Journal of Advanced Research Design 118, Issue 1 (2024) 56-71

Penerbit Akademia Baru

Journal of Advanced Research Design

Journal homepage:
https://akademiabaru.com/submit/index.php/ard
ISSN: 2289-7984

Physical Properties, Nutritional Composition and Sensory Acceptance of Eggless Pumpkin Muffin Prepared Using Plant-Based Ingredients

Muhammad Iqbalhakeem Haslubis[1], Norlelawati Arifin[1,*]

[1] Programme of Food Biotechnology, Faculty of Science and Technology, Universiti Sains Islam Malaysia, Nilai, Negeri Sembilan, Malaysia

ARTICLE INFO

Article history:
Received 7 May 2024
Received in revised form 17 July 2024
Accepted 26 July 2024
Available online 2 August 2024

Keywords:
Pumpkin muffin; eggless muffin; chia seeds; flaxseeds; mashed banana

ABSTRACT

Eggs play a crucial role in the production of muffins by contributing to their moistness and tenderness. However, several issues arise with using eggs in muffin formulation, such as egg allergies and the sustainability of egg supply in the market. Therefore, this study aimed to determine the effect of incorporating plant-based ingredients (chia seeds, flaxseeds and mashed banana) in eggless pumpkin muffin formulations on physical properties, nutritional composition and sensory acceptance. Four samples were prepared as follows: Control (muffin with egg), F1 (muffin with chia seeds), F2 (muffin with flaxseeds) and F3 (muffin with mashed banana). The samples were analysed for batter density, muffin height, texture profile analysis, muffin crumb colour, nutritional composition and sensory preference using a nine-point hedonic scale. Generally, muffins prepared with plant-based ingredients showed a decrease in height (3.97–3.83 cm) and water activity (0.88–0.89) compared to the control muffins (4.37 cm and 0.90, respectively). On the contrary, the batter density of wet batter eggless pumpkin muffins increased compared to those prepared with egg. The replacement of egg with plant-based ingredients resulted in muffins with a harder texture, as indicated by the increased hardness values compared to the control muffin. The use of plant-based ingredients in pumpkin muffin formulations produced muffins with a lighter colour due to the absence of colour pigments in chia seeds, flaxseeds and mashed banana. The inclusion of plant-based ingredients in eggless pumpkin muffin formulations increased the ash, fibre and carbohydrate content while decreasing the fat content. Overall, the preference test revealed that eggless pumpkin muffins prepared using chia seeds (6.93) and mashed banana (7.58) rated higher for overall acceptance attribute as compared to the control pumpkin muffin.

1. Introduction

Muffins are considered quick bread products due to their use of basic ingredients such as flour, sugar, egg, shortening, milk, baking powder and sodium bicarbonate. Each of these ingredients plays a crucial role in determining the appearance, structure and mouthfeel of the final product. The addition of pumpkin puree in the recipe for muffins provides a desirable taste, texture and variety to the muffin products. The preparation of pumpkin muffins involves minimal mixing of the dry and wet

* *Corresponding author.*
E-mail address: norlela@usim.edu.my

https://doi.org/10.37934/ard.118.1.5671

ingredients, followed by baking in an oven. Among all the ingredients, egg plays an important role in muffin production. It serves multiple purposes because the texture and sensory qualities of food are influenced by its thickening, gelling, emulsifying, foaming, colouring and flavouring properties [1]. Eggs play a crucial role in baking by helping to hold all other ingredients together and by increasing the viscosity of batters and dough. Eggs have multiple functional properties, such as acting as an emulsifier to ensure even dispersion of liquids and fats, contributing to the desirable colour of the final product, and providing liquid during mixing and baking.

Nowadays, the inclusion of eggs in commercially produced muffins raises concerns regarding awareness among individuals with egg allergies, and the sustainability of eggs in the market. Egg allergies in some individuals usually children are one of the disadvantages of eggs that have led to the substitution of eggs with alternative ingredients in modern muffin products. In Malaysia, cow's milk (44.4 %), peanut (36.4 %), soy (25 %) and egg white (60 %) were the top four dietary allergies among children under two years old [2]. Additionally, there is also an issue of the sustainability of eggs in the market. The deputy president of The Federation of Livestock Farmers' Associations of Malaysia (FLFAM), Lee Yoon Yeau pointed out that the current supply of eggs in the market is insufficient and has not yet returned to previous levels [3].

Research has been conducted to study these potential ingredients to replace eggs in food product formulations such as the inclusion of different percentages of chia seeds in sponge cake formulations [4]. The findings showed as the concentration of chia seed increased, the batter density and textural properties (hardness, cohesiveness, springiness and chewiness) also showed an increment in values. Kostor *et al.,* [5] reported no significant difference ($p > 0.05$) between the control muffin and those prepared using aquafaba and flaxseeds for textural properties and moisture content. Previous research has indicated that adding egg replacer ingredients to food products can enhance the nutritional profile of the products, while still producing food products that as just as appealing to consumers as traditional food products made with eggs. To date, very little data has been reported to compare the properties and sensory attributes among plant-based ingredients such as egg replacers in pumpkin muffins. The objective of this study, therefore, was to determine the effect of chia seeds, flaxseed and mashed banana as an egg replacer in pumpkin muffin formulations, subsequently producing pumpkin muffins with better nutritional values.

2. Methodology

2.1 Materials

Local pumpkin (*Cucurbita moschata spp*.), and banana (*Musa spp*.) were purchased from the grocery store at Nilai, Negeri Sembilan, Malaysia. All-purpose flour (Cap Ros, Malayan Flour Mills Berhad, Kuala Lumpur, Malaysia), sugar (Prai, MSM Prai Berhad, Pulau Pinang, Malaysia), baking powder (Meriah Baking Powder, Seafield Food Sdn Bhd, Selangor, Malaysia), sodium bicarbonate (Meriah Baking Soda, Seafield Food Sdn Bhd, Selangor, Malaysia), coconut milk (Ayam Brand, Clouet & Co (KL) Sdn Bhd, Selangor, Malaysia), chia seeds (Love Earth-Origin from South America, Wide Tropism Trading Sdn Bhd, Selangor, Malaysia), flaxseeds (Country Farm Organic-Product of China, Country Farms Sdn Bhd, Selangor, Malaysia) and oil (Saji, FGV Group, Kuala Lumpur, Malaysia) were bought from local supermarkets in Nilai, Negeri Sembilan, Malaysia as the ingredients in the production of eggless pumpkin muffins.

2.2 Pumpkin Puree Preparation

Pumpkin puree was prepared according to the method of Baier [6]. Pumpkin was sliced into halves and the seeds and strings were taken out. After that, the pumpkin was chopped into little cubes and rinsed with distilled water. For 40 to 60 mins, the cut pumpkin was roasted in the oven at 200 °C. The purpose of roasting pumpkin was to produce the sweeter and richer taste of pumpkin. Finally, the skin was removed from the pumpkin before being processed into a puree using a processor.

2.3 Plant-Based Egg Replacer Ingredients Preparation

For chia seed mucilage preparation, chia seeds were mixed at a ratio of 1:15 with cold water, and the mixture was left for about 30 minutes [7]. Then, the soaked chia seed was blended using a mixer for 5 minutes or until the finest texture was obtained. The preparation method for flaxseed was adapted from Ahmad [8]. Approximately 40 g of water and 10 g of ground flaxseed were mixed, stirred, and left to create a gelatinous texture known as flax meal or flaxseed mucilage as an egg substitute for 1 h. This flaxseed mucilage served as an alternative to eggs. Then, the soaked flaxseed was blended using a mixer for 5 minutes until the finest texture was obtained. For the first step of mashed banana preparation, the banana peel from ripe banana (*Musa Acuminata Colla*) was peeled off. The banana was then pressed using the bottom of a fork in a bowl until it was well mashed and become a smooth paste.

2.4 Eggless Pumpkin Muffin Preparation

Muffin production was originally adopted from Mckenney's recipe [9]. However, the recipe underwent several modifications to the ingredients, quantity and preparation methods. A control sample of the pumpkin muffin was formulated using eggs while the other three formulations of pumpkin muffins were formulated with different plant-based replacer ingredients. The three muffin formulations were A (pumpkin muffin with chia seeds substitute), B (pumpkin muffin with flaxseeds substitute) and C (pumpkin muffin with mashed banana substitute). The ingredients and amount used in the preparation of pumpkin muffins are shown in Table 1.

Table 1
Eggless pumpkin muffin formulations for 6 cups

Formulation / Ingredients	Control (Pumpkin muffin with egg)/ in g	Formulation A (Pumpkin muffin with chia seeds substitution)/ in g	Formulation B (Pumpkin muffin with flaxseeds substitution)/ in g	Formulation C (Pumpkin muffin with mashed banana substitution)/ in g
All-purpose flour	109.5	109.5	109.5	109.5
Pumpkin puree	150	150	150	150
Sugar	70	70	70	70
Coconut milk	30	30	30	30
Palm oil	54.5	54.5	54.5	54.5
Egg	111.0	-	-	-
Egg substitute	-	5.8	5.8	28.8
Baking powder	2.8	2.8	2.8	2.8
Sodium bicarbonate	2.8	2.8	2.8	2.8
Total	530.6	425.4	425.4	439.6

Note: 5.8g of chia seeds or flaxseeds, and 28.8g of mashed banana were used to replace 32.5g of egg (1/2 egg) [14]

Initially, the oven was preheated to 180 ˚C for 30 mins. The dry ingredients [all-purpose flour (109.5 g), sodium bicarbonate (2.8 g) and baking powder (2.8 g)] were sifted into a bowl and set aside. In another bowl, 111 g of whole eggs (or weight of egg replacer), palm oil (54.5 g), sugar (70 g), pumpkin puree (150 g) and coconut milk (30 g) were mixed using a mixer. Once combined, the dry components were added to the wet ingredients and mixed until homogeneous. Just stir until everything is mixed into the batter without over-mixing. To properly put the mixture into each muffin cup, it is beneficial to use a large scoop (similar to an ice cream scoop). Approximately ¾ of the muffin cup was filled with 61.3 g of batter. A toothpick put into the centre of each pumpkin muffin should come out clean after 25 mins of baking at 180 ˚C. Before analysis, the pumpkin muffins were cooled to room temperature for 20 mins (25 ˚C).

2.5 Food Analysis

2.5.1 Physical analysis

The batter density of pumpkin muffins was determined by dividing the weight of the batter (W1) by the weight of the distilled water (W2) in the same cup [10]. Approximately 1 g/cm^3 is the density of water. On the other hand, the height of the pumpkin muffin was measured using a ruler in centimetres (cm). This analysis was conducted once the pumpkin muffin had been cooled for an hour at room temperature (25 °C). The muffin was cut in half and measured at the centre of the muffin. The height of the muffin was measured from its top to its bottom after the cooling process had taken for an hour [11]. The water activity of the pumpkin muffin was measured by using a Benchtop Water Activity meter, Aqualab 4TE. The sample cup was filled with pumpkin muffins (ground state) and did not exceed half of the cup. The cup was set inside the sample drawer before being closed. The measurement ended when the beep sound was heard. Triplicate samples were used for each analysis.

2.5.2 Texture profile analysis (TPA)

The characteristics of the texture of pumpkin muffins were examined, including chewiness, cohesiveness, springiness and hardness. A 0.25-inch-diameter spherical probe was utilized in a 2-fold compression test using a texture analyser (TA-XT Plus Model, Stable Micro System, Surrey, London). For this study, the initial height of compression was 50 %, the speed was 1 mm/s, and the waiting period was 5 s. The probe applied was a 0.25 mm spherical probe. Six samples were used for this analysis. Each sample was trimmed at the top and prepared into cubes measuring 5 centimetres in height and 3 centimetres in width.

2.5.3 Colour analysis

Colorimeter (LabScan®XE Spectrophotometer Model, HunterLab) and the L*a*b* colour scale system were used to determine and analyse the pumpkin muffins' colour. The systems calculated the intensity of light (L), the intensity of red or green (+/-a), and the intensity of yellow or blue (+/-b) [18]. Each 20-gram pumpkin muffin crumb was ground into tiny pieces before being placed on a designated plate for analysis. According to the manufacturer's instructions, the pumpkin muffins' colour was automatically measured and presented on a computer screen. Triplicate samples were used for each analysis.

2.5.4 Nutritional analysis

The determination of the nutritional composition of pumpkin muffins such as moisture, protein, fat, ash, fibre, carbohydrate and calorie contents was analysed using the Association of Official Analytical Chemists (AOAC) methods [12]. Determination of the moisture content of pumpkin muffin samples was carried out using a moisture analyser. Nitrogen content or crude protein in pumpkin muffins was determined using the Kjeldahl method. The percentage of crude protein indicates the total nitrogen percentage present in the sample was calculated by multiplying it with a conversion factor of 6.25 [12].

The crude fat content of pumpkin muffin samples was analysed using the Automatic Soxhlet extraction method (Soxhterm® extraction, Gerhardt). Total ash content was expressed as mineral content in the samples. The total ash content of pumpkin muffins was determined using conventional dry ashing based on the method of AOAC [12]. The carbohydrate content of pumpkin muffin samples was determined by deducting 100 % from the sum of protein, fat, ash and moisture percentages. The crude fibre analysis of pumpkin muffin samples was carried out using a fibre bag which is the Gerhardt method. The calorie content of pumpkin muffin samples was calculated manually by multiplying each macronutrient by its caloric equivalent. Triplicate samples were used for each analysis.

2.5.5 Sensory analysis

A hedonic test was conducted to assess consumer acceptability. The sensory evaluation of pumpkin muffins was performed by 60 panellists aged 19-21 years in individual booths at the Sensory Laboratory, Universiti Sains Islam Malaysia, Nilai, Malaysia. Among the 60 panellists, 15 were male and the remaining 45 were female. The panellists received 4 samples from each pumpkin muffin formulation namely, control, Formulation A (chia seeds), Formulation B (flaxseed) and Formulation C (mashed banana). Each pumpkin muffin sample (15 grams) was weighed and filled in muffin cups (3.8 × 3.0 centimetres). After the pumpkin muffin samples were baked and cooled, they were cut into 2 portions and served to panellists with three-random-digit numbers to avoid bias. They were asked to evaluate the appearance, colour, texture, aroma, taste and overall acceptability of the samples given. A 9-point hedonic scale with a range of extremely dislike (score = 1) to extremely like (score = 9) was used to evaluate the samples. To reduce any lingering effects, panellists were instructed to rinse their mouths with water in between samples as they evaluated the samples in a testing area.

2.6 Statistical Analysis

The statistical analyses were conducted using Minitab statistical software (Minitab 19, Minitab Inc., Pennsylvania). The one-way analysis of variance (ANOVA) was used to compare the data. The sample means were compared using Tukey's test. The 95 % confidence intervals for Tukey's test were used at $p < 0.05$.

3. Results and Discussion

3.1 Physical and Textural Properties of Eggless Pumpkin Muffin

Figure 1 shows the data obtained for batter density, muffin height and water activity of pumpkin muffins prepared using chia seeds, flaxseeds and mashed banana compared to control muffins. Batter density analysis was carried out on the wet batter, while height and water activity measurements were taken for the baked pumpkin muffins. The results indicated that the replacement of egg with plant-based egg replacers in muffin formulations significantly ($p < 0.05$) increased batter density compared to the control muffin. The batter density of the egg muffin was 0.90, while the values for the eggless pumpkin muffins ranged between 0.97 and 1.00 (Figure 1). The higher batter density in eggless pumpkin muffins was likely due to less air being incorporated into the batter during mixing. Air entrapment in the batter produces muffins with low batter density, which is a desirable property in baked products such as muffins and cakes. Insufficient air bubbles in batters with high density will restrict the expansion of the muffins [13].

Moreover, one of the functions of the egg was to give aeration to the batter simultaneously producing a higher muffin. Kiosseoglou [14] found that the control sample had a higher amount of air bubbles with a lower density as the egg yolk proteins decreased the surface area and interfacial tensions during batter mixing, leading to stable emulsion formation. Other than that, the higher density of the bread could result in a decrease in egg proteins, e.g. lecithoproteins from egg yolk and albumin from egg whites [15]. Based on the findings from Aljobair [4], a control sample (without incorporation of chia seed flour), with a full egg protein content, which could give the batter a better foaming ability, was the lighter and most aerated sample as it has the lowest value of batter density which was 1.11 g/cm^3. A previous study revealed that the batter density of a composite cake prepared from wheat, amaranth, malted finger millet and sprouted soy had been increased by incorporating chia seed in eggless cakes as an egg replacer [16].

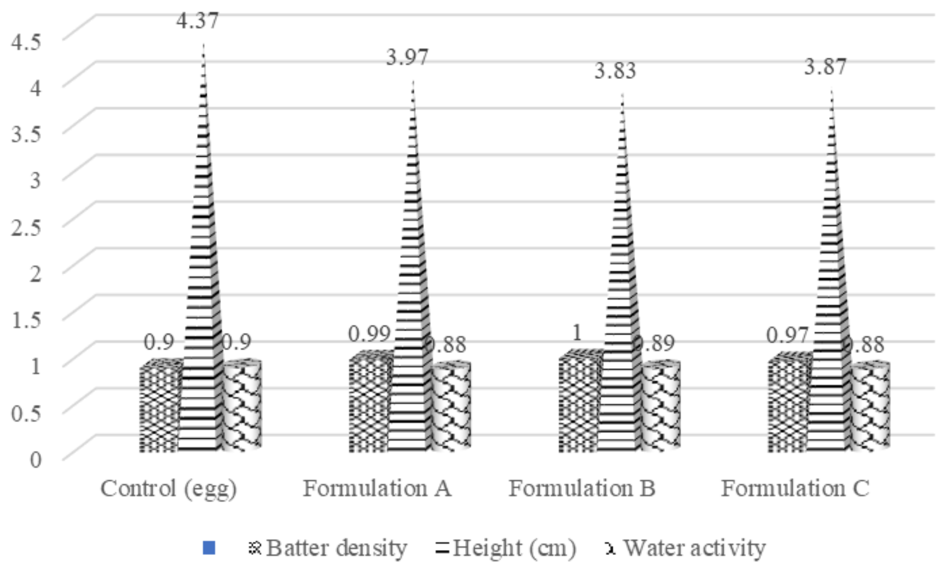

Fig. 1. Physical properties of eggless pumpkin muffin

Note: Control (egg); Formulation A, pumpkin muffin with chia seeds substitution; Formulation B, pumpkin muffin with flax seeds substitution; Formulation C, pumpkin muffin with mashed banana substitution

From Figure 1, it was shown that the replacement of plant-based egg replacer ingredients (3.83 cm – 3.97 cm) in the muffin significantly decreased ($p < 0.05$) the height of eggless pumpkin muffin compared to the control muffin (muffin prepared using egg, 4.37 cm). This finding was in line with the study by Kostor [5], where the height of the muffin decreased when incorporated with plant-based egg replacer ingredients (aquafaba and flaxseeds) (1.53 cm and 1.30 cm) as compared to control muffins (4.13 cm).

For texture profile analysis, the substitution of egg replacer ingredients (chia seed, flaxseeds and mashed banana) in the production of eggless pumpkin muffin significantly ($p < 0.05$) affected hardness properties with eggless pumpkin muffin exhibited higher hardness values indicating these samples were harder in texture. On the other hand, springiness, chewiness and cohesiveness were not statistically significant ($p > 0.05$) with the egg replacement of plant-based ingredients. Results of the muffin's hardness were also shown in Table 2 and obtained that the hardness of eggless pumpkin muffins with plant-based egg replacer ingredients in the muffins (chia seed, flaxseed and mashed banana) was significantly higher ($p < 0.05$) than in control muffin. The hardness of eggless pumpkin muffins was 52.42 N (pumpkin muffin with chia seed substitution), 53.4 N (pumpkin muffin with flaxseeds substitution) and 51.52 N (pumpkin muffin with mashed banana substitution). The hardness of control (pumpkin muffin with egg) had the lowest value which is 44.62 N.

Table 2
Textural Profile Analysis (TPA) of eggless pumpkin muffin

Formulations	Control (Pumpkin muffin with egg)	Formulation A (Pumpkin muffin with chia seeds substitution)	Formulation B (Pumpkin muffin with flax seeds substitution)	Formulation C (Pumpkin muffin with mashed banana substitution)
Texture Profile Analysis (TPA)				
Hardness (N)	44.62 ± 3.58^{b}	52.42 ± 2.26^{a}	53.04 ± 0.99^{a}	51.52 ± 0.82^{a}
Springiness (cm)	0.87 ± 0.04^{a}	0.81 ± 0.01^{a}	0.77 ± 0.06^{a}	0.88 ± 0.04^{a}
Chewiness (N/cm)	0.43 ± 0.01^{a}	0.41 ± 0.00^{a}	0.43 ± 0.01^{a}	0..44 ± 0.05^{a}
Cohesiveness (ratio)	16.86 ± 2.62^{a}	17.84 ± 1.40^{a}	19.69 ± 1.19^{a}	19.69 ± 1.19^{a}

Note: Superscripts within the same row with the different letters are significantly different at ($p < 0.05$)

The substitution of plant-based egg replacer ingredients (chia seeds, flax seeds and mashed banana) in the pumpkin muffin decreased significantly ($p < 0.05$) the water activity compared to the control muffin which was prepared using egg. The water activity of an egg pumpkin muffin was 0.90 while the range of an eggless pumpkin muffin ranged from 0.88 to 0.89 (Figure 1). The low values of water activity in eggless pumpkin muffins were possibly due to the high concentration of fibre in each of the plant-based egg replacer ingredients (chia seeds, flaxseeds and mashed banana). The higher number of hydroxyl groups found within the fibre structure, which tends to allow for enhanced water interactions through hydrogen bonding, was a factor behind the good water absorption in fibre-rich powder [21]. This statement is concurrent with the definition of water activity which commonly refers to the amount of bound water.

Meanwhile, the springiness, chewiness and cohesiveness of the control muffin and eggless pumpkin muffin did not have significant differences at $p > 0.05$. These data indicated that the various plant-based ingredients used in the eggless pumpkin muffin preparation did not significantly affect springiness, chewiness and cohesiveness. However, cohesiveness values for eggless pumpkin muffins prepared with chia seed, flaxseed and mashed banana showed higher values than control muffins. It shows that plant-based ingredients blended well with the other ingredients to form a unified texture by intermolecular attraction. Cohesiveness normally refers to the measurement of the amount of force required to destroy the structure of a product. High cohesiveness values can be interpreted as the muffin is difficult to disintegrate by chewing process.

3.2 Colour Analysis of Pumpkin Muffin

Figure 2 shows the colour analysis of eggless pumpkin muffins with chia seeds, flaxseeds and mashed banana substitution in muffin formulations. Control muffins were found to have the highest and the most significant values ($p < 0.05$) of L* (53.18) as compared to plant-based egg replacer ingredients in muffins (44.03 to 49.46) suggesting the darkest colour of the latter samples. The colour of the crust was determined by the Millard reaction, the interaction between the reduction of sugars and amino acids, and the caramelization of sugars [26]. The high protein content of eggs compared with egg substitution led to the caramelization of sugars probably a reason for the increased L* value in the control muffin [27]. The dark colour of egg replacer ingredients used in the experiment may contribute to the dark colour of the finished products. Eggless pumpkin muffins prepared using mashed banana had the lowest values of L* due to the enzymatic browning of the banana itself during processing.

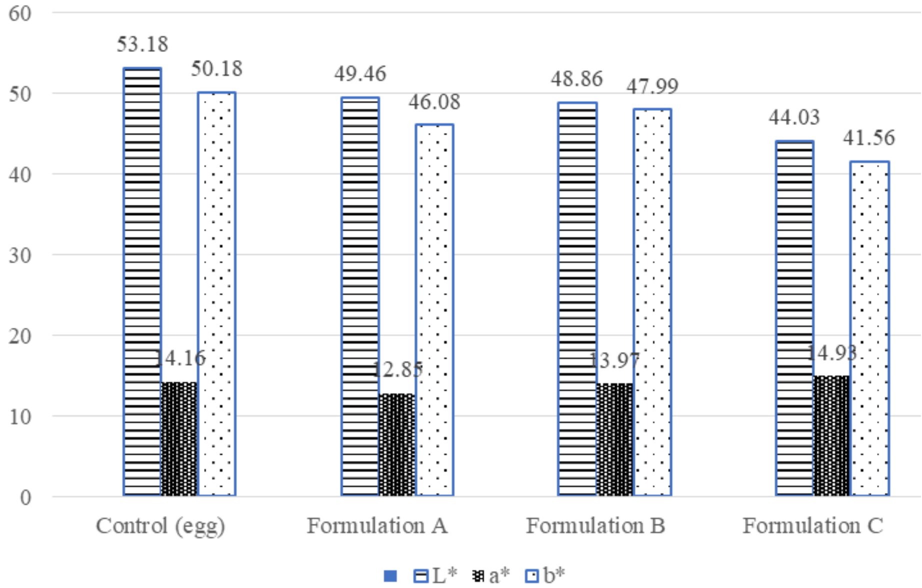

Fig. 2. Colour analysis using Hunter lab colourimeter for eggless pumpkin muffin with various plant-based egg replacer ingredients

Note: Control (egg); Formulation A, pumpkin muffin with chia seeds substitution; Formulation B, pumpkin muffin with flax seeds substitution; Formulation C, pumpkin muffin with mashed banana substitution

On the other hand, a* (red/green), value of eggless pumpkin muffin substituted with mashed banana (14.93) was significantly the highest ($p < 0.05$) compared to other ingredients (12.85 to 14.16). This result could be due to enzymatic and non-enzymatic browning reactions occurring in muffins prepared with mashed banana. Banana flesh contains a high level of *phenolase* enzyme, which can lead to enzymatic browning, and it is also rich in simple carbohydrates such as glucose, which can cause Maillard reactions.

For the b* (yellow/blue), the value of control (50.18), chia seeds substitution (46.08) and mashed banana substitution (41.56) showed significant differences ($p < 0.05$) while flax seeds substitution (47.99) shows that it was almost similar to control and chia seeds substitution. The high value of b* value in the control muffin (muffin with egg) may be due to the yellow colour that was produced by egg yolk carotenoid that was composed mostly of carotene and xanthophylls [28], which also plays an important role in contributing to the distinctive yellow colour of a variety of bakery products. The value of b* for a muffin with flaxseeds substitution that was almost similar to the control muffin could also be due to the yellow/orange pigments of carotenoid pigments. There were also small amounts of tocopherol, tocotrienol, sterol and carotenoid pigments present in flaxseed oil [29].

3.3 Nutritional Composition of Pumpkin Muffin

Table 3 indicates the results of the nutritional composition of pumpkin muffins including moisture, ash, protein, fat, carbohydrates, fibre and calorie contents. Results showed that the control pumpkin muffin (muffin prepared using egg) was significantly the lowest ($p < 0.05$) in values for ash, carbohydrates, fibre and calorie contents in comparison to the eggless pumpkin muffin.

Table 3
Nutritional composition of pumpkin muffin

Formulations	Control (Pumpkin muffin with egg)	Formulation A (Pumpkin muffin with chia seeds substitution)	Formulation B (Pumpkin muffin with flax seeds substitution)	Formulation C (Pumpkin muffin with mashed banana substitution)
Moisture content	38.47 ± 1.26^a	31.63 ± 0.51^b	33.70 ± 0.67^b	32.14 ± 0.43^b
Ash content	1.29 ± 0.02^b	1.34 ± 0.02^b	1.40 ± 0.06^b	1.55 ± 0.01^a
Protein	5.27 ± 0.17^a	3.97 ± 0.02^b	3.98 ± 0.02^b	4.08 ± 0.02^b
Fat	14.34 ± 0.12^a	14.10 ± 0.17^a	13.50 ± 0.21^b	13.02 ± 0.18^b
Carbohydrates content	40.63 ± 1.17^b	48.95 ± 0.62^a	47.43 ± 0.50^a	49.22 ± 0.59^a
Fibre content	0.48 ± 0.04^b	0.72 ± 0.04^a	0.85 ± 0.05^a	0.74 ± 0.04^a
Calorie content	312.60 ± 5.38^c	338.75 ± 3.15^a	327.12 ± 3.80^b	330.35 ± 0.98^{ab}

Note: Superscripts within the same row with the different letters are significantly different at ($p < 0.05$)

Similarly, results found that the replacement of plant-based egg replacer ingredients in the muffin significantly ($p < 0.05$) decreased the moisture content compared to the control muffin. Egg pumpkin muffin was found to have the highest value which was 38.47 %. Moisture content was commonly referred to as water that evaporates off during heating in an oven above the water boiling point. On the other hand, the moisture content among eggless pumpkin muffins was not statistically different ($p > 0.05$) with the moisture contents ranging between 31.63 to 33.70 %. The moisture content of egg and eggless pumpkin muffins was also in correlation (R^2=0.87) with water activity (Table 4). The increase in moisture was aligned with the water activity. The high value of moisture content in the control muffin is probably due to its water content and volatile compounds in the egg. The proportions of water, protein, fat, carbs and ash in a whole, raw, freshly laid egg were approximately 76.1, 12.6, 9.5, 0.7 and 1.1 %, respectively [30].

Furthermore, the ash contents of eggless pumpkin muffin prepared using mashed banana were significantly ($p < 0.05$) higher in value (1.55 %) followed by eggless pumpkin muffin prepared using flaxseeds (1.40 %) and chia seeds (1.34 %). Muffins prepared using eggs were observed to have the lowest ash content (1.29 %). These findings showed that the replacement of egg with chia seeds, flaxseeds and mashed banana in muffin formulations increased the mineral content of muffin. The total ash contents in each of the plant-based egg replacer ingredients according to the research paper were as follows which were mashed bananas contain 4.93 % [31], chia seeds contain 4.77 % [32] and flaxseeds contain 3.4 % [33]. This result was in line with some of the research where the increased ash content in the bakery product may have been due to the greater concentration of minerals in plant-based egg replacer ingredients. According to Aljobair [4], the sample containing 7 % chia seed (CSF7) showed the greatest ash content (4.31 %), nearly twice as high as the chia seed flour-free control sample (CSF0). In another study carried out by Sunwar [34], muffins that contain 100 % flaxseeds (1.97 %) had a higher value of ash than egg muffins (1.28 %). Lakshmi and others [35] also found that sample C (Substitution of 50 % mashed banana as a fat replacer in cookies) showed a higher value (1.98 %) as compared to sample A (100 % use of batter in cookies).

As expected for the protein content of the pumpkin muffin, results found that the replacement of plant-based egg replacer ingredients in the muffin decreased ($p < 0.05$) the protein content compared to the control muffin. The protein content of the control pumpkin muffin (pumpkin muffin made with egg) had the highest value which was 5.27 % followed by Formulation C (Pumpkin muffin with mashed banana substitution) with 4.08 %, Formulation B (Pumpkin muffin with chia seeds substitution) with 3.98 %, and Formulation A (Pumpkin muffin with flaxseeds substitution) with 3.97 %. Egg muffins had the highest protein content due to the rich protein in eggs [36]. It is well known that compared to plant-based products, animal proteins have a complete composition of essential amino acids and high digestibility [37]. It was also anticipated that the substitution of plant-based egg replacer ingredients in pumpkin muffin decreased significantly ($p < 0.05$) the fat content compared to the control muffin which was prepared using egg. Regarding the fat content, the control pumpkin muffin (muffin made with egg) contained the highest fat content, which was 14.34 %, the pumpkin muffin substituted with chia seeds contained 14.10 % and the pumpkin muffin substituted with flaxseeds contained 13.50%, whereas the pumpkin muffin substituted with mashed banana contained 13.02 %. The high fat content in egg pumpkin muffins possibly is due to the concentration of saturated fatty acid in the egg yolk. According to Amir *et al.*, [38], the average fat of egg yolk was 24 %. Some of the researchers found similar results where the protein and fat content were higher in the control sample as compared to samples substituted with plant-based egg replacer ingredients (Chia seeds, flaxseeds and mashed banana) [4,35,34].

From the results in Table 3, the substitution of plant-based egg replacer ingredients in the pumpkin muffin increased ($p < 0.05$) the carbohydrate content as compared to the control pumpkin muffin (pumpkin muffin made with egg). The carbohydrate value of the egg pumpkin muffin (Control) was 40.63 % while the carbohydrate value for the eggless pumpkin muffin was higher in value (between 47.43 and 49.22%). The total carbohydrate contents in each plant-based egg replacer ingredient according to the research paper were as follows which were flaxseeds 43.60 % [39], chia seeds 42.10 % [40] and mashed banana 46.58 % [31]. In a similar study, Sunwar [34] also found similar results where the carbohydrate content was higher when samples were substituted with plant-based egg replacer ingredients (flaxseeds) as compared to the control sample.

From Table 3, the results also showed that the substitution of plant-based egg replacer ingredients in the pumpkin muffin significantly increased the fibre content ($p < 0.05$) as compared to the control muffin (pumpkin muffin made with egg). The fibre content of egg pumpkin muffins was 0.48 which was the lowest value among the pumpkin muffins. However, the fibre content of eggless pumpkin muffins showed an increasing trend where Formulation A (pumpkin muffin with chia seeds substitution), was the lowest among them, followed by Formulation C (pumpkin muffin with mashed banana substitution) and Formulation B (pumpkin muffin with flaxseeds substitution) with values of 0.72, 0.74 and 0.85 % respectively. This finding was correlated to the study from Sunwar [34] where incorporation of flaxseeds in muffins for 0, 25 and 100 % substitution of flaxseeds showed an increase in fibre contents which were 0.6, 0.7 and 1.3 %, respectively. To replicate the emulsification properties of eggs, vegan eggs contain high amounts of fibres [41]. Two of the highest fibre contents in pumpkin muffins were flaxseeds and chia seeds. Chia seeds are the same as flaxseeds in terms of their substance composition. Whereas flaxseed was a potential source of protein (20–30 %), fat (30–41 %) and dietary fibre (20–35 %) and is rich in ω-3 fatty acids [42]. Chia seeds contained a significant amount of protein (17–24 %), dietary fibre (18–22 %), antioxidant compounds and oil (25–35 %) with ω-3 fatty acids [42].

For the calorie content based on Table 3, the value of control (312.60 kilocalories), chia seeds substitution (338.75 kilocalories) and flax seeds substitution (327.12 kilocalories) showed significant differences ($p < 0.05$) among them. However, the value of mashed banana substitution (330.35 kilocalories) was in between the value of flaxseeds and chia seeds substitutions which indicated no significant difference at $p > 0.05$ between them. So, the substitution of plant-based egg replacer ingredients in pumpkin muffins will increase the calorie contents of the pumpkin muffin. The high-calorie content in the eggless pumpkin muffin was also possibly due to the carbohydrate contents present in each muffin. A positive correlation R^2 = 0.93 was found between the comparison of the carbohydrate content and the calorie content in the pumpkin muffin (Table 4). The calorie content of a pumpkin muffin was raised when the carbohydrate content had risen. The highest calorie content was provided by a vegetarian egg followed by whole eggs, yolks and whites [37].

In addition, the muffin height of the pumpkin muffin was highly correlated to batter density values. A negative correlation R^2 = - 0.88 between them was observed when comparing the height and the density of the pumpkin muffin (Table 4). The height of the muffin was reduced as the density of the batter went up. The density of batter and baking cake plays a role in the texture of cakes, depending on the amount of air trapped in them [17,18]. The determination of rheological characteristics in cake batter was essential because the quality characteristics of cakes, such as texture and volume, had a significant influence on their rheological properties [19,20].

Table 4
Correlation coefficient

Property	Correlation coefficient	
Height vs density	0.88	Positive
Fiber content vs water activity	0.78	Negative
Fiber content vs hardness	0.96	Positive
Height vs hardness	0.97	Negative
Moisture content vs water activity	0.87	Positive
Carbohydrate content vs calorie	0.93	Positive

A negative correlation R^2 = -0.78 between the fibre content of the pumpkin muffin and the water activity of the pumpkin muffin was observed when comparing the fibre content of the pumpkin muffin with the water activity of the pumpkin muffin. The water activity of the pumpkin muffin is reduced when the fibre content of the pumpkin muffin increases. Flaxseed gum/mucilage (hydrocolloid) which is a soluble fibre has a significant ability to bind water at the level of 16–30 g water/1 g flaxseed gum [22]. The fibre-rich fraction in chia seeds had higher water holding, absorption, and organic-molecule absorption with high emulsifying activity (53.26 mL/100 mL) and emulsion stability (94.84 mL/100 mL) in comparison to other fibre sources (soybean, wheat, maize and wheat hulls) [23]. Natural fibres like banana fibre had a lot of hydroxyl groups (−OH) and were highly hydrophilic which allowed them to form hydrogen bonds with water molecules, which helped them absorb moisture [24].

This finding was aligned with the study from Aydogdu [25] where incorporations of higher concentrations of fibres increase the hardness value of cakes and this indicated that the hardness of cakes increased with the increase in fibre content. The comparison of the fibre content and hardness of the pumpkin muffin showed a highly positive correlation (R^2 = 0.96). This data indicates that a high fibre content in muffin formulations will increase the hardness value, subsequently producing a product with a firmer texture. Moreover, when the height of the muffin is low, it will produce a muffin with a dense and hard texture. The comparison of the height of the pumpkin muffin and the hardness of the pumpkin muffin showed a negative correlation with the value of R^2 = -0.97 indicating a high correlation between these two parameters (Table 4).

3.4 Sensory Acceptance

Table 5 presented the data of the 9-hedonic test based on the mean score of consumers' preference for eggless pumpkin muffins formulated with chia seeds, flaxseeds and mashed bananas involving 60 untrained panellists. Generally, Formulation C (pumpkin muffin with mashed banana substitution) was rated with the highest mean score in all attributes evaluated indicating that this pumpkin muffin was the most acceptable by the consumers (7 is a score for moderately acceptable). The sensory acceptance findings also showed that eggless pumpkin muffins prepared using flaxseed obtained the lowest score among the samples, followed by egg pumpkin muffins. However, there was no statistical difference ($p > 0.05$) was found between the eggless pumpkin muffins prepared with flaxseed and those pumpkin muffins prepared with egg. Consumers did not like pumpkin muffins substituted with flaxseed probably due to the hardness of the pumpkin muffin caused by the high fibre content in flaxseed. On the contrary, results found the preferences of consumers among formulated eggless pumpkin muffins were not significantly different ($p > 0.05$) to control muffins (7.08) for sensory attributes of appearance with the mean score in formulated eggless pumpkin muffins ranging from 6.80 to 7.43. The highest score given by the untrained panellists for the appearance of a pumpkin muffin that was prepared with mashed banana could be attributed to the smooth surface offered by the muffin.

Table 5
Mean scores of hedonic tests for eggless pumpkin muffins with various plant-based egg replacer ingredients

Formulations	Control (Pumpkin muffin with egg)	Formulation A (Pumpkin muffin with chia seeds substitution)	Formulation B (Pumpkin muffin with flax seeds substitution)	Formulation C (Pumpkin muffin with mashed banana substitution)
Appearance	7.0 ± 1.3^{a}	6.9 ± 1.4^{a}	6.8 ± 1.5^{a}	7.43 ± 1.2^{a}
Colour	7.2 ± 1.4^{ab}	7.0 ± 1.4^{ab}	6.7 ± 1.4^{b}	7.38 ± 1.2^{a}
Texture	7.2 ± 1.4^{ab}	7.1 ± 1.4^{ab}	6.8 ± 1.5^{b}	7.63 ± 1.3^{a}
Aroma	6.5 ± 1.5^{b}	6.8 ± 1.3^{ab}	6.4 ± 1.6^{b}	7.23 ± 1.4^{a}
Sweetness	6.3 ± 1.7^{b}	6.8 ± 1.5^{ab}	6.1 ± 1.7^{b}	7.22 ± 1.5^{a}
Overall acceptance	6.8 ± 1.4^{b}	6.9 ± 1.4^{b}	6.5 ± 1.6^{b}	7.58 ± 1.2^{a}

Note: Superscripts within the same row with the different letters are significantly different at ($p < 0.05$)

In the context of the colour attribute of the experimental eggless pumpkin muffin, it was found that the mean score given by the panellists was between 6.70 and 7.38 ($p < 0.05$) while the control pumpkin muffin scored 7.18. The results showed that the panellists significantly preferred the colour of eggless pumpkin muffins with mashed banana substitution. Formulation C obtained the highest mean score (7.38) of colour indicating the pumpkin muffin with mashed banana substitution in eggless pumpkin muffin was well accepted in colour compared to the control sample. In addition, according to Shewfelt and Brückner [43], colour and appearance attract the consumer to a product and can help in impulse purchases. At the point of purchase, the consumer used appearance factors to indicate freshness and flavour quality. Additionally, enzymatic and non-enzymatic browning occurring in bananas may also improve the colour of eggless pumpkin muffins by producing muffins with darker in colour.

There was no significant difference ($p > 0.05$) in texture attribute for pumpkin muffin prepared with mashed banana (Formulation C), chia seeds (Formulation A) and control (muffin prepared using egg) with formulation C (7.63) was rated as the highest preference among all the muffin samples. Similar to appearance and colour, eggless pumpkin muffin prepared with flaxseed was given the lowest scores indicating that panellists did not prefer the texture of the muffin. This was in agreement with the study carried out by Sunwar [34], where the incorporation of 100 % of flaxseed in the muffin gave the lowest mean score for texture acceptance of the muffin among consumers. Although the hardness result of mashed banana (51.52N) was higher than the control (44.62N), the texture acceptance of mashed banana was still the highest among the formulations. In contrast, according to Lakshmi and others [35], higher incorporation of bananas in replacing the butter in the cookies showed a decline in texture preference among consumers. This was probably due to the incorporation of bananas in biscuits cannot mimic the tender properties that are provided by the butter. As compared to the muffin, the hardness of the muffin was possibly hard to distinguish among the samples by the panellist. Other than that, the panellist perhaps used their hand to score the texture instead of using their mouth because it might give a different perception. If the hand was used conceivably the texture of the muffin would be hard, but if the mouth was used to feel the texture of the muffin, the muffin used banana substitution may give desirable texture to the panellist.

In terms of aroma and sweetness, there were significantly higher scores between formulations C (7.23 and 7.22, respectively), control muffin and formulation B indicating eggless pumpkin muffin prepared using mashed banana was the most preferred by panellists for these attributes. This might be due to the volatile compound and sugar contents in bananas that contributed to the aroma and sweetness of the pumpkin muffin. In bananas, almost 200 volatile materials had been identified. The major volatile compound of most bananas is hexanol [44]. For the sweetness, total sugar concentrations of 4.3 and 15–17 g/100 g in unripe and slightly ripe to overripe bananas, respectively, sucrose made up just 25 % of the sugars in unripe bananas, 22-27 % in slightly ripe/ripe bananas and 11 % in overripe bananas [44].

Lastly, the overall acceptance of eggless pumpkin muffin substituted with mashed banana that was given by the mean score of panellists showed a higher significance ($p < 0.05$) as compared to other formulations of pumpkin muffin. The overall acceptance of formulation C was 7.58 followed by formulation A (6.93), control (6.77) and formulation B (6.47) respectively. Surprisingly, panellists significantly preferred eggless muffins with mashed banana rather than control muffins. According to a study by Agrahar-Murugkar and others [16], bananas were comparable to controls for total acceptability attributes on a nine-point hedonic scale among all cakes with egg replacers. This finding is similar to the results obtained in this study.

4. Conclusions

In physical analysis, the substitution of plants-based egg replacers (chia seed, flaxseeds and mashed banana) in the production of pumpkin muffins significantly affected batter density, muffin height, water activity and hardness values. Additionally, the use of these ingredients in muffin formulations produced muffins darker in colour in comparison to egg muffins. As expected, the replacement of eggs with plant-based ingredients improves the ash and fibre contents while fat and protein decrease in percentage. The substitution of egg replacer ingredients (chia seed and mashed banana) in the production of eggless pumpkin muffins improved the scores of aroma, sweetness and overall acceptability attributes as compared to egg muffins. The preference test conducted found that pumpkin muffins prepared with mashed banana rated the highest in scores (> 7) for all attributes in comparison to egg muffins. These findings indicate that mashed banana is the best egg replacer alternative in eggless pumpkin muffin formulations.

Acknowledgement
The authors wish to express their gratitude to the Faculty of Science and Technology (FST), USIM for their financial support. Additionally, appreciation is extended to the laboratory technicians who contributed to the completion of this project: Puan Normah Harun, Puan Rina Wahap, Puan Hafiza Abdul Ghafar and En Hassan Azhari.

References

[1] Kiosseoglou, Vassilis, and Adamantini Paraskevopoulou. "Molecular interactions in gels prepared with egg yolk and its fractions." *Food Hydrocolloids* 19, no. 3 (2005): 527-532. https://doi.org/10.1016/J.FOODHYD.2004.10.027

[2] Yadav, Aravind, and Rakesh Naidu. "Clinical manifestation and sensitization of allergic children from Malaysia." *Asia Pacific allergy* 5, no. 2 (2015): 78-83. https://doi.org/10.5415/APALLERGY.2015.5.2.78

[3] Sun, K.G. (2023) Egg supply still low.https://www.thestar.com.my/news/nation/2023/11/04/egg-supply-still-low. [Access online 15 January 2023].

[4] Aljobair, Moneera Othman. "Effect of chia seed as egg replacer on quality, nutritional value, and sensory acceptability of sponge cake." *Journal of Food Quality* 2022, no. 1 (2022): 9673074. https://doi.org/10.1155/2022/9673074

[5] Kostor, S. N. S. (2021). Effect of physical properties of aquafaba and flaxseed on a basic muffin as an egg replacer. E-festival agromakanan dan bioteknologi. 21(1), 1-6.

[6] Baier, L., Lacey, M., Boone, M., Owens, J., Paul, P., and Owens-Peter, S. (2018). *How to make Pumpkin Puree.* A Sweet Pea Chef. How To Make Pumpkin Puree - A Sweet Pea Chef. [Access online 15 January 2023].

[7] Capitani, Marianela I., Vanesa Y. Ixtaina, Susana M. Nolasco, and Mabel C. Tomás. "Microstructure, chemical composition and mucilage exudation of chia (Salvia hispanica L.) nutlets from Argentina." *Journal of the Science of Food and Agriculture* 93, no. 15 (2013): 3856-3862. https://doi.org/10.1002/JSFA.6327

[8] Ahmad, Noorlaila, Nurul Ashikin Mohammad Zaki, and Nurul Nor Izzuani Nor Sham. "Effects of flaxseed (Linum Usitatissimum) as fat mimetics on physicochemical and sensory properties of muffin." *2289-6368* 9 (2021): 183-191.

[9] McKenny, S., (2022). Simply Pumpkin Muffins. https://sallysbakingaddiction.com/pumpkin-muffins-recipe/ [Access online 15 January 2023].

[10] Gómez, Manuel, Felicidad Ronda, Pedro A. Caballero, Carlos A. Blanco, and Cristina M. Rosell. "Functionality of different hydrocolloids on the quality and shelf-life of yellow layer cakes." *Food hydrocolloids* 21, no. 2 (2007): 167-173. https://doi.org/10.1016/J.FOODHYD.2006.03.012

[11] Scheuer, Patrícia Matos, Bruna Mattioni, Pedro Luiz Manique Barreto, Flávio Martins Montenegro, Cristiane Rodrigues Gomes-Ruffi, Sílvia Biondi, Mariana Kilpp, and Alicia de Francisco. "Effects of fat replacement on properties of whole wheat bread." *Brazilian Journal of Pharmaceutical Sciences* 50 (2014): 703-712. https://doi.org/10.1590/S1984-82502014000400005

[12] AOAC 2005

[13] Majzoobi, Mahsa, Safoora Pashangeh, and Asgar Farahnaky. "Effect of wheat bran of reduced phytic acid content on the quality of batter and sponge cake." *Journal of Food Processing and Preservation* 38, no. 3 (2014): 987-995. https://doi.org/10.1111/JFPP.12055

[14] Kiosseoglou, V. "Interactions and competitive adsorption effects in egg-based products." *World's Poultry Science Journal* 60, no. 3 (2004): 311-320. https://doi.org/10.1079/WPS200419

[15] Lin, Muyang, Siang Hong Tay, Hongshun Yang, Bao Yang, and Hongliang Li. "Replacement of eggs with soybean protein isolates and polysaccharides to prepare yellow cakes suitable for vegetarians." *Food Chemistry* 229 (2017): 663-673. https://doi.org/10.1016/j.foodchem.2017.02.132

[16] Agrahar-Murugkar, Dipika, Aiman Zaidi, Nachiket Kotwaliwale, and Chetan Gupta. "Effect of egg-replacer and composite flour on physical properties, color, texture and rheology, nutritional and sensory profile of cakes." *Journal of Food Quality* 39, no. 5 (2016): 425-435. https://doi.org/10.1111/JFQ.12224

[17] Majzoobi, Mahsa, Safora Pashangeh, and Asgar Farahnaky. "Effect of different particle sizes and levels of wheat bran on the physical and nutritional quality of sponge cake." *International Journal of Food Engineering* 9, no. 1 (2013): 29-38. https://doi.org/10.1515/IJFE-2012-0160/HTML

[18] Sahi, Sarabjit S., and Juan M. Alava. "Functionality of emulsifiers in sponge cake production." *Journal of the Science of Food and Agriculture* 83, no. 14 (2003): 1419-1429. https://doi.org/10.1002/JSFA.1557

[19] Sakiyan, Ozge, Gulum Sumnu, Serpil Sahin, and Goknur Bayram. "Influence of fat content and emulsifier type on the rheological properties of cake batter." *European Food Research and Technology* 219 (2004): 635-638. https://doi.org/10.1007/S00217-004-1020-4

[20] Turabi, Elif, Gulum Sumnu, and Serpil Sahin. "Rheological properties and quality of rice cakes formulated with different gums and an emulsifier blend." *Food hydrocolloids* 22, no. 2 (2008): 305-312. https://doi.org/10.1016/J.FOODHYD.2006.11.016

[21] Rajeswari, H., S. L. Jagadeesh, and G. J. Suresh. "Physicochemical and sensory qualities of bread fortified with banana, aonla and sapota powders." *Journal of Nutritional Health & Food Engineering* 8, no. 6 (2018): 487-492. https://doi.org/10.15406/jnhfe.2018.08.00315

[22] Kajla, Priyanka, Alka Sharma, and Dev Raj Sood. "Flaxseed—a potential functional food source." *Journal of food science and technology* 52 (2015): 1857-1871.https://doi.org/10.1007/S13197-014-1293-Y
[23] Alfredo, Vázquez-Ovando, Rosado-Rubio Gabriel, Chel-Guerrero Luis, and Betancur-Ancona David. "Physicochemical properties of a fibrous fraction from chia (Salvia hispanica L.)." *LWT-Food Science and Technology* 42, no. 1 (2009): 168-173. https://doi.org/10.1016/J.LWT.2008.05.012
[24] Husseinsyah, S., and M. Mostapha. "The effect of filler content on properties of coconut shell filled polyester composites." *Malaysian polymer journal* 6, no. 1 (2011): 87-97.
[25] Aydogdu, Ayca, Gulum Sumnu, and Serpil Sahin. "Effects of addition of different fibers on rheological characteristics of cake batter and quality of cakes." *Journal of food science and technology* 55 (2018): 667-677. https://doi.org/10.1007/S13197-017-2976-Y
[26] Hedayati, Sara, and Mostafa Mazaheri Tehrani. "Effect of total replacement of egg by soymilk and lecithin on physical properties of batter and cake." *Food science & nutrition* 6, no. 4 (2018): 1154-1161. https://doi.org/10.1002/FSN3.656
[27] Rahmati, Nazanin Fatemeh, and Mostafa Mazaheri Tehrani. "Replacement of egg in cake: Effect of soy milk on quality and sensory characteristics." *Journal of Food Processing and Preservation* 39, no. 6 (2015): 574-582. https://doi.org/10.1111/JFPP.12263
[28] Wu, Jianping. "Eggs and egg products processing." *Food processing: Principles and applications* (2014): 437-455. https://doi.org/10.1002/9781118846315.CH19
[29] Daun, J. K., V. J. Barthet, T. L. Chornick, and Scott Duguid. "Structure, composition, and variety development of flaxseed." (2003): 1-40. https://www.cabdirect.org/cabdirect/abstract/20043187402
[30] USDA. (2018b). Food Group: Dairy and Egg Products. https://fdc.nal.usda.gov/fdc-app.html#/food-details/748967/nutrients [Access online 15 January 2023].
[31] Ramu, Ramith, Prithvi S. Shirahatti, K. R. Anilakumar, Shivasharanappa Nayakavadi, Farhan Zameer, B. L. Dhananjaya, and MN Nagendra Prasad. "Assessment of nutritional quality and global antioxidant response of banana (Musa sp. CV. Nanjangud Rasa Bale) pseudostem and flower." *Pharmacognosy research* 9, no. Suppl 1 (2017): S74. https://doi.org/10.4103/PR.PR_67_17
[32] Jin, Fuxia, David C. Nieman, Wei Sha, Guoxiang Xie, Yunping Qiu, and Wei Jia. "Supplementation of milled chia seeds increases plasma ALA and EPA in postmenopausal women." *Plant foods for human nutrition* 67 (2012): 105-110. https://doi.org/10.1007/S11130-012-0286-0
[33] Morris, Diane H. *Flax: A health and nutrition primer*. Flax Council of Canada, 2007.
[34] Sunwar, Rupshana. "Effect of flaxseed on the physiochemical and sensory quality of muffin as egg replacer." PhD diss., Department of Food Technology Central Campus of Technology Institute of Science and Technology Tribhuvan University, Nepal 2022, 2022.
[35] Lakshmi, B., Aishwarya, R., Divya, J., and Simmi. (2023). Development and analysis of shortbread cookies using mashed banana as a fat replacer. *IARJSET*, *10*(11). https://doi.org/10.17148/IARJSET.2023.101118
[36] Chepkemoi, M., D. Sila, P. Oyier, P. Malaki, E. Ndiema, B. Agwanda, V. Obanda, K. J. Ngeiywa, J. Lichoti, and S. Ommeh. "Nutritional diversity of meat and eggs of five poultry species in Kenya." In *Scientific conference proceedings*, no. 1. 2016.
[37] Boukid, Fatma, Cristina M. Rosell, Sara Rosene, Sara Bover-Cid, and Massimo Castellari. "Non-animal proteins as cutting-edge ingredients to reformulate animal-free foodstuffs: Present status and future perspectives." *Critical Reviews in Food Science and Nutrition* 62, no. 23 (2022): 6390-6420. https://doi.org/10.1080/10408398.2021.1901649
[38] Chandra, Stefan Pratama, Yoanes Maria Vianney, Theresia Liliani Christie, Merlyn Wongso, Melisa Widjaja, Deok-Chun Yang, Se Chan Kang, Manar Fayiz Mousa Atoum, and Johan Sukweenadhi. "Mass production of Panax ginseng CA Mey. root cultures in Indonesia." *Sarhad Journal of Agriculture* 37, no. 1 (2021): 98-109. https://doi.org/10.17582/journal.sja/2021/37.s1.98.109
[39] Chishty, Sadia, and Monika Bissu. "Health benefits and nutritional value of flaxseed-a review." *Indian J Appl Res* 6, no. 1 (2016): 243-245.
[40] USDA. (2018). Chia seeds. https://fdc.nal.usda.gov/fdc-app.html#/food-details/170554/nutrients [Access online 15 January 2023].
[41] Boukid, Fatma, and Mohammed Gagaoua. "Vegan egg: a future-proof food ingredient?." *Foods* 11, no. 2 (2022): 161. https://doi.org/10.3390/FOODS11020161
[42] Hedayati, Sara, Seid Mahdi Jafari, Siavash Babajafari, Mehrdad Niakousari, and Seyed Mohammad Mazloomi. "Different food hydrocolloids and biopolymers as egg replacers: A review of their influences on the batter and cake quality." *Food Hydrocolloids* 128 (2022): 107611. https://doi.org/10.1016/J.FOODHYD.2022.107611
[43] Shewfelt, R. L., and Brückner, B., (2019). Fruit & vegetable quality : An integrated view. CRC Press LLC, Boca Raton, Florida.

[44] Mostafa, Salma, Yun Wang, Wen Zeng, and Biao Jin. "Floral scents and fruit aromas: Functions, compositions, biosynthesis, and regulation." *Frontiers in plant science* 13 (2022): 860157. https://doi.org/10.3389/fpls.2022.860157