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Antioxidant activities and physical properties of milk chocolate enriched with plant-based functional ingredients

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Abstract

The improvement of health-promoting properties of chocolate is a nowadays trend in the food industry. Plant-based foods, such as mung bean, fenugreek seed and moringa leaf, are well-acknowledged to have functional properties which are beneficial for health. Nevertheless, incorporating these materials into chocolate may affect the character of chocolate. This research, therefore, aimed to study the effect of powdered mung bean, fenugreek seed and moringa leaf addition on the antioxidant activity and physical properties of milk chocolate. The materials were added in a range of 5-15%. Antioxidant properties, including total phenols, total flavonoids and DPPH-radical scavenging activity as well as colour and texture were thoroughly analysed. The results showed that the addition of mung bean, fenugreek seed and moringa leaf significantly improved the antioxidant activity of milk chocolates. The addition of the above-mentioned materials also had a significant impact on the physical properties of the products. However, the effect was ingredient type-dependent, and thus it indicates the importance of ingredient selection in the making of functional chocolate.

1. Introduction

Cocoa (*Theobroma cacao* L.) is one of the potential commodities in Indonesia as indicated by a large total area of cocoa plantation, about 1.7 ha, located in 32 of 34 provinces in the country. Indonesia has been listed as the biggest cocoa-producing country in Asia with 713,400 tonnes of cocoa production in 2020 (Central Bureau of Statistics, 2021). However, up till now, the agro-industry of cocoa in Indonesia faces many challenges as studied by Praseptiangga and his co-workers (2020). As such, the cocoa farmers think that cocoa farming has less profit than other activities making them unmotivated to continue cocoa farming. To overcome this problem, many stakeholders, including the government and the academician, attempted to empower cocoa farmers, particularly in order to sustain cocoa production in Indonesia (Yunindanova *et al.,* 2020). An alternative way to maintain cocoa production in Indonesia is by ensuring the cocoa farmers obtain high income which may be conducted by educating them to make high-quality cocoa-derived products, including chocolate bars and cocoa drinks, with high added value (Muhammad, Zulfa, Purnomo *et al*., 2021).

Creating chocolates with high phenolic content has been gaining high interest from food scientists and the food industries (Muhammad *et al*., 2017, Muhammad *et al*., 2019). According to Muhammad *et al.* (2018), two approaches can be conducted to create chocolate with high phenolic content which is maintaining cocoa's phenol degradation during processing and enriching the final product with phenol-rich substrates. The latter, however, is considered more feasible as compared to the first approach, particularly for small-scale industries as it needs less time and effort. Cinnamon and ginger are some examples of polyphenol-rich materials that were successfully added to chocolates and cocoa drinks (Ilmi *et al.*, 2017; Muhammad *et al*., 2020; Faiqoh *et al.*, 2021; Muhammad, Tuenter, Patria, *et al*., 2021; Muhammad, Tuenter, Patria, *et al*., 2021). Moreover, in the second approach, chocolate and cocoa drink may be enriched not only by using phenol-rich substrates but also by other functional ingredients such as fibre and probiotics

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(Erdem *et al.,* 2014; Konar *et al.,* 2016; Muhammad, Rahayu and Fibri, 2021).

In our previous study, powdered mung bean (*Vigna radiata*), fenugreek seed (*Trigonella foenum-graecum*) and moringa leaf (*Moringa oleifera*) have been successfully added to milk chocolates by using small-scale chocolate processing (Muhammad, Zulfa, Purnomo *et al*., 2021). Reformulation of chocolate by using these ingredients was based on the fact that mung bean, fenugreek seed and moringa leaf contain specific bioactive compounds and nutrition that may be useful to improve the health-promoting properties of milk chocolate. For instance, mung beans contained flavonoids and amino acids which are related to some biological activities such as antioxidant, anti-inflammatory, antihypertensive and antitumor activities (Tang *et al.*, 2014). Fenugreek seed, in another study by Nagulapalli-Venkata *et al.* (2017), also has potency as an antidiabetic, anticancer, anti-inflammatory and antioxidant agent due to its phytochemical contents such as alkaloids, polyphenols, flavonoids and amino acids. While, according to Chhikara *et al.* (2020), moringa leaves contained terpenoids, polyphenols, flavonoids, and carotenoids which may play an important role in the prevention of several chronic and degenerative diseases. Interestingly, the materials have similarities which are strongly associated with the improvement of breastfeeding performance in many countries (Sumarni *et al.*, 2020).

In addition, mung beans, fenugreek seeds and moringa leaves were intentionally used in our previous study in reformulating milk chocolate as they represent different categories of foods, *i.e.,* bean, seed and leaf. It was notable that the addition of these materials altered the sensory characteristics of milk chocolate to some extent, but still in the range of acceptable (Muhammad, Zulfa, Purnomo *et al*., 2021). Hence, further study is required to investigate the potential health benefit of milk chocolate formulated with mung beans, fenugreek seeds and moringa leaves. This study, therefore, aimed to determine the chemical, nutritional as well as chemical properties of the chocolate enriched with these ingredients.

2. Materials and methods

2.1 Preparation of milk chocolate samples

Mung beans, fenugreek seeds and moringa leave obtained in bulk from a local market in Madiun, East Java was firstly dried using a cabinet dryer at 60°C for 5 hrs to obtain materials with moisture content of less than 10%. Separately, the milk chocolate compound (PT Frey Abadi Indotama, Karawang, Indonesia) was melted in a microwave (Panasonic Microwave Oven Low Watt - NN -SM32, PT. Panasonic Gobel Indonesia, Bekasi, West Java). The powdered mung bean, fenugreek seeds and moringa leaves were then independently mixed with the molten chocolate at a concentration of 5, 10 and 15% (w/w), and then followed by manual temper and moulding. After a 2-hour incubation in a controlled temperature chamber, the samples were demoulded and packed into aluminium foil.

2.2 Determination of moisture, fat and protein content

The analysis of moisture, fat and protein content of the samples (*i.e.,* mung bean, fenugreek seed, moringa leaf and chocolates) were conducted using thermogravimetry, Soxhlet and Kjeldahl methods, respectively, following the standard method of AOAC (2019).

2.3 Determination of total phenols and DPPH-radical scavenging activity

The total phenolic content of the samples was determined using the Folin-Ciocalteu method following the protocol of Muhammad *et al.* (2018). Prior to the analysis, the powdered mung beans, fenugreek seeds and moringa leaves were first extracted using methanol (70%), while the chocolate samples were extracted by conducting several consecutive steps. The chocolate was washed with n-hexane in a ratio of 1:5 (w/v) twice to remove the fat content. The defatted sample was then extracted two times using a mixture of solvents consisting of acetone, distilled water and acetic acid in a ratio of 70: 29.8: 0.2 assisted by stirring for 10 mins.

To estimate the phenolic content of each sample, 0.2 mL of extract was added to a mixture of distilled water (1 mL) and Folin-Ciocalteu reagent (0.2 mL). Afterwards, a solution of natrium carbonate (7%, 2.5 mL) and distilled water (2.1 mL) were added after the mixture was incubated for 6 mins. After incubation at room temperature for 90 mins, the absorbance was measured at 760 nm using a UV-visible spectrophotometer. Total phenolic content was expressed as milligrams of gallic acid equivalent per gram of samples (mg GAE/g).

2.4 Determination of DPPH-radical scavenging activity

In the analysis of DPPH-radical scavenging activity, a solution of DPPH (2,2-diphenyl-1-picrylhydrazyl) at a concentration of 0.3 mM was first prepared. Afterwards, 3.3 µL of the sample extract was added into ethanol (467 µL) and then continued with an addition of the DPPH solution (0.5 mL). A vortex was used to ensure the mixture had been well-blended. After incubation for 30 mins in a dark condition, the absorbance was measured

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at 517 nm using a UV-visible spectrophotometer. The DPPH-radical inhibition was calculated using Eq. 1.

$$\text{Inhibition} = \left(1 - \frac{\text{Abs sample}}{\text{Abs control}}\right) \times 100\% \quad (1)$$

2.5 Physical analysis

The textural properties of the chocolates were evaluated using Universal Testing Machine (Model Zwick I Z0.5, United Kingdom). The measurement was set with a pre-load of 1 N and the test speed was set at 0.5 mm/s. A set of data on hardness and fracture was then obtained.

A Chromameter CR-400 (Konica Minolta Optic, Inc.) was used to determine the L* (lightness component), a* (green to red component) and b* (blue to yellow component) of the samples. The level of Chroma (C*) and °Hue as well as the whiteness index (WI) and the degree of difference between chocolate samples and chocolate control (ΔE*) were then calculated using Eq. 2 to Eq. 5, respectively.

$$C^* = \sqrt{a^{*2} + b^{*2}} \quad (2)$$

$$°\text{Hue} = \tan^{-1}(b^*/a^*) \quad (3)$$

$$WI = 100 - \sqrt{(100 - L^*)^2 + a^{*2} + b^{*2}} \quad (4)$$

$$\Delta E = \sqrt{(L_1^* - L_2^*)^2 + (a_1^* - a_2^*)^2 + (b_1^* - b_2^*)^2} \quad (5)$$

The textural properties of the chocolates were evaluated using Universal Testing Machine (Model Zwick I Z0.5, United Kingdom). The measurement was set with a pre-load of 1 N and the test speed was set at 0.5 mm/s. A set of data on hardness and fracture was then obtained (Muhammad *et al*., 2018).

2.6 Data analysis

Data are obtained from three independent experiments. IBM SPSS Statistics 23 software was used for the statistical analysis, including one-way ANOVA and Duncan's Multiple Range Test (DMRT), with a confidence level of 95%.

3. Results and discussion

3.1 Characteristics of powdered mung beans, fenugreek seeds and moringa leaves

Mung beans, fenugreek seeds and moringa leaves were used in this study due to the fact that these materials contained nutrition and phytochemicals potentially used for the improvement of the health-promoting properties of milk chocolate. In this study, therefore, the nutritional content, as well as the antioxidant potential of powdered mung beans, fenugreek seeds and moringa leaves, were analysed prior to the enrichment of the milk chocolate (Table 1).

This study shows that mung bean was rich in protein agreeing on a common theoretical recognition regarding the nutritional content of this plant-based food. As stated by Tang *et al.* (2014), mung bean has been used as food for thousands of years because it contains balanced nutrients, including protein and dietary fibre. Mung bean also was identified to have a higher fat content as compared to fenugreek seed and moringa leaf. Nevertheless, in terms of antioxidant properties, the total phenols and DPPH-radical scavenging activity of powdered mung bean were lower than the other materials.

Interestingly, fenugreek seed had the highest protein content which was about 25% (w/w). In the study of Wani *et al.* (2018), the protein content of fenugreek was even identified at a level of 43.8 g/100 g. However, on the other hand, fenugreek seed had relatively a low level of fat and phenols. Rhaponticin and isovitexin were some phenols that have been identified in fenugreeks seed as studied by He *et al.* (2015). According to Naidu *et al.* (2010), the free-radical scavenging activity of fenugreek seed was in the range of 56% and 72%. In this research, the DPPH radical scavenging activity was found at about 12%. This disparity may be due to the different methods used in the study, including the method of extraction, the concentration of DPPH as well as the amount of extract used in the analysis.

Moringa leaves were identified as the best material in terms of phenols and antioxidant activity in this study. It was confirmed that the total phenolic content and the DPPH-radical scavenging activity of the powdered moringa leaves were about 16.41 mg GAE/g and 92.54%, respectively. This finding is in line with the

Table 1. Quality characteristics of mung bean, fenugreek seed and moringa leaf.

Parameters	Mung bean	Fenugreek seed	Moringa leaf
Moisture content (%)	9.40±0.03	10.18±0.25	6.32±1.28
Fat content (%)	6.10±0.14	3.87±0.08	1.8±0.32
Protein content (%)	20.97±0.06	25.20±0.58	17.08±1.06
Total Phenols (mg GAE/g)	9.68±0.28	9.28±0.37	16.41±0.45
DPPH-radical scavenging activity (%)	9.70±0.95	12.82±0.52	92.54±3.31

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statement of Chhikara *et al.* (2020) who mentioned that dried moringa leaves contained polyphenols, including quercetin, kaempferol, apigenin, luteolin, myricetin glycosides, caffeoylquinic acid, coumaroylquinic acid and hydroxybenzoic acids. Interestingly, these polyphenols potentially play a role in decreasing the risk of both Type 1 and 2 diabetes and the occurrence of chronic inflammation.

However, the fat and protein contents of the moringa leaves were lower than these of mung beans and fenugreek seeds. The information about the difference in the nutritional and chemical compositions among the materials is substantial to predict the effect of the addition of these materials in milk chocolate. It was also notable that each material had different water content. As such, moringa leaves, mung beans and fenugreek seeds contained moisture at a level of about 6.32%, 9.40% and 10.18%, respectively. This information is important because the moisture content is acknowledged to play a significant role in determining the other quality attribute of milk chocolate, such as texture and flow behaviour (Muhammad *et al.*, 2018).

3.2 Nutritional and antioxidant properties of milk chocolate enriched with powdered mung beans, fenugreek seeds and moringa leaves

The use of mung beans, fenugreek seeds and moringa leaves in the chocolate formulation was intended to improve its nutritional and antioxidant properties. Table 2 shows the protein and fat content as well as total phenols and DPPH radical inhibition of milk chocolate formulated with varied levels of these ingredients.

It was shown that the incorporation of mung beans, fenugreek seeds and moringa leaves successfully improved the protein content of milk chocolate. As such, the chocolate control contained about 4.55% of protein, while the chocolate formulated with these ingredients contained protein in the range of 5.96% to 6.92%. It is worth noting that the incorporation of powdered fenugreek resulted in a more pronounced escalation in the protein content as compared to that of powdered mung beans and moringa leaves. This result is in excellent agreement with the data on protein content shown in Table 1 where fenugreek seeds had the highest protein content. It was also shown that the increase in protein content was directly proportional to the concentration of the additional ingredients, regardless of the type of functional ingredients added to the chocolate.

In the parameter of fat content, it was shown that the addition of these ingredients caused a decreased fat level. It can be understood that chocolate is actually a matrix where sugar and cocoa particles were dispersed in a fat phase (Glicerina *et al.*, 2016). Thus, the addition of material with a low-fat content can significantly decrease the proportion of fat in the chocolate. As previously presented in Table 1, all of the additional ingredients had a fat content lower than 10%. Whereas, the initial fat content of chocolate control was about 33.78%. Therefore, the more proportion of the additional material added to the chocolate formula, the lesser the fat content.

As presented in Table 2, there were significant improvements in the antioxidant properties of the milk chocolate formulated with those three functional ingredients, including in the parameters of total phenols and DPPH-radical scavenging activity. The rise of total phenols and DPPH-radical scavenging activity had positive correlations with the concentration of plant-based functional materials. As expected by considering

Table 2. Nutritional and antioxidant properties of milk chocolate formulated with mung beans, fenugreek seeds and moringa leaves.

Formulated chocolate	Protein (%)	Fat (%)	Total Phenolic (mg GAE/g)	DPPH radical inhibition (%)
Milk chocolate with mung beans				
15%	6.39±0.01^{ef}	30.26±0.11^{a}	9.89±0.11^{c}	28.76±0.35^{c}
10%	6.24±0.01^{ef}	31.26±0.21^{ab}	9.38±0.04^{bc}	26.89±0.20^{b}
5%	5.50±0.19^{b}	32.07±0.12^{bc}	8.84±0.07^{b}	24.83±0.62^{a}
Milk chocolate with fenugreek seeds				
15%	6.92±0.01^{g}	32.35±0.32^{bc}	9.85±0.09^{c}	36.48±0.14^{e}
10%	6.46±0.20^{f}	33.82±0.69^{de}	9.38±0.13^{bc}	36.53±0.07^{e}
5%	5.96±0.15^{cd}	34.34±0.55^{e}	9.13±0.35^{b}	29.63±0.33^{c}
Milk chocolate with moringa leaves				
15%	6.16±0.07^{de}	32.05±0.18^{bc}	12.23±0.13^{e}	42.18±0.98^{g}
10%	5.96±0.07^{cd}	31.53±0.28^{b}	11.61±0.75^{d}	38.49±0.06^{f}
5%	5.84±0.07^{c}	32.78±0.28^{cd}	11.39±0.05^{d}	35.49±0.14^{d}
Chocolate control	4.55±0.11^{a}	33.78±1.04^{de}	8.17±0.05^{a}	26.79±0.20^{b}

Values are presented as mean±SD. Values with different superscripts within the same column are statistically significantly different ($p<0.05$).

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the antioxidant property data displayed in Table 1, a more pronounced increase in the antioxidant properties was shown by the addition of moringa leaves as compared to the supplementation of mung beans and fenugreek seeds. It has been well-known that cocoa as the main ingredient of chocolate is naturally rich in polyphenols and exhibits strong antioxidant activity. However, during the process, the polyphenol content significantly decreases resulting in a low phenolic content in the final product (Muhammad *et al*., 2018). As such, in this study, milk chocolate control contained 8.17 mg GAE/g of phenols and exhibited 26.79% of DPPH - radical scavenging activity, while the chocolates added with moringa leaves at a level of 15% had 12.23 mg GAE/g of phenols and exhibited 42.18 % of DPPH - radical scavenging activity.

3.3 Physical properties of milk chocolate enriched with powdered mung beans, fenugreek seeds and moringa leaves

Colour properties are very substantial in defining the quality of chocolates, and may strongly influence consumer acceptance of the chocolate. Colour, the main component in forming the overall appearance of food, often becomes the first attribute identified by consumers before they detect the other attributes such as taste, texture and flavour (Muhammad *et al.*, 2018). The colour properties of milk chocolate formulated with mung beans, fenugreek seeds and moringa leaves are presented in Table 3.

It was shown that the addition of functional ingredients significantly reduced the lightness of the chocolates. Chocolate control had a lightness level of about 37.49 while the modified chocolates had less than 34. The higher proportion of the functional material added to chocolate, the darker the chocolate. Also, it is noteworthy that the impact of moringa leaves was more pronounced than that of fenugreek seeds and mung beans.

An alteration was not only detected in the lightness parameter but also in *a (green to red component) and *b (blue to yellow component) values resulting in a change in the chroma value of milk chocolates. Chroma can be defined as the purity of colour which is not affected by the lightness level. Table 3 shows that powdered moringa leaves gave a more effect on the chromatic colour of the chocolate than powdered fenugreek seeds and mung beans. As well-stressed earlier by Muhammad, Kongor and Dewettinck *et al.* (2021), the colour of the final product is generally influenced by the initial colour of the raw material and ingredients. Changes in *a and *b values, however, were considered not significant to change the °Hue value. It was recorded that the °Hue value of all samples is in the range of 0.68-1.01 which is in the area of red.

Furthermore, the changes in the lightness, as well as the *a and *b values, affect the whiteness index (WI) further. The enrichment of the plant-based functional materials led to reducing the WI meaning that the chocolates became less white. In accordance with the other parameters, moringa leaves had a more pronounced effect on the WI attributes. This finding was also supported by the data of ΔE (the degree of difference between the chocolate formulated with functional ingredients and chocolate control). The addition of moringa leaves resulted in a high ΔE indicating that there was a big difference between the chocolate formulated with moringa leaves and chocolate control. This may be explaining the results obtained in our previous studies that the chocolate formulated with moringa leaves got a

Table 3. Colour properties of milk chocolate formulated with mung beans, fenugreek seeds and moringa leaves.

Formulated chocolate	Colour parameters						
	L*	a*	b*	Chroma	Whiteness Index (WI)	°Hue	ΔE
Milk chocolate with mung beans							
15%	32.83±0.49^{cd}	10.42±0.36^{c}	9.49±0.29^{c}	14.10±0.05	27.11±0.37	0.73±0.03	4.9
10%	34.55±0.40^{e}	11.19±0.22^{e}	10.65±0.86^{d}	15.46±0.30	28.70±0.21	0.75±0.05	3.0
5%	36.46±0.47^{f}	11.52±0.11^{f}	9.44±0.25^{c}	14.90±0.05	30.44±0.25	0.68±0.02	1.6
Milk chocolate with fenugreek seeds							
15%	31.95±0.37^{bc}	10.77±0.02^{d}	9.78±0.57^{c}	14.55±0.03	26.93±0.24	0.73±0.01	5.6
10%	32.93±0.90^{d}	10.31±0.01^{c}	8.52±0.14^{b}	13.37±0.06	28.26±0.58	0.69±0.01	5.2
5%	33.36±0.23^{d}	10.28±0.15^{c}	8.51±0.32^{b}	13.34±0.22	28.02±0.31	0.69±0.11	4.8
Milk chocolate with moringa leaves							
15%	30.38±0.15^{a}	5.33±0.06^{b}	6.46±0.21^{a}	8.37±0.09	25.12±0.14	0.88±0.02	10.9
10%	30.62±0.29^{a}	4.16±0.01^{a}	6.72±0.06^{a}	7.90±0.03	25.07±0.24	1.01±0.01	10.8
5%	31.74±0.08^{b}	5.36±0.02^{b}	7.75±0.28^{b}	9.60±0.01	26.05±0.05	0.97±0.01	8.9
Chocolate control	37.49±0.04^{g}	11.56±0.02^{f}	10.68±0.01^{d}	15.74±0.01	31.38±0.03	0.74±0.01	-

Values are presented as mean±SD. Values with different superscripts within the same column are statistically significantly different ($p<0.05$).

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lower consumer acceptance as compared to those with fenugreek seeds and mung beans in the attributes of appearance (Muhammad, Zulfa, Purnomo *et al.*, 2021). As stated by Żyżelewicz *et al.* (2014), ΔE more than 3 means the colour differences are obvious for the human eyes. Thus, in terms of colour, only milk chocolate formulated with 5% and 10% mung beans could result in products with a similar colour to the chocolate control.

Besides colour, texture is another important quality parameter of chocolate. The texture is related to sensory perception as it is useful to describe the stiffness and the degree of 'snap' of chocolate (Muhammad *et al.*, 2018). In this study, hardness and fracture were determined (Table 4). Hardness can be defined as the force required to bite completely through a sample placed between molars, while fracturability is the force with which the sample ruptures when placed between molars and bitten completely down at a fast rate (Meilgaard *et al.,* 1999). In this study, however, the addition of powdered mung beans, fenugreek seeds and moringa leaves resulted in a statistically insignificant change in the fracturability of milk chocolate. The addition of functional materials may alter its fracturability. However, the powder indeed did not exist in every part of the chocolate as the maximum amount of the functional ingredients added to chocolate was 15%. Hence, the deviation of the results of the fracturability test is big making the result of statistical analyses showed no significant difference among the samples. Thus, hardness became the point of interest.

It was shown in Table 4 that the hardness level of the chocolate control was 512.44 N. The incorporation of powdered mung beans, fenugreek seeds and moringa leaves, in general, softened the chocolate. Most of the modified chocolate had a lower hardness value than the control, except the chocolate formulated with 15% of mung beans. Still, based on the statistical analysis, this sample was not significantly different from the chocolate control. There was no regular pattern in the result of the effect of ingredient concentration on the hardness of the chocolate, and thus a clear conclusion could not be drawn yet. Theoretically, some factors can significantly affect the hardness of chocolate, including moisture content and particle size distribution (PSD). For instance, the presence of moisture triggers sugar network formation and thus strengthens the interparticle interaction resulting in a higher breaking resistance. Interparticle interaction may also increase due to the increased solid volume fraction caused by the presence of the additional ingredients, thus hardening the chocolate (Saputro *et al.,* 2017). In this study, the moisture content of the additional ingredients was known at a quite high level, in a range of 6.32% to 10.18%, possibly resulting in harder chocolate. Notwithstanding, the modified chocolates were softer than the chocolate control. In this case, therefore, the particle size distribution of the functional ingredients probably had more effect than the moisture content. As aforementioned, 80-mesh sized powdered materials were used in this study. In general, 80-mesh sized material is equal to 177 µm which is bigger than the average particle size of chocolate. It is well-known that the recommended particle size of chocolate is 30 µm to avoid grittiness perception (Muhammad *et al.*, 2018). Hence, it was hypothesized that materials with bigger particle size led to a lower solid volume fraction resulting in a lower hardness level. Nevertheless, further study is required to prove this presumption.

4. Conclusion

This research shows that mung beans and fenugreek seeds were identified as protein-rich materials, and thus

Table 4. Textural properties of milk chocolate formulated with mung beans, fenugreek seeds and moringa leaves.

Formulated chocolate	Textural Properties	
	Hardness	Fracture
Milk chocolate with mung beans		
15%	570.12±97.35^{c}	11.32±0.26^{a}
10%	271.09±37.87^{ab}	45.75±0.82^{a}
5%	162.56±45.23^{a}	7.73±3.39^{a}
Milk chocolate with fenugreek seeds		
15%	207.25±13.86^{a}	55.06±51.45^{a}
10%	379.35±124.66^{abc}	49.30±47.60^{a}
5%	294.82±5.07^{ab}	17.55±3.18^{a}
Milk chocolate with moringa leaves		
15%	349.04±133.70^{abc}	85.26±4.87^{a}
10%	367.09±184.16^{abc}	53.17±47.50^{a}
5%	471.27±60.21^{bc}	41.61±39.15^{a}
Chocolate control	512.44±154.44^{bc}	26.48±17.85^{a}

Values are presented as mean±SD. Values with different superscripts within the same column are statistically significantly different ($p<0.05$).

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the supplementation of these ingredients in milk chocolate significantly improved its protein content. Moringa leaf contained a high level of phenols and antioxidant activity, and thus this material is potentially used to improve the health-promoting properties of milk chocolate. The enrichment of these three materials decreased the lightness of milk chocolate and altered the colour properties of the chocolate to some extent. The addition also decreased the hardness and other textural attributes of the chocolates. Thus, this study serves as a model for the use of functional ingredients from different types of plant-based materials to enhance the nutritional and health-promoting properties of milk chocolate. Chocolate formulated with moringa leaves was recommended in terms of potential antioxidant activity. This can be a promising formula for the future, and thus consumers may obtain the positive health effects of moringa leaves in an enjoyable way. Further study, however, needs to be undertaken to evaluate the ability of the moringa leaves-enriched chocolate for preventing oxidative stress in different assays in order to validate the potential health benefit of the chocolate.

Conflict of interest

The authors declare no conflict of interest.

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