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EFFECTS OF FLAXSEED (*Linum Usitatissimum*) AS FAT MIMETICS ON PHYSICOCHEMICAL AND SENSORY PROPERTIES OF MUFFIN

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Abstract

Muffin is a sweet baked product with soft texture and good taste. Egg as one of the main ingredients in muffins plays a pivotal role in maintaining nutritional and physical properties of baked products. However, eggs have high cholesterol content and are related to cardiovascular disease and hypercholesterolemia. Therefore, the aim of this study is to investigate the functional properties of seed flour, physicochemical and sensorial properties of muffin with flaxseed (*Linum usitatissimum*) as egg substitute at different concentrations. Egg was substituted with flaxseed at 25, 50, 75 and 100% whilst control muffin contains 100% egg. The percentage of emulsifying capacity, emulsion stability, water holding capacity and oil binding capacity of flaxseed flour were 9.42% ±1.36, 8.02% ±0.27, 472% ±2.65 and 222.67% ±2.52 respectively. Meanwhile, the protein content and fat content in muffin decreased with an increase of flaxseeds but ash, fiber and carbohydrate showed an increase at higher percentage of flaxseed substitutions. The calorie content for muffin substituted flaxseed decreased between 3.83 - 7.83%. The flaxseed substituted muffin also has a lower value for hardness (1279.00 ±3.61g) at 25% substitution and 720.67 ±4.04g at 100% substitution as compared to control muffin with the significantly highest ($p<0.05$) hardness value of 1638.00 ±7.21g. Sensory evaluation indicated that muffin with 25-100% flaxseed substitution showed non-significant difference with control sample in taste, texture and overall acceptability. Therefore, flaxseed is suitable as an egg substitute in the production of muffin with high nutritional value and acceptable sensory characteristics.

Keywords: Fat mimetics, flaxseed, muffin, physicochemical properties, sensory properties

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Introduction

Baked products are the most consumed foods as stated in the Malaysian Adult Nutrition Survey in Malaysia (Norimah *et al*., 2008). It is because muffins have various types of delightful flavour, easy to be obtained and can be eaten as a snack. In addition, muffins have a delicious taste, appetizing, sweet, soft and spongy texture but has high calorie content. Egg, as the main ingredient in most baked products like cakes and muffins possess high nutritional value and it also provides functional properties which are coagulation, flavouring, tenderizing, emulsification, foaming, leavening, glazing, and binding ingredients (Yang *et al*., 1995). Although eggs offer plenty of advantages in most baked products, consumers and processors in the baking industry are triggered to search for alternative ingredients as egg replacer due to many factors (Singh *et al*., 2003) that are related to motivation for less and free from cholesterol foods, low- calorie content, vegan, cheap raw materials, diminished allergens, food safety and far less of microbial concerns (Lin *et al*., 2003). These days, there are many demands from health-conscious publics for high quality and low-calorie products with low fat and sugar content. This is due to the incidences and morbidity of many cancers, coronary heart disease, stroke, high blood pressure, obesity and diabetes (Grossklaus, 1996; Sandrou and Arvanitoyannis, 2000). The most practical approach is the application of fat replacer with the aims of reducing the calories of baked products. An example is by using carbohydrate -based fat mimetics such as cellulose, microcrystalline cellulose, dextrin, maltodextrins, gums, fiber and modified starch. These fat replacers can provide up to 4 kcal/g, but, the calorie can be reduced between 1-2 kcal/g when mixed with water and in some instances, some can provide zero calorie for example the cellulose (Conforti and Archilla, 2001). However, the main challenges faced by the food industries when substituting the fats with carbohydrate-based fat mimetics is the inferior quality of food products like texture, mouthfeel and appearance although the calorie of the food is reduced (Khalil, 1998). Therefore, an option is by partial replacement of fat with fat replacers such as carbohydrate-based fat replacers in cakes. Flaxseed gum is a newly potential source of mucilage that can be applied in cakes as fat replacer. It comprises about 8% of the seed, and it yields L-galactose, D-xylose, L-arabinose, L-rhamnose and D-galacturonic acid by acid hydrolysis (Warrand *et al*., 2005). It has similar properties with others gums which includes good water holding capacity, water binding ability and also rheological properties (Fedeniuk and Biliaderis, 1994). Since flaxseed mucilage has weak gel properties, it can be used to replace most of the non-gelling gums for food and non-food applications (Chen *et al*., 2006). A study by Sansevieri *et al.* (2018) shows that flaxseed mucilage can be used as an egg replacer in pumpkin pie since it produces acceptable sensorial properties in terms of taste and texture. Therefore, this study was undertaken to evaluate the functional properties of flaxseed mucilage. The effects of the substitution of egg with flaxseed mucilage in muffin formulations will be studied in terms of its physicochemical, sensorial properties and calorie content.

Materials and methods

Preparation of flaxseed flour

Flaxseeds were thoroughly cleaned manually to remove physical hazards like dust particles, damaged seeds, other crop grains and impurities. Flaxseeds were grounded in a grinder mixer and sieved through 500 µm sieves. The yield was then stored in an airtight container.

Water and oil absorption capacities

Water and oil absorption capacities were determined by centrifugation methods (Sosulski *et al.*, 1976). About 10 ml of distilled water or oil was mixed with 1 g of flaxseed flour. After mixing, the contents were allowed to rest at 30 ± 2°C for 30 minutes and finally centrifuged at 200g for 30 minutes. The water and oil absorption capacities of the flours were expressed as grams of water or oil absorbed per 1 g of flaxseed flour.

Emulsifying capacity and stability

Emulsifying capacity and emulsifying stability were determined using the homogenization method (Coorey *et al.*, 2013). For emulsifying capacity, about 100 mL of 1% (w/w) solution of flaxseed powder in water was added into the volumetric flask. The solution was then transferred into 250 mL measuring cylinder, homogenized with 100 mL of oil using homogenizer and centrifuged at 3000 rpm for 15 minutes. Finally, the volume of the emulsified layer was measured. The result of emulsifying capacity was expressed as a percentage of emulsifying capacity and calculated using the following formula.

Emulsifying capacity (%) = 100 × (total emulsified layer (mL)/total volume of suspension (mL)).

Emulsion stability was determined using the homogenization method. The solution was homogenized and later heated at 85 °C for 30 minutes using a water bath. Then, it was allowed to cool at room temperature (20 ± 2 °C) using a cold-water bath. This solution was centrifuged at 3000 rpm for 15 minutes. Then, the emulsified layer was measured. The calculation as follow:

Emulsion stability (%) = 100 × (total heated emulsified layer (mL)/total volume of heated suspension (mL))

Production of muffin

The muffins formulations consisted of control and treated sample with 25, 50, 75 and 100% flaxseed mucilage substitution are presented in Table 1. The control muffin was prepared by mixing the sieved dry ingredients of wheat flour and baking powder in a bowl. Then sugar, vegetable oil, water, vanilla flavouring and egg were whisked together in another large bowl. The sieved flour and baking powder were added little by little into the mixture and mixed together until it became a smooth batter. The batter was poured into the muffin tin and baked in an oven for 25 minutes at 160 °C. Then, it was cool, stored in container and kept at room temperature for further analysis. For the treated samples, about 10 g of ground flaxseed was mixed with 40 g water, stirred and allowed to sit for 10 minutes to develop gelatinous texture, known as flax meal/flaxseed mucilage as egg substitution. This flaxseed mucilage was used as an egg replacer. The methods for the preparation of treated muffin were similar as control muffin, however, the whole egg was substituted with flaxseed mucilage at 25, 50, 75 and 100%, based on weight to weight basis.

Table 1. Formulation of muffin with substitution of flaxseed mucilage

Ingredients (g)	**MA(Control)**	**MB**	**MC**	**MD**	**ME**
Wheat flour	125.0	125.0	125.0	125	125.0
Baking powder	7.0	7.0	7.0	7.0	7.0
Sugar	75.0	75.0	75.0	75.0	75.0
Vegetable oil	75.0	75.0	75.0	75.0	75.0
Water	75.0	75.0	75.0	75.0	75.0
Vanilla flavouring	4.0	4.0	4.0	4.0	4.0
Egg	50.0	37.5	25.0	12.5	0.0
Flaxseed mucilage	0	12.5	25.0	37.5	50.0

Notes: MA = 100% egg, 0% flaxseed (control); MB = 75% egg, 25% flaxseed; MC = 50% egg, 50% flaxseed; MD = 25% egg, 75% flaxseed; ME = 100% flaxseed

Physicochemical Properties of muffins

Protein, fat, fiber, moisture and ash were carried out based on Association of Official Analytical Chemists (2000). Total carbohydrate content was determined by difference method (Southgate, 1991). The energy values of five different formulations of the vanilla muffin were calculated by applying factors 4, 9 and 4 for each gram of protein, lipid and carbohydrate respectively (AOAC, 2000). The calculation of the energy value is as follows:

Energy Value (kcal/100g) = (% protein × 4) + (% fat × 9) + (% carbohydrate × 4)

Determination of hardness

The textural properties of five different formulations of the muffin with dimension of 2×2×2cm on the midsection of the cakes were analysed by Stable Micro System Texture Analyser (Model T.A. XT2plus, Texture Technologies Corp., Scarsdale, New York, U.S.A.) with 36 mm cylinder probe and 5 kg load, compression of 25% of the muffin height, test speed of 2 mm/min and distance of 10 mm. These measurements were for the hardness of the muffin (Hosseini *et al*., 2018).

Determination of cake volume

Cake volume was determined by rapeseed displacement method, according to AACC Method 10-05.01. Muffin was placed in a container and followed with rapeseed displacement into the container until the muffin was fully submerged. The volume of seed displaced in the container is equal to the volume of muffin. Specific volume was divided by sample mass.

Sensory evaluation of muffin

Sensory evaluation of the freshly baked muffins was carried out by 30 untrained panelists using a nine-point hedonic scale. The panelists received 5 samples from the midsection of each muffin and were requested to rate their sensory properties (i.e., appearance, colour, taste, texture and overall acceptability) as (1) dislike extremely, (2) dislike very much, (3) dislike moderately, (4) dislike slightly, (5) neither like or dislike, (6) like slightly, (7) like moderately, (8) like very much and (9) like extremely. Panelists evaluated the samples in a testing area, and they were instructed to rinse their mouths with water between samples to minimize any residual effect.

Statistical analysis

The statistical analysis was determined using the SPSS statistical computer software package version 15. One- way ANOVA Analysis of the variance (ANOVA), was performed for triplicate samples to determine if there is significant difference of flaxseed mucilage substitutions in muffins and control muffin. Statistical significance was set at $p < 0.05$.

Results and discussions

Water absorption capacity (WAC) is an important parameter affecting the viscosity of food products. Oil absorption capacity (OAC) is an indicator for rate of protein binds to fat in food formulations (Singh *et al*., 2005). Water holding capacity of flours plays a vital role in food preparation since it influences the functional and sensory properties of foods. The functional properties of flaxseed flour are presented in Table 2. Flaxseed flour has a higher water absorption capacity (472 %) as compared to oil absorption capacity (222.6%). The WAC of the Flaxseed Protein Isolate (472%) was higher than the soy protein isolate (289%) and the peanut protein isolate (135%) (Kanu *et al*., 2007; Wu *et al*., 2009), respectively. The results showed that the FPI has good WAC and could be used in several food formulations, such as meat and pastry products. Flour with high WAC is associated with more hydrophilic constituents like polysaccharide and non-starch components, mainly the mucilage (Aboubakar *et al*., 2008). In addition, the high mucilage content in flaxseed increased the water absorption properties of dough and impacted on mixing time and handling characteristics (Shaikh *et al*., 2020). The OAC that presents in plaintain flour (129%) plays an important role in food formulations as it is facilitating enhancement of flavor and mouthfeel when used in food preparation (Adegunwa *et al*., 2017)

The result of the emulsifying capacity of the mucilage of flaxseed mucilage is presented in Table 2. The emulsifying capacity of flaxseed is 9.42 %. This value was lower as compared to emulsifying capacity of the pod mucilage of okra accessions which ranged from 42.22 to 74.45% (Gemede *et al*., 2018). Although the emulsifying capacity of the flaxseed mucilage value is lower than pod mucilage of okra, the protein present in the mucilage able to enhance the formation and stabilization of emulsion in many food products such as chopped and comminute meat, cake batter, coffee whitener, milk, mayonnaise, salad dressing, and frozen dessert (Elbaloula *et al*., 2014). Emulsion stability of flaxseed mucilage was 8.02 % (Table 2). The value of emulsion stability of flaxseed mucilage was lower as compared to pod mucilage, which is in the range of 42.22 to 74.45%. Emulsion stability is important to provide stability of the emulsions and also as thickening agent (Capitani *et al*., 2013).

Table 2. Functional Properties of flaxseed flour

Functional Properties	Percentage (%)
Water absorption capacity	472 ±2.65
Oil absorption capacity	222.67 ±2.52
Emulsifying capacity (EC)	9.42 ±1.36
Emulsion stability (ES)	8.02 ±0.27

The physical analysis investigated on the formulated muffins are volume and hardness. These analyses are of great importance since they determined the quality of baked products prepared. The increasing substitution of mucilage in muffin formulation decrease the hardness value of these muffin. The value of hardness ranged from 720.67 to 1638.00 g (Table 3). The highest hardness value was in MA (1638.00 g) and the lowest was ME muffin (720.67g). The highest hardness value in MA muffin was due to the presence of egg that develop a protein matrix during baking that enable the protein matrix to entrap water, milk fat globules and other ingredients. In addition, egg yolk phospholipid and lecithin aid by homogenizing the water and fats components within the matrix, hence producing dense and heavy muffin (Sansevieri *et al*., 2018). The flaxseed mucilage enable interaction with oil present in the muffin mixture which further tenderizes and moistens the product, thus reduced hardness of muffin. In addition, the high fat content in flaxseed can cause the gluten become shorter and consequently produce a softer baked product (Brown, 2008).

Cake volume is one of the important aspects in indicating the quality of finished formulated muffins. Muffin with high volume often attract consumers. In this study, it shows that the volume of muffin increased with an increase of flaxseed mucilage substitutions, which ranged from 985.00 ml to 1025.67 ml in MA and ME muffin. The significantly higher volume of ME muffin showed a higher amount of air remained in the cake during baking. This could be due to the ability of flax meals to improve air retention and enhanced batter aeration (Hussain *et al.*, 2013).

Table 3. Physical properties of muffin using flaxseed as egg substitute and control sample.

Formulation	**Cake Volume (mL)**	**Hardness (g)**
MA	985.00 ±3.00[d]	1638.00 ±7.21[a]
MB	1007.67 ±2.52[c]	1279.00 ±3.61[b]
MC	1015.33 ±2.52[b]	1054.33 ±5.13[c]
MD	1022.00 ±2.65[a]	852.33 ±7.09[d]
ME	1025.67 ±1.15[a]	720.67 ±4.04[e]

Notes: Values are mean ± standard deviation, n=5. a-e Mean with different letters are statistically different at ($p<0.05$). MA = 100% egg (control); MB = 25% flaxseed; MC = 50% flaxseed; MD = 75% flaxseed; ME = 100% flaxseed

The proximate composition of the muffin with and without the flaxseed mucilage are shown in Table 4. The moisture content in five different formulations ranged from 22.08 ±0.67 to 23.95 ±0.34 %. There was no statistically significant difference ($p>0.05$) in moisture content between the five formulations. Hence, the substitution of egg with flaxseed does not have any effects on the moisture content of the formulated muffins. The protein content in muffin decreased as the substitution of egg with flaxseed increased (Table 3). The protein content in all muffin formulations ranged between 3.20 – 3.97%. The highest protein content was observed in MA muffin which was 3.97% while the lowest protein value was in ME muffin (3.20%). The protein content was significantly different ($p<0.05$) amongst the muffin formulations. MA muffin had the significantly highest ($p<0.05$) protein content and it was due to the rich protein in egg (15.4%) (Chepkemoi *et al*., 2017), as compared to the low protein content in flaxseed mucilage (2.93-3.12%) (Mehtre *et al*., 2017). Thus, egg substitution with flaxseed mucilage in muffin resulted in a lower protein content in muffin. MA muffin contained the significantly highest ($p<0.05$) fat content (40.80%) as compared to substituted flaxseed mucilage muffin (25-100%) with fat content ranged from 35.20 - 38.35% (Table 3). It was reported that crude fat content of flaxseed mucilage ranged from 0.39-0.44% (Mehtre *et al*., 2017), which was lower than fat content in egg (2.34%) (Chepkemoi *et al*., 2017). The fiber content was significantly different ($p<0.05$) between MA and flaxseed mucilage muffin (50-100% substitution) which ranged between 0.41- 0.70% (Table 3). Flaxseed contains about

28% of both soluble and insoluble fiber of which one-third of the fiber is soluble (Hussain *et al*., 2006). The ash content showed an increase trend for all flaxseed mucilage muffin, with value ranged from 1.08 - 1.46% compared to control muffin (0.77%). Ash content in flaxseed mucilage ranged from 2.85-3.11% (Mehtre *et al*., 2017), which was higher than in egg (0.86%) (Chepkemoi *et al*., 2017). According to Bernacchia *et al.,* (2014) there are many types of minerals present in flaxseed such as calcium, magnesium, and phosphorus. The carbohydrate content was the significantly highest ($p<0.05$) in ME muffin (35.48%) as compared to the other muffin formulations (Table 3).

Table 4. Proximate composition (%) of muffin using flaxseed as egg substitution & control sample.

Formulation	**Moisture (%)**	**Protein (%)**	**Fat (%)**	**Carbohydrate (%)**	**Fiber (%)**	**Ash (%)**
MA	22.08±0.67^{a}	3.97±0.04^{a}	40.80±1.33^{a}	32.13 ±1.61^{b}	0.25±0.02^{c}	0.77±0.02^{d}
MB	23.40±0.83^{a}	3.78±0.03^{b}	38.25±0.33^{b}	33.17 ±0.87^{ab}	0.33±0.06^{bc}	1.08±0.02^{c}
MC	22.43±0.64^{a}	3.70±0.07^{b}	38.00±1.73^{b}	33.78 ±1.13^{ab}	0.41±0.02^{b}	1.3±0.11^{b}
MD	23.00±1.89^{a}	3.50±0.10^{c}	37.13±0.36^{b}	34.34 ±1.77^{ab}	0.63±0.09^{a}	1.42±0.35^{ab}
ME	23.95±0.34^{a}	3.20±0.04^{d}	35.20±0.24^{c}	35.48 ±0.25^{a}	0.70±0.03^{a}	1.46±0.32^{a}

Notes: Values are mean ± standard deviation, n=5. a-e Mean with different letters are statistically different at ($p<0.05$). MA = 100% egg (control); MB = 25% flaxseed; MC = 50% flaxseed; MD = 75% flaxseed; ME = 100% flaxseed

The effectiveness of flaxseed mucilage as carbohydrate-based fat mimetics in muffin was assessed based on the calculation of calorie content of all formulated muffin. The calorie value ranged from 471.53±2.41 kcal to 511.61±6.69 kcal. The calorie content of the muffin decreased with increased substitution of flaxseed mucilage. The MA muffin had the significantly highest ($p<0.05$) calorie content (511.61 kcal) as compared to flaxseed mucilage muffin (471.53-492.06 kcal) with ME muffin attained the significantly lowest ($p<0.05$) calorie content (471.53kcal).

As stated earlier, the substitution of flaxseed mucilage plays an important role in reducing the fat content of the muffin. According to Mehtre *et al.,* (2017) flaxseed mucilage contains 0.39-0.44% fat while egg has 2.34% of fat (Chepkemoi *et al*., 2017). The percentage of fat reduction was between 3.83-7.83% for 25-100% for flaxseed mucilage muffin, with highest calorie reduction in ME muffin (Table 5). It was reported by Hussein *et al.*, (2011) that the calorie of cakes had significantly ($p<0.05$) decreased as the fat replacer levels increased when using artichoke as a fat replacer at 0, 25, 50 and 75% substitutions.

Table 5. Calorie content in muffin by using flaxseed as egg substitution and control sample.

Formulation	**Calorie (kcal)**	**Calorie decreased (%)**
MA	511.61±6.69^{a}	0
MB	492.05±4.04^{b}	3.83
MC	491.92±11.29^{b}	3.85
MD	485.49±9.34^{b}	5.11
ME	471.53±2.41^{c}	7.83

Notes: Values are mean ± standard deviation, n=5. a-e Mean with different letters are statistically different at ($p<0.05$). MA = 100% egg, 0% flaxseed (control); MB = 25% flaxseed; MC = 50% flaxseed; MD = 75% flaxseed; ME = 100% flaxseed

Sensory attributes play an important role in determining the acceptability of a product (Hesarinejad *et al*., 2019). The sensory evaluation of muffin was evaluated in terms of appearance, colour, taste, texture and overall acceptability (Table 6). In general, with the addition of mucilage, all sensory attributes showed significant difference ($p<0.05$) except for taste and texture as compared to control muffin. The MC and MD muffin showed significant difference in appearance, colour and overall acceptability but MB and ME muffin showed no significant difference in all attributes with control muffin. Thus, mucilage at 25 and 100% are most suitable in muffin formulations since they have the highest mean score in all attribute as compared to MC and MD muffin. The presence of gums increases acceptability relating to texture (softness) of the cakes (Bench, 2005). The investigation on the effect of different gum addition in baked food especially the cake texture has been reported previously by other researchers (Sowmya *et al*., 2009; Hajmohammadi *et al*., 2014; Beikzadeh *et al*., 2018).

Table 6. Sensorial attributes of muffin in five different formulations of muffin

Formulation	**Appearance**	**Colour**	**Taste**	**Texture**	**Overall**
MA	$6.93±1.11^{a}$	$7.03±1.19^{a}$	$6.50±1.63^{a}$	$6.43±1.43^{a}$	$7.27±0.45^{ab}$
MB	$6.37±1.10^{abc}$	$6.60±1.19^{ab}$	$6.63±1.47^{a}$	$6.97 ±1.19^{a}$	$7.33 ±0.66^{a}$
MC	$6.27±1.05^{bc}$	$6.30±0.88^{bc}$	$6.47±1.17^{a}$	$6.53 ±1.25^{a}$	$6.67 ±0.48^{c}$
MD	$5.80 ±1.27^{c}$	$5.90 ±1.27^{c}$	$6.47±1.41^{a}$	$6.50 ±1.28^{a}$	$7.05±0.33^{b}$
ME	$6.70 ±1.06^{ab}$	$6.57±1.17^{ab}$	$6.63±1.33^{a}$	$6.27 ±1.57^{a}$	$7.30±0.27^{ab}$

Notes: Values are mean ± standard deviation, n=30.
The 9-point hedonic scale with 1 = dislike extremely, 2= dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5= neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, 9 = like extremely. MA = 100% egg (control); MB = 25% flaxseed; MC = 50% flaxseed; MD = 75% flaxseed; ME = 100% flaxseed.

Conclusion

This study showed that Flaxseed mucilage did not have any undesirable effect on the physicochemical and sensory properties of muffin. In addition, it improved the physical properties of muffin, increased the moisture, protein, fiber and ash content and decreased the fat and calorie content of muffin with increase substitution of mucilage in muffin formulations. The sensory properties in MB and ME muffin were the most acceptable by panelists for all attributes. In conclusion, it is possible to take advantage of this mucilage to improve physical and sensory properties of foods such as muffin. Further studies are recommended to determine the applicability of this novel additive in other bakery products.

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