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Effect of Formulation with Papaya Sauce as Fat Replacer on Butter Cake Texture

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Abstract: Fat helps to provide better creaminess, appearance, flavour and texture in food. However, excessive intake of fats may cause obesity, coronary heart disease, high blood cholesterol and diabetes. Fat replacer may help reduce the fat content in food while retaining the sensory properties because it has some or same function as fat. The aim of this research was to investigate the effect of ingredient formulation with papaya sauce as fat replacer in butter cake. Amounts of butter, fresh milk, and papaya sauce were the independent variables. Papaya was chosen as a fat replacer due to the presence of pectin. The dependent variables were firmness and fat content of the cake. Cake slices with 25 mm × 25 mm × 25 mm dimensions were prepared after the cake cooled for one hour at room temperature. It was observed that by varying substitution level of papaya sauce in the formulation, the texture of the cake was affected. The texture profile analysis of butter cakes showed that the cakes become softer with increasing amount of papaya sauce and decreasing amount of milk in the formulation. The replacement of fat by substituting with other ingredient affected the gluten development in cake that in turn influenced the texture. Hence, it is concluded that increasing substitution of papaya sauce affects the firmness of cake.

Keywords: Butter cake; fat replacer; ingredient; papaya; texture.

1. Introduction

Fat is an important component of various food products such as chocolate, ice cream, biscuit, cake, and bread because it plays a vital role in imparting flavour, aroma, taste, and mouthfeel of food [1]. Intake of fat in our diet is important to our body as it helps in growth, development, and maintaining our health [2]. Fat provides the most energy which is 9 kcal/g compared to protein and carbohydrate which give only 4 kcal/g of energy [3, 4]. Thus, fat will increase the energy density of the food and enhance absorption of the fat-soluble vitamins such as vitamin A, D, E and K [2].

The main ingredients in the cake are flour, sugar, oil/fat and eggs. Generally, cake contains 20% to 50% of fat and 10% to 30% of sugar [5]. This recipe formulation shows that fat is a major ingredient in producing cake. Although fat has many benefits and functions, excessive intake of fats will cause obesity, coronary heart disease, high blood cholesterol, dental caries, diabetes and gallbladder disease [6]. Hence, fat replacer helps to reduce those disorders which are caused by excessive intake of fat as it helps to reduce the fat and calorie contents in food [6]. Fat replacers can be classified into three main sources such as carbohydrate-, protein- and lipid-based fat replacers [7,8]. Fat replacers have some or same function as the normal fat [9] and can be categorised into two groups which are fat substitutes and fat mimetics [10]. Fat substitutes have the same physiochemical properties like fats while fat mimetics are usually carbohydrate- or protein-based and have chemical structures which are distinctly different from fat [7].

A study found that papaya can be used in the baked product as carbohydrate-based fat replacer [8, 11]. Papaya puree helps to lower trans-fatty acid and total fatty acid in baked foods and also increase overall nutritional value [8]. Papaya (*Carica papaya Linn*) is considered as one of the tastiest and healthiest foods because it contains vitamins A, vitamin C, thiamine, potassium, magnesium, iron, calcium, and riboflavin [12,13]. Previous research showed that the unripe papaya has

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0.28% fat, 0.47% protein, 6.37% carbohydrate and 8.2% total ash as compared to ripe papaya which contains 0.18% fat, 0.39% protein, 8.30% carbohydrates and 6.1% total ash [14]. This shows that ripe papaya has lower fat and high carbohydrate content compared to unripe papaya. According to National Key Economic Areas, papaya is one of the six high-value and non-seasonal tropical fruits [15]. There are currently two popular papaya varieties in Malaysia namely Eksotika and Sekaki [16].The two types of papaya differ in size, flesh colour and sugar content as shown in Table 1.Sekaki papaya is of more preference in Malaysia due to red flesh and medium size [17].

Table 1 Differences between Eksotika and Sekaki papaya [18].

Criteria	Eksotika	Sekaki
Size	Small to medium between 400 to 800 grams	Medium size fruit 1.5 kg –2 kg
Flesh Colour	Orange	Red
Sugar Content	12°Brix to 14°Brix	Less than 10 °Brix

Papaya consists of protein digesting enzymes such as chymopapain and papain. Both enzymes can reduce inflammation and help healing from burns [19].The nutrients such as vitamin C, folate, vitamin E, and beta-carotene in papaya help to prevent colon cancer as the papaya's fibre binds with the cancer toxins in the colon [20]. Thus, these nutrients provide protection for colon cells to prevent free radical damage to their deoxyribonucleic acid (DNA) [21].The folic acid in papaya helps to prevent heart attack and stroke because folic acid changes homocysteine, which affects blood vessel walls and lead to heart attack or stroke, into cysteine or methionine [21].

The global production of papaya was 11.22 million metric tonnes in 2010 [22]. However, papaya is a highly perishable fruit that easily leads to wastage due to postharvest losses such as fruit over ripening, mechanical injury, parasitic diseases and physiological disorders [23]. Tropical fruits will have shorter shelf life normally few days to a week depending on the storage condition and maturity of the fruit [24]. The papaya skin changes from yellow-green to yellow and softens after harvest. The fruit easily gets spoiled during the peak harvesting period due to excessive production [24]. Previous research found that papaya normally has four to six days shelf life at ambient temperature between 25°C to 28°C or three weeks shelf life when placed at lower storage temperatures between 10°C to 12 °C [25]. However, papaya fruit begins latex oozing, browning at the surface, delayed ripening, and rubbery pulp texture when stored at temperature above 32.2°C [26]. The aim of this paper is to utilize the papaya fruit as an ingredient and investigate its effect as fat replacer in butter cake.

2. Methods

2.1 Butter cake preparation

The research process can be divided into two stages. At the first stage, Sekaki papayas were allowed to ripen at 20°C to 25°C room temperature and were checked daily. Papayas with same maturity level which changed their skin to fully yellow reddish (Table 2) were washed with water to remove any impurities. Then, the papayas were peeled and the seeds were removed. Sekaki papayas were cut into pieces to make papaya sauce by adding 206 grams sugar, 100 grams water and 55 gram of lemon juice into blender (HR 2102, Philip, Netherland) Then, it was homogenised into liquid form as sauce [27], heated slowly on stove for 15 minutes, allowed to cool and placed in a refrigerator (6.35±2.03°C).

Table 2 Ripening index for Sekaki papaya [28].

Stage of ripeness	Characteristics
1	Fully dark green
2	Green with yellow strip
3	Green to yellow
4	Yellow to green
5	Yellow with some green
6	Fully yellow reddish

For the second stage, the mixture formulation data of papaya sauce, butter, and fresh milk were generated using Design Expert® software given the responses such as

firmness and fat content in cake as shown in Table 3.

The control recipe for butter cake ingredients were listed in Table 4. An oven (EEO-E6090, ELBA, Malaysia) was preheated to 180°C. Creaming method is usually used for butter cake production [29]. First, all the ingredients were measured using a weighing balance (FX-300i, AND, United State) at controlled room temperature of 20°C to 25°C. Fat and sugar were mixed using an electric mixer (MK-GB1WTZ, Panasonic, Japan) until fluffy and light at moderate speed for 8 to 10 minutes. Then, egg was added gradually and mixing was continued for another five minutes. All the dry ingredients such as superfine flour and baking powder were added into the mixer. After the dry ingredients were mixed, vanilla essence was added into the batter. Lastly, the batter was poured into a tray and baked at 180°C for 35 minutes [29]. After baking the cakes, a toothpick was put into the centre of the cake to test the cake doneness. If the toothpick comes out clean, it indicates that baking is complete. The cake was left at room temperature for one hour for cooling prior to analysis.

Table 3 Formulations of butter cake.

Formulation	Papaya sauce (g)	Butter (g)	Fresh Milk (g)
Control	0	102	90
1	32	32	128
2	192	0	0
3	128	32	32
4	96	96	0
5	32	128	32
6	64	64	64
7	0	0	192
8	96	0	96
9	0	192	0

Table 4 Standard butter cake recipe [30].

Ingredients	Amount (g)
Superfine flour	146
Castor Sugar	135
Baking Powder	2.99
Butter	102
Vanilla Essence	0.61
Whole Egg	98
Fresh Milk	90

For low-fat butter cake formulation, all the ingredients remain the same as Table 4 except for the amount of fresh milk and butter. In this design, the effect of three factors such as papaya sauce, butter, and milk were evaluated by changing the amount simultaneously and keeping their total weight of 192 grams as constant which is the total weight of butter and fresh milk in the original formulation.

2.2 Texture profile analysis

Low-fat cake and butter cake firmness was measured by using the Texture Analyser (TA-XT plus, Stable Micro System, UK). After the cake cool for one hour at room temperature, the inner parts of the cake slices with 25 mm × 25 mm × 25 mm dimensions were prepared as in Fig. 1 [31]. The force by which the cake was compressed by 50% at a speed of 2 mm/s for first was measured [31]. A 2-cm diameter aluminium cylindrical probe was used to measure the texture of the cake [32]. The measurements were carried out in triplicate. The maximum peak force value in the graph was recorded for each cake formulation, and the average force was calculated and expressed in Newton unit (N).

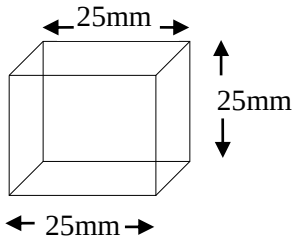

Fig. 1 Size of each cake.

2.3 Total fat

Fat content was determined by using Soxhlet solvent extractor (SER 148 Series, VELP Scientifica, Italy) [33]. 5 g of sample undergone acid hydrolysis in Hydrolysis Unit 6 (VELP Scientifica, Italy) at 170°C for 60 minutes and was dried in an oven for 3 hours. The extraction was carried out by immersing sample in petroleum ether at 110°C for 60 minutes then, washed for another 60 minutes. After extraction, the remaining residue was oil and some moisture. The residue was dried in an oven for 16 hours and the weight of dried sample was measure and calculated as in Eq.1.

$$\text{Fat content, \%} = \frac{W2-W1}{W3} \times 100 \quad (1)$$

Where;
W1= Weight of extraction flask
W2=Weight of extraction flask with fat
W3= Weight of sample

2.4 Statistical Analysis

Interaction effect between fat sources on fat content and firmness in butter cake were analysed either synergism or antagonism by Design Expert® software and from calculation. When the combination response is greater than predicted value and owns positive term, then the combination was classified as synergistic. The combination was categorised as antagonistic when the combination produces less than the predicted value, and additive indicates combination response equal to predicted value [34]. Predicted value was calculated as in Eq.2 [35].

$$E = X*Y /100 \quad (2)$$

Where;
E= Expected result of mixture A and B
X= Effect of A ingredient applied alone
Y= Effect of B ingredient applied alone

3. Results and Discussions

Comparing the results, the butter cake made from formulation 4 (96 grams of papaya sauce and 96 grams of butter) had the closest firmness value with that of the control as shown in Fig. 2. This sample, however, had a little higher fat content than the control formulation (Table 5).

The results show that firmness increased by reducing fat content in baked product [36]. The dough became hard due to insufficient fat that contributes to the fluidity and plasticity of the dough [37]. Ripe papaya has the potential to replace fat in cake due to the pectin, fibre and sugar content which has similar function as that of fat [8]. Reducing the amount of fat by substituting the ingredients imparting the fat component to the cake led to smaller crumb cell size which in turn affected the cake texture [38]. Flour particles covered with fat affect the development of gluten and the cake becomes softer. Increase in firmness may be due to the molecular entanglements between gluten proteins and fibre [39]. Cakes containing fibre source possess firmer texture because of the interactions among the swollen starch granules, fibre and the protein network which actively contribute to crumb firmness [40].

As shown in Fig. 2, formulations 5 and 9, with the highest butter content, were less firm and had high fat content. This is because when creaming sugar and butter, the sugar crystals produced tiny pockets of air in the butter that helped in dough expansion upon baking [40]. This shows that the free fat from butter disrupted the gluten network resulting in softer dough and a softer texture [41].

Formulation 1 and formulation 7 with high milk substitution in butter cake helped to enhance the development of gluten and gelatinisation of starch in the flour, thus, it had the highest value of firmness. Milk also contains proteins which act as a structural enhancer [42]. However, too much liquid will cause a baked good to collapse or the batter to become too thin.

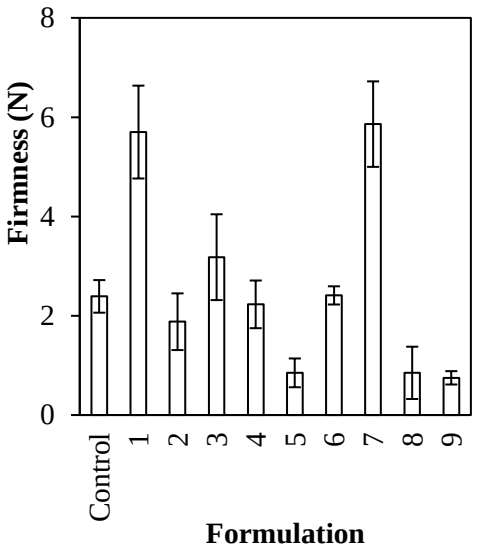

Fig. 2 Firmness and fat content of all cake formulations.

Table 5 Fat content of all cake formulations.

Formulation	Fat Content (%)
Control	28.77 ±0.02
1	32.33 ±0.20
2	37.47 ±0.08
3	38.03 ±0.29
4	34.40 ±0.12
5	42.10 ±0.08
6	34.27 ±0.28

7	37.13 ±0.13
8	34.63 ±0.11
9	45.83 ±0.33

Table 6 shows that the cake firmness, which contains butter and fresh milk, and papaya sauce and fresh milk own antagonistic interaction effect. This finding indicates that the cake firmness of the combined ingredients are less firm. Combination of papaya sauce and butter had synergistic effect, where this condition led to increase in cake firmness.

Table 7 shows the combinations of butter and fresh milk, as well as papaya sauce and butter have antagonistic interaction effect. This condition indicates that both combinations causes low fat content of cake. The mixture of papaya sauce and fresh milk owns an additive effect since the value of predicted and test value are comparable. The additive interaction means that the effect of two ingredients is equal to the total effect of each ingredient.

Table 6 Interaction effect between fat source on firmness of cake.

Fat source	Firmness (N)			Interaction Effect
	Predicted Value	Test Value	Sign	
Butter and fresh milk	3.29	2.39	Negative	Antagonistic
Papaya sauce and butter	1.18	2.23	Positive	Synergistic
Papaya sauce and fresh milk	3.94	0.46	Negative	Antagonistic

Table 7 Interaction effect between fat source on fat content of cake.

Fat source	Fat Content (%)			Interaction Effect
	Predicted Value	Test Value	Sign	
Butter and fresh milk	41.81	28.77	Negative	Antagonistic
Papaya sauce and butter	41.98	34.40	Negative	Antagonistic
Papaya sauce and fresh milk	36.69	36.30	Positive	Additive

4. Conclusion

Substitution of papaya sauce as a fat replacer helped to reduce the amount of fat present in the cake while improving the sensory property, specifically the texture, of butter cake. Combination of papaya sauce with butter in the formulation resulted in soft texture of cake, comparable with that of the control. However, complete substitution with papaya sauce led to a not significantly different texture with that of the control. Milk was the primary ingredient which contributed much to the increase in firmness as it contains proteins which may aid in the gluten development. Results of the experiments showed that substituting the ingredients which contains the fat component in a formulation could significantly affect the texture of food products. Overall, the results showed that papaya sauce can be utilised as an ingredient in cake and similar products as fat replacer without compromising the textural properties of the product.

Acknowledgements

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