2013) stated that Moringa leaves contain quite high crude protein, namely 26.79%. The highest ash content was found in the fortified Moringa leaf extract with a 6% concentration of 1.64% and the lowest ash content was in the control treatment, namely 1.45%. Kou et al. (2018) stated that Moringa leaves are rich in minerals. Clarita et al. (2021), the mineral content contained in Moringa leaves is iron, calcium, potassium, zinc, phosphorus, and magnesium. Agus et al. (2023) ash content is the mineral content of food products. The higher the ash content, the more mineral content the product contains.

The fat content in the cheese was not significantly affected by the fortification of Moringa leaf extract at a concentration range of 2-8% ($p>0.05$). The oil or fat component in Moringa leaves provides positive functional value to cheese, namely as a natural preservative for cheese (Dina et al., 2023). The water content is not significantly influenced by the concentration of moringa leave, the highest water content is found in P2, namely fortified Moringa leaf extract with a concentration of 4%, namely 42.53%. The water content value can affect the appearance, texture and taste. High water content can make it easier for microorganisms such as mold, yeast and pathogenic bacteria to reproduce (Ni Luh et al., 2021). Bulang et al. (2021) water content affects the durability of a food ingredient and can affect its physical, chemical, enzymatic and microbiological quality. This is in accordance with the statement of Salsabila et al. (2023) that water content is one of the parameters to determine the quality of a product. Water content can affect the texture and taste of food. High water content will affect microbial activity and food will spoil more quickly due to increased microbial activity.

Antioxidant capacity of cheese

A study of fortification of Moringa leaf extract significantly increased ($p<0.05$) the the antioxidant capacity of cheese, and an overview of the results is presented in Figure 1. At the 0% level, the antioxidant capacity of cheese was relatively lower as evidence that the complexation between the internal components of milk was relatively weak as an effect of the low component bioactive types of polyphenols (Park et al., 2018). Increasing the concentration of Moringa leaf extract 2-8% actually provides a linear increase in antioxidant capacity. This is thought to be the effect of the interaction of polyphenols and milk proteins by forming strong cross-links (Lee et al., 2016). Moringa leaves have real nutritional and therapeutic value with high antioxidant characteristics such as flavonoids, carotenoids, terpenoids, phenolic acids, and alkaloids (El-Massry et al., 2013; Kou et al., 2018; Ahmadifar et al., 2020; Razzak et al., 2022). Polyphenol compounds function as antioxidants and antibacterials which can extend the shelf life of food and can prevent the growth of microbes which can reduce nutritional and sensory quality (Salsabila et al., 2023). Antioxidant compounds found in Moringa leaves include ascorbic acid, flavonoids, phenolic compounds, and carotenoids which function as natural antioxidants (Clarita et al., 2021). The antioxidants in Moringa leaves have the function of neutralizing free radicals to prevent oxidative damage to antioxidant compounds (Ni Luh et al., 2021).

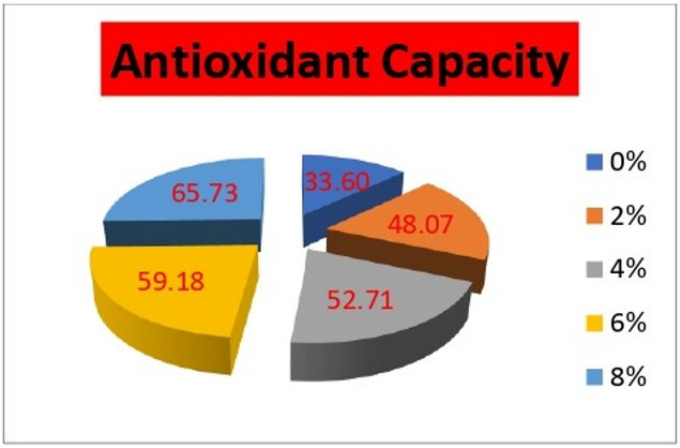

Figure 1: Antioxidant capacity of Cheese(mg/L GAEAC) with fortified Moringa Leaf Extract at different concentration levels (0%, 2%, 4%, 6% and 8%).

Texture attributes and cheese color

Cheese texture is an important factor influencing consumer preference due to its interaction with other ingredients. The results of the texture and color analysis of the fortified moringa leaf extract are presented in Table 2. The hardness (hardness value) of cheese at the 2% concentration level of Moringa leaf extract was significantly highest ($p<0.05$) compared to other treatments. The interaction of bioactive components in Moringa leaf extract (especially phenolic compound components) is quite optimal at a concentration of 2% to provide cheese hardness values. The interaction

Table 1: pH value and proximate analysis of fortified cow's milk cheese moringa leaf extract.

Variable	Fortification of moringa leaf extract				
	P0	P1	P2	P3	P4
pH	4.50±0.05[a]	4.48±0.09[a]	4.47±0.02[a]	4.34±0.07[a]	4.40±0.19[a]
Water content (%)	42.42±2.69[a]	41.69±1.34[a]	42.53±2.80[a]	41.08±0.98[a]	41.89±2.51[a]
Protein content (%)	15.87±0.11[a]	17.60±1.54[b]	16.83±0.11[ab]	16.67±0.45[ab]	16.47±0.20[ab]
Fat level (%)	21.45±0.45[a]	21.64±0.19[a]	21.42±0.45[a]	2170±0.83[a]	21.92±1.10[a]
Ash content (%)	1.45±0.07[a]	1.50±0.13a[b]	1.62±0.18[ab]	1.64±0.09[b]	1.56±0.04[ab]

All values are mean ± SD with three repetitions. A-c values with different notations and columns show significantly different values ($p<0.05$). [1)] P0: Control; P1: fortification of moringa leaf extract at a concentration of 2%; P2: fortification of moringa leaf extract at a concentration of 4%; P3: fortification of Moringa leaf extract at a concentration of 6% and P4: fortification of Moringa leaf extract at a concentration of 8%.

Table 2: Texture attributes and color quantity of fortified cow's milk cheese moringa leaf extract.

Variable	Fortification of moringa leaf extract				
	P0	P1	P2	P3	P4
Hardness (kg)	0.17±0.03[a]	1.18±0.34[b]	0.22±0.04[a]	0.14±0.03[a]	0.22±0.04[a]
Guminess	55.51±07.29[a]	121.85±49.72[b]	86.04±16.23[ab]	60.06±9.21[a]	97.54±14.11[ab]
Cohesiveness (%)	0.34±0.02[b]	0.27±0.03[a]	0.39±0.01[c]	0.43±0.03[cd]	0.45±0.03[d]
Springiness (mm)	047±0.05[a]	0.37±0.01[a]	0.71±0.17[b]	0.61±0.07[b]	0.62±0.02[b]
Chewiness	26.14±3.24[a]	117.47±18.07[c]	62.43±27.46[b]	35.94±1.73[ab]	60.10±7.42[b]
CIE L*	45.25±0.13[a]	34.12±0.68[b]	27.06±0.02[c]	31.97±0.13[d]	27.19±0.80[c]
CIE a*	-0.51±0.13[a]	-3.71±0.68[b]	-4.11±0.41[b]	-3.93±0.16[b]	-4.14±0.32[b]
CIE b*	20.03±0.30[a]	21.56±0.40[b]	22.80±0.01[c]	22.83±0.43[c]	22.84±0.35[c]

All values are mean ± SD with three repetitions. A-c values with different notations and columns show significantly different values ($p<0.05$). [1)] P0: Control; P1: fortification of moringa leaf extract at a concentration of 2%; P2: fortification of moringa leaf extract at a concentration of 4%; P3: fortification of Moringa leaf extract at a concentration of 6% and P4: fortification of Moringa leaf extract at a concentration of 8%.

of phenolic compounds and milk proteins is important in their contribution to providing antioxidant effects (Park et al., 2018; Gad and El-Salam, 2010). The same thing applies to the level of stickiness (guminess value), namely increasing Moringa leaf extract in its fortification in cheese, which has a significantly different impact compared to the control ($p<0.05$). The interaction of milk protein with the antioxidant components in Moringa leaves increasingly influences the hardness value (hardness value) and stickiness (guminess value) of the cheese product produced. Park et al. (2018) stated that the complexation properties of milk protein and its phenolic type antioxidant components were relatively weak due to the low concentration of antioxidants in milk. Still, with increased fortification of Moringa leaf extract in cheese, it provided increased antioxidant potential so that it was thought to be able to strengthen the protein complexation and bioactive components of Moringa leaves. This was also proven by the significantly increased gel strength (cohesiveness value) and also the significantly increased springiness value ($p<0.05$) at the concentration level of Moringa leaf extract 4-8%. Finally, the chewiness (chewiness value) of the cheese was also significantly affected ($p<0.05$) by increasing the fortification of Moringa leaf extract.

Analysis of the color of the cheese resulting from fortification of Moringa leaf extract is presented in Table 2. Statistical studies showed a significant decrease ($p<0.05$) in the L* value with increasing fortification of Moringa leaf extract in the cheese-making process. Likewise, the value of a* significantly decreased ($p<0.05$). The b* value also experienced a significant increase ($p<0.05$) with increasing Moringa leaf extract fortification. The dark green color of the Moringa leaves has affected the final product of the cheese. The bioactive components of Moringa leaves are thought to affect the cheese color quantity significantly. Salsabila et al. (2023) phenolic compounds function as antioxidants and antimicrobials which can inhibit fat oxidation, thus affecting the lightness of a product. Coconut shell liquid smoke contains organic acids and phenols which contribute to the formation of red and yellowness colors in food products. Sardar et al. (2021) stated that antioxidant components, such as phenol with moringa leaf pigments (carotene and chlorophyll a and b) have a significant relationship, and this is thought to have a significantly different effect on L*, a*, and b* values.

Hedonic value of cheese

The hedonic attributes of cheese from cow's milk with fortified moringa leaf extract at different concentrations

(0%; 2%; 4%; 6%, and 8%) are presented in Figure 2. The degree of preference for the color appearance of the cheese (Figure 3) with fortified moringa leaf extract with a concentration of 0-6% did not differ significantly. Still, the preference level significantly decreased at a concentration of 8% ($p<0.05$). The difference is in the aroma aspect, namely the 2% level is preferred by the panelists with the highest preference value compared to other treatments. The texture and taste of the panelist's preference level were real up to 4%, and increasing the level decreased the preference level ($p<,05$). Overall acceptance and fortification of Moringa leaf extract up to a concentration of 4% in the cheese was no significant difference with the control. Still, it was significantly different at a concentration of 6-8% ($p<0.05$). Some researchers say that the content of alkaloid-type bioactive components has a negative hedonic value, but other bioactive components found in Moringa leaves provide health benefits (Razzak et al., 2022; Mabaso and Bertling, 2021).

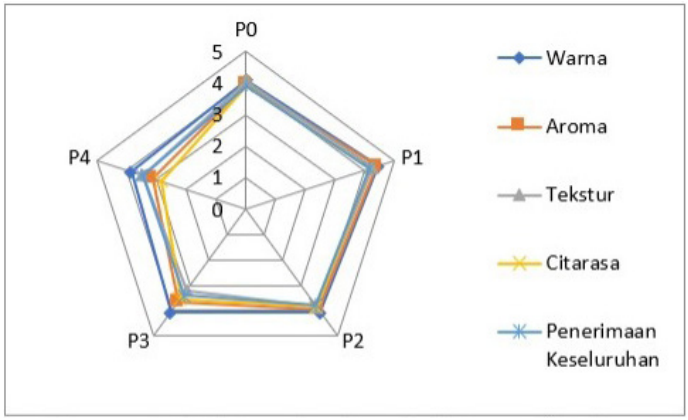

Figure 2: Ranking of average Hedonic intensity of fortified cheese of Moringa Leaf extract. There were 25 panelists, and each hedonic attribute was tested in triplicate from the sample type P0: control; P1: fortification of moringa leaf extract at a concentration of 2%, ; P2: 4%; P3, 6% and P4: 8%.

Figure 3: The appearance of Cheese with fortified Moringa leaf extract (0%, 2%, 4%, 6% and 8%).

CONCLUSIONS AND RECOMMENDATIONS

With Moringa leaf extract fortification, the research was conducted to strengthen functionality's value, especially cheese's antioxidant potential. Physico-chemical changes, including texture and color analysis and hedonic properties of cheese, can be applied fortification at 2%-4% and with significant antioxidant capacity. Furthermore, this research can simultaneously expand the potential use of Moringa leaves, especially through their fortification in the cheese-making process.

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NOVELTY STATEMENT

This research highlights the effect of adding Moringa leaf extract to cow's milk cheese products to provide functional value, especially in increasing the antioxidant activity of cheese and improving texture and hedonic properties in increasing consumer acceptance.

AUTHOR'S CONTRIBUTION

INSM: Data conceptualization and curation. INSS: Data curation, formal analysis. AS: Writing editor.

Conflict of interest

The authors have declared no conflict of interest.

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