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Effects of Partial Substitution of *Melissa Officinalis* Powder on Muffin Quality Characteristics

Jun Ho Lee*

Department of Food Engineering, Daegu University

Abstract

To develop quality-improved muffins, the influence of the partial replacement of wheat flour with lemon balm powder (LBP) on their quality characteristics was analyzed. Studies were carried out to examine the supplementation of different percentages of LBP (2%, 4%, 6%, and 8%) on the quality characteristics of LBP muffins. The incorporation of LBP significantly affected the physicochemical parameters of muffins. Such incorporation at different levels significantly decreased pH, moisture content, baking loss, hardness, and color parameters, including L*, a*, and b* values of muffins ($p<0.05$). No significant effect of LBP substitution was found in height changes ($p>0.05$). Finally, the consumer acceptance test indicated that the highest levels of LBP incorporation (*i.e.*, 8%) had a considerably adverse effect on consumer preferences in all attributes. In contrast, muffins with moderate levels of LBP (4%) showed a good and satisfactory sensorial acceptance in general. Thus, LBP was successfully employed in muffins, improving quality and broadening its potential applications in other bakery products.

Keywords: lemon balm powder, muffins, physicochemical properties, consumer acceptances

Introduction

Lemon balm (*Melissa officinalis* L.) a perennial medicinal herb from the Lamiaceae family native to the coastal areas of the Mediterranean Sea, widely spread worldwide (Omidi et al., 2018). High quantities of secondary metabolites such as phenolic compounds, tannins, and flavonoids in leaves were identified in *M. officinalis* and represent a potential functional ingredient for pharmaceutical and food industry (Moradkhani et al., 2010). *M. officinalis* has traditionally been used in folk medicine for digestion relief, ease of headaches and rheumatism, and other effects encompass antitumor, antiproliferative, antioxidant, and anti-Alzheimer properties among many others (Carocho et al., 2015).

The market for bakery product has been continuously growing all around the world, and food industry is avid for development in novel food ingredients in order to create new markets and stimulate purchasing (Carocho et al., 2016), and the main challenge would be the development of new formulations based on new food ingredients (Shaabani et al., 2018). Plants are an abundant in health-promoting compounds and their use in the diet continues to grow, especially in developed countries (Carocho et al., 2016). Baked products such as muffins are suitable for functional food. They are widely consumed due to their affordable cost, taste, and convenience, and new food ingredients are easily supplemented in their formulation. Thus, adding plant source food ingredient to muffins could be a promising and health-promoting strategy to increase the consumption of healthy food ingredients in a convenient diet (Klopsch et al., 2019).

Many plant source functional ingredients have been supplemented to improve muffins' overall quality including sensory properties; namely, mulberry leaf powder (Ahn & Yuh, 2004), dropwort powder (Seo et al., 2011), freeze dried-perilla leaves powder (Yoon et al., 2011), kale powder (Choi, 2015), barnyard millet (Goswami et al., 2015), moringa leaf powder (Jung, 2016), chickpea protein isolate (Shaabani et al., 2018), and enzymatically hydrolysed brewers' spent grain (Cermeno et al., 2021) to name a few among many others. Nevertheless, application of *M. officinalis* for food product development is scarce to date and there is no information on the use of lemon balm powder (LBP) in muffin-making. In this study, we attempted to assess the suitability of LBP utilization for improvement in overall quality of muffins.

Materials and Methods

Materials

All recipes were made with the same common ingredients

*Corresponding author: Jun Ho Lee, Department of Food Engineering, Daegu University, 201 Daegudae-ro, Jillyang, Gyeongsan, Gyeongbuk 38453, Korea
Tel: +82-53-850-6531; Fax: +82-53-850-6539
E-mail: leejun@daegu.ac.kr
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procured from a local market or from online stores. The ingredients were soft wheat flour (WF, composition from manufacturer: Na 0.058 mg/100 g, carbohydrate 7.8 g/100 g, sugars 0.117 g/100 g, fat 0.13 g/100 g, trans fatty acids 0 g/100 g, saturated fat 0.05 g/100 g, protein 0.8 g/100 g), white sugar (CJ Cheiljedang, Seoul, Korea), salt-free butter and milk (Seoul Milk Co., Yangju, Korea), salt (Chung Jung Won, Seoul, Korea), baking powder (Orco Corp., Goyang, Korea), and eggs. LBP and extrait de vanille (Vaniflor 200, Prova S.A., France) were purchased from Natural Agricultural Food (Goesan, Korea) and Hello Baking (Suwon, Korea), respectively.

Preparation of muffins

A reference muffin recipe from Kim & Lee (2012) with slight modification was employed as a control. The standard muffins' recipe consisted of 80 g (100%) of flour (white wheat flour as a control), 120 g of egg, 70 g of white granulated sugar, 30 g of salt-free butter, 30 g of milk, 2 g of baking powder, 2 g of extrait de vanille, and 1 g of salt, which made up 335 g of control batter. Muffins containing LBP were prepared by replacing wheat flour with LBP at 2% (78.4 g/335 g), 4% (76.8 g/335 g), 6% (75.2 g/335 g), and 8% (73.6 g/335 g), respectively. Samples were coded as control (recipe without LBP), LBP2, LBP4, LBP6, and LBP8 for recipes where 2%, 4%, 6%, and 8% of wheat flour was replaced with LBP, respectively.

For the muffin manufacture, whole egg, sugar, and salt were mixed for 1 min with a silicone spatula. Then all the other ingredients were added: butter, milk, extrait de vanille, flour (for control muffins) or flour and LBP (for LBP2~LBP8 muffins), and baking powder. The ingredients were well mixed and portions of *ca*. 60 g of batter were added to paper muffin cases and then placed onto metallic muffin trays. Muffins were baked in groups of twelve units in a pre-heated ventilated oven (GOR-704C, TongYang Magic Corp., Seoul, Korea) for 25 min at 180°C. After 30 min of cooling at ambient comdition, the muffins were kept in sealed plastic bags to prevent moisture loss prior to further analyses.

pH and moisture content

A batter and muffin samples (*ca*. 5 g) were mixed with 45 mL of distilled water and vortexed for 1 min. The mixture was held at ambient temperature for 1 h in order to separate solid and liquid phases. The pH of the supernatant was measured using a pH meter (pH/Ion F-72, Horiba Co., Kyoto, Japan). Moisture content of muffins was obtained by drying a specific amount (*ca*. 5 g) of sample to a constant weight at 105°C in an oven (FOL-2, Jeio Tech Co., Daejeon, Korea), and the results were reported on a wet basis (w.b.).

Height and bake loss

The height of muffins was measured by using calipers to measure from the base of each muffin to the highest top end (Marchetti et al., 2018). The bake loss is expressed as percent weight ratio before and after the muffins had been baked and the following formula from Heo et al. (2019) was calculated as follows:

$$\text{Bake loss (\%)} = \frac{\text{(Batter weight - Muffin weight)}}{\text{Batter weight}} \times 100$$

Crumb texture

Hardness of the muffin cubes cut from the center (5.3 cm × 5.3 cm × 2 cm) was measured using a texture analyzer (LRX*Plus*, Lloyd Instrument Limited, Fareham, Hampshire, UK) in a compression mode, using a disc-type probe with 50 mm diameter and a test speed of 1 mm/s. The probe compressed the sample to 30% of the sample's height. The peak value of maximum force was recorded as hardness of the specific sample. Measurements were carried out on fifteen muffins for each recipe.

Crumb color

Color determinations were performed using a Chroma Meter CR-600d colorimeter (Minolta Co., Osaka, Japan) on surface of transversally cut muffin slices. CIE-LAB parameters (lightness, L*, white to black, 100 to 0; redness, a*, red to green, +60 to -60; and yellowness, b*, yellow to blue, +60 to -60) were determined. Color readings were taken on three muffins for each recipe, on three points of each muffin's internal crumb surface. The total color difference (ΔE*) between the control and LBP containing muffin samples was calculated as follows:

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{0.5}$$

Sensory evaluation

Muffins were subjected to sensory evaluation using twenty six untrained volunteer panelists (13 males and 13 females, aged from 21 to 26), drawn within the University community. Samples were evaluated for consumer acceptance of color, flavor, softness, taste, and overall acceptance. The ratings were carried on a 9-point hedonic scale ranging from 9- (like extremely) to 1- (dislike extremely). Orders of serving were completely randomized in a balanced order and single-blinded using three-digit number codes. Overall acceptance was evaluated first, and another session was held to evaluate the rest of the attributes. There was an interstimulus interval of 30 s imposed between samples, to allow time to recover from adaptation. Participants were advised to rinse their palates between samples with water. Enough space was given to handle the samples and questionnaire, and evaluation time was not constrained. No specific compensation was given to the participants.

This study was approved by the Daegu University Institutional Review Board (IRB #1040621-202203-HR-021).

Statistical analysis

The data, collected in triplicates except for color and bake loss (n=9), pH (n=10), hardness (n=15), and sensory evaluation (n=26), have been expressed by its mean and standard deviation values. The results were subjected to one way analysis of variance (ANOVA) using the general linear models (GLM) procedure. Analysis was performed by Statistical Analysis System ver. 9.4 (SAS/STAT, Cary, NC, USA) software. Mean values were compared using Duncan's multiple range test and the significance was defined at the 5% level.

Results and Discussion

pH and moisture content

The data regarding physicochemical properties of muffins prepared from blends of wheat flour and LBP are depicted in Table 1. A progressive decrease in pH values of batter and muffins as well as moisture content of muffins was observed as the amount of LBP increased from 0 to 8% in the blends. The pH ranged from 7.68 to 7.97 (range=0.29) and 8.46 to 8.63 (range=0.17) for batter and muffins, respectively. On the other hand, the moisture content ranged from 30.27 to 34.93% (w.b.) with the range of 4.66% (w.b.). These decreases were due to the specific characteristics of these constituents in LBP itself, whose pH is 7.17 and moisture content is 5.43% (w.b.) as well as the higher LBP inclusion level. The results obtained in the present study were in close agreement with those reported by other workers (Kim et al., 2019; Choi et al., 2020) who also observed that LBP incorporated sponge cake (Kim et al., 2019) and cookies (Choi et al., 2020) had decreased the pH values of each model foods. A similar reduction in moisture content was observed for muffins incorporated with ground flaxseed (Kaur & Kaur, 2018) and upcycled defatted sunflower seed flour (Grasso et al., 2020).

Muffin height and bake loss

There was a non-significant increase in height during baking in the muffin samples with increasing level of LBP. These results are in agreement with the findings on replacing the wheat flour with domestic dropwart powder (Seo et al., 2011), barnyard millet flour (Goswami et al., 2015), mealworm powder (Hwang & Choi, 2015), coffee ground residue water extracts (Kim et al., 2016), upcycled defatted sunflower seed flour (Grasso et al., 2020), and enzymatically hydrolysed brewers' spent grain powder (Cermeno et al., 2021). This increase in height of the muffins containing LBP may be attributed to the enhanced viscoelasticity of the batter, which retained more of the air incorporated during mixing (Marchetti et al., 2018; Cermero et al., 2021) or more of the CO_2 produced from the baking powder (Cermero et al., 2021). The highest height due to baking was observed in the muffin sample prepared with the 8% LBP blend lowest being in the LBP2 muffins although the differences were not significant (p>0.05) (Table 1).

Bake loss is described as a process in which gas is produced and vapor pressure increases due to the expansion of liquids when heat permeates the batter in the baking process. Muffins can be damaged if gas escapes; thus, bake loss and its effects on shelf-life are of concern for the structural transformation of muffins (Kim et al., 2012). This parameter is also of industrial interest since the lower the bake loss, the higher the yield; thus, resulted in the higher product weight (Marchetti et al., 2018). Bake loss was significantly different across the five recipes

Table 1. Physicochemical properties of muffins prepared from blends of wheat flour and LBP

Parameters		Control	LBP2	LBP4	LBP6	LBP8
pH	*Batter*	7.97±0.02[a]	7.93±0.00[ab]	7.84±0.01[b]	7.72±0.00[b]	7.68±0.00[b]
	Muffin	8.63±0.22[a]	8.56±0.00[ab]	8.52±0.00[bc]	8.48±0.00[bc]	8.46±0.00[c]
Moisture content (%)		34.93±0.50[a]	34.40±0.69[ab]	34.03±0.45[b]	32.00±0.10[c]	30.27±0.25[d]
Height (cm)		3.98±0.34[a]	3.96±0.28[a]	4.02±0.37[a]	4.18±0.14[a]	4.49±0.20[a]
Bake loss (%)		12.87±0.59[a]	10.84±0.57[b]	9.25±0.66[c]	7.51±0.60[d]	6.02±0.76[e]
Hardness (N)		57.35±0.46[a]	55.74±0.47[b]	50.59±0.48[c]	45.43±0.49[d]	39.29±0.41[e]

Values followed by a same superscript in a row do not differ significantly (p>0.05).

and progressive replacement of wheat flour with LBP resulted in to a significant decrease ranged from 6.02 to 12.87% in the bake loss of baked muffins, with control sample exhibiting the highest value ($p<0.05$) (Table 1). This may imply that a proper amount of LBP can lead to improved texture quality during baking. A similar trend was also reported for muffins supplemented with kale powder (Choi, 2015), moringa leaf powder (Jung, 2016), and *Chenopodium pallidicaule* flour (Kim et al., 2020).

Crumb texture and color

The LBP incorporated muffins had a softer texture as compared with the control and Table 1 clearly shows the significant decrease in hardness of muffins with increasing level of LBP ($p<0.05$). The hardness of muffin samples decreased significantly and it ranged from 57.35 N to 39.29 N. These results indicate the LBP muffins were softer and this can be attributed to the dilution of gluten in muffin recipe (Goswami et al., 2015). Previous study also indicated that the replacement of wheat flour with gluten-free flours such as quinoa or rice flour in the muffin recipe resulted into a decrease in hardness (Bhaduri, 2013). A similar decrease in hardness was reported for muffins incorporated with increasing amount of fenugreek seed husk (Srivastava et al., 2012), red ginseng marc powder (Jung et al., 2015), and barnyard millet (Goswami et al., 2015). These results also agree well with others when yacon flour is incorporated in gluten-free muffins (Lancetti et al., 2020).

The data regarding color characteristics as expressed as CIE-LAB L*, a*, b*, BI, and ΔE* values of the muffins from different formulation are given in Table 2 and also shown in Fig. 1. The L* values of the muffins decreased significantly with increasing concentrations of LBP ($p<0.05$). A similar trend was also observed in the a* (red-blue) and the b* (yellow-green) values. The incorporation of LBP into muffins significantly decreased the lightness values compared to the control ($p<0.05$), thus, led to a darker muffin appearance as shown in Fig. 1. ΔE* represents the visual difference of color to the human eye and ΔE* > 3 indicating clear differences for the human eye (Cermeno et al., 2021). The ΔE* values ranged from 13.25 to 22.58, increased upon progressive replacement of wheat flour with LBP, indicating clear differences for the human eye. These color changes could be attributed to formation of Maillard browning reactions between the free amino groups (liberated during enzymatic hydrolysis) and free reducing sugars (Michalska et al., 2008). These results were in accordance with the findings reported for muffins supplemented with powders of mulberry leaf (Ahn & Yuh, 2004), freeze-dried perilla leaves (Yoon et al., 2011), unmodified brewers' spent grain (BSG), and enzymatically modified BSG (Cermeno et al., 2021). This effect was also described in Kim et al. (2019) where increasing LBP

Table 2. Color characteristics of muffins prepared from blends of wheat flour and LBP

Parameters		Control	LBP2	LBP4	LBP6	LBP8
Color	L*	44.60±0.05^{a}	35.97±0.05^{b}	34.00±0.10^{b}	32.52±0.08^{b}	30.56±0.20^{b}
	a*	3.21±0.03^{a}	2.54±0.08^{b}	1.31±0.10^{c}	1.28±0.10^{c}	0.58±0.00^{d}
	b*	18.87±0.11^{a}	10.24±0.05^{b}	9.51±0.09^{c}	8.73±0.05^{d}	6.02±0.11^{e}
	ΔE*	–	13.25	13.83	15.44	22.58

Values followed by a same superscript in a row do not differ significantly ($p>0.05$).

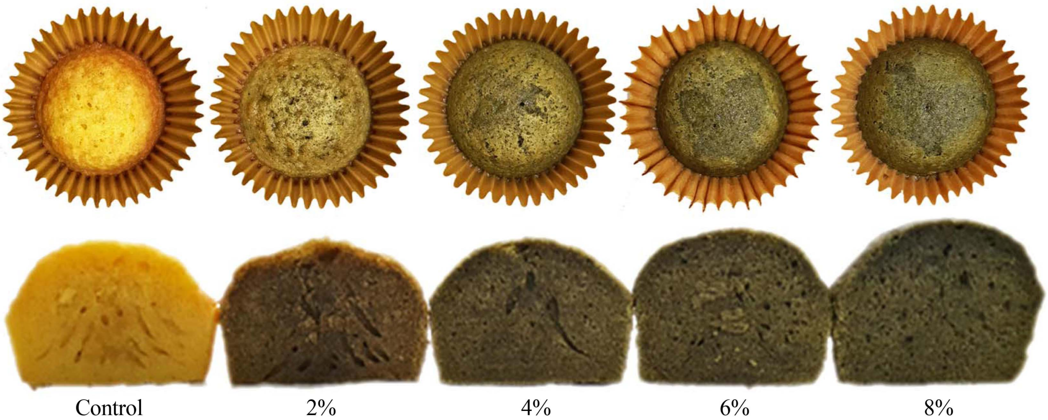

Fig. 1. The crust and crumb appearance of muffins prepared from blends of wheat flour and LBP.

Table 3. Consumer acceptance of muffins prepared from blends of wheat flour and LBP

Attributes	LBP level in muffins (%)				
	0	2	4	6	8
Overall acceptance	5.46±1.14^{b}	5.69±1.23^{ab}	5.92±1.44^{ab}	6.27±1.31^{a}	5.15±1.35^{b}
Color	5.77±1.27^{bc}	5.73±1.28^{bc}	6.19±1.20^{ab}	6.50±1.21^{a}	5.23±1.34^{c}
Flavor	4.27±1.48^{c}	6.19±1.23^{a}	6.81±1.23^{a}	5.38±1.55^{b}	4.81±1.30^{bc}
Softness	5.42±1.03^{b}	6.23±1.39^{ab}	7.00±1.55^{a}	6.77±1.45^{a}	5.81±1.52^{b}
Taste	5.08±1.35^{d}	7.00±1.20^{ab}	7.23±1.07^{a}	6.27±1.82^{bc}	5.69±1.83^{cd}

Values followed by a same superscript in a row do not differ significantly (p>0.05).

incorporation levels into sponge cakes led to lower L*, a*, and b* values. This result can be understood considering the differences in color parameters of LBP (L*=45.58, a*=0.03, b*=15.28) and WF (L*=76.13, a*=0.18, b*=7.75). Thus, the resulting crumb color is further related to the relative proportion of LBP/WF in the system.

Sensory characteristics of muffins

Table 3 shows the consumer acceptance of muffins as influenced by the incorporation of LBP and it was found that incorporating LBP in wheat flour significantly affected all the consumer acceptance attributes evaluated for the muffins (p<0.05). The mean sensory scores of control muffins were 5.77, 4.27, 5.42, 5.08, and 5.46 respectively for color, flavor, softness, taste, and overall acceptance. The highest flavor, taste, and softness scores were given to muffins prepared from the blend containing 4% LBP, whose scores were significantly different from those of the control and LBP8 (p<0.05). The addition of further LBP appeared to decrease those scores. The LBP4 did not achieve the highest scores in terms of preferred color and overall acceptance; nevertheless, its values were significantly higher than those of the control and LBP8 (p<0.05). The LBP2, LBP4, and LBP6 received the significantly higher overall acceptance scores than other samples (p<0.05); however, further increase in LBP level beyond 6% significantly lowered the scores (p<0.05). In general, the acceptance scores of all attributes studied continued to decrease with increasing levels of LBP incorporation especially at levels above 6%. In summary, the LBP4 received scores over 6.10 on a nine-point hedonic scale, except for overall acceptance (5.92), which is very acceptable. The overall results showed that the LBP muffins best achieved the improved the sensory quality when the LBP level was at 4%.

Conclusions

This research paper has analyzed the effects of LBP addition at levels of 0~8% during muffin baking. Muffins incorporated with LBP showed a progressive decrease in pH, moisture content, bake loss, hardness, and color parameters including L*, a*, and b* values of muffins, making them softer, darker and less yellow than control. LBP inclusion did not affect muffins' height. In terms of sensory quality, muffins enriched with 4% LBP were found to have improved overall characteristics. These results indicated that LBP could be a good alternative to wheat flour in bakery products without adversely affecting the physical and sensory quality. Instrumental and sensorial data showed that the optimum concentration of wheat flour replacement with LBP in a basic muffin formulation would be 4%.

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Author Information

Jun Ho Lee: Ph.D., Professor, Department of Food Engineering, Daegu University