Food Research 6 (3) : 254 - 261 (June 2022)
Journal homepage: https://www.myfoodresearch.com

FOOD RESEARCH

FULL PAPER

Conversion of leftover ice cream into bakery product for food sustainability

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Article history:
Received: 8 June 2021
Received in revised form: 10 July 2021
Accepted: 3 October 2021
Available Online: 5 June 2022

Keywords:
Ice cream,
Food by-products,
Sustainability,
Innovative food formulations,
Gastronomy

DOI:
https://doi.org/10.26656/fr.2017.6(3).410

Abstract

Food sustainability has become so important nowadays not only in order to ensure all raw materials are converted into food for consumption, but also to recycle leftover food for gastronomy. The innovative product created from leftover or unfinished food is a good alternative to throwing away food by-products. In this study, the unutilized ice cream post -selling or post-production process was reformulated with other ingredients to produce bakery products such as cake. Four different cake formulations were used which consisted of melted leftover ice cream, instant cake mix and eggs. The physical qualities of the samples were investigated, and sensory evaluation was also conducted. Cake made conventionally from instant cake mix without the addition of the leftover ice cream was used as a control sample in this study. Cake produced from melted ice cream using three eggs (sample A) had the highest moisture content among all samples which was 39.09%. The control sample had the highest specific volume (2.99 cm^3/g) which indicated a high amount of air remained in the structure after baking. All samples showed a positive symmetry index which indicated good expansion except for cake produced from melted ice cream with no egg (sample D). Cake produced from melted ice cream with no egg (sample D) had the lowest firmness as compared to other cake samples. Cake produced using melted ice cream which contained two eggs (Sample B) had the highest value of springiness which was 0.94 mm. A plot of chewiness as a function of firmness with an R^2 value of 0.9887 confirms the positive correlation between firmness and chewiness. From the sensory evaluation conducted, the cake produced from melted ice cream using three eggs (sample A) scored the highest mark for colour, aroma, sweetness, taste and overall acceptability among the formulated cakes. The results suggested that using melted ice cream as the base ingredient for cake making would tremendously help in solving food waste created by the by-product of the ice cream business and turn it into profit.

1. Introduction

Ice cream is an enormously popular food and is known for its soft texture, temperature sensitivity and creamy mouthfeel (Rahman *et al*., 2013). The term "ice cream" in its broadest sense covers a wide range of different types of frozen desserts. The main ones are dairy ice cream, non-dairy ice cream, gelato, frozen yoghurt, milk ice, sorbet, sherbet, water ice and fruit ice (Clarke, 2012). What all these have in common is that they are sweetened, flavoured, contain ice and, unlike any other frozen food, they are normally eaten in the frozen state. Today, ice cream is found in almost any restaurant, or corner store, and is recognized globally as the perfect summer treat. Textural attributes of ice are the key factors determining the market success of the product. Many industries manufacture ice cream at a global level such as Unilever and Nestlé. The global ice cream market is forecasted to grow at a compound annual growth rate (CAGR) of 2.87% from 2020 until 2026 (Mordor Intelligence, 2021).

In Malaysia, the consumption trends have evolved and grown from traditional ice confection made by

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eISSN: 2550-2166 /
Published by Rynnye Lyan Resources

simply freezing the mixture of flavoured syrup and water, into churned gelato and artisanal premium ice cream. The lifestyles of the consumers nowadays lead to the types of ice creams sold in shops and online platforms. International premium brands such as Häagen-Dazs, Baskin Robbins and Ben and Jerry have penetrated the Malaysian market since long ago. Consumers demand good quality frozen desserts to be indulged. This had led to the emergence of local premium ice cream brands such as The Ice-Cream Project, Sangkaya, Softsrve and Inside Scoop (TallyPress, 2016).

Ice cream typically has more than 10% milkfat by legal definition and generally between 10% and as much as 16% fat in some premium ice creams, 9 to 12% of milk-solid-non-fat (also known as serum solids) which consists of proteins (caseins and whey proteins) and carbohydrates (lactose) found in milk, 12-16% sweeteners or sweetening agents that are usually a combination of sucrose and glucose-based corn syrup sweeteners, 0.2 to 0.5% of stabilizers and emulsifiers, and 55 to 64% of water which comes from milk or other ingredients (Clarke, 2004; Goff and Hartel, 2013). These percentages are by weight, either in the mix or in the ice cream. Ice cream can be categorized based on its fat content i.e., low-fat (3-5% fat), light (6-8%) and hard- or soft- frozen ice cream (more than 10% fat) (Parid *et. al*., 2020).

In the ice cream business, there are days when the retailers are unable to finish the ice cream inside the machine. The leftover ice cream is normally kept inside the chiller to be reused for the next production. Cold weather is one of the factors that lead to ice cream being leftover. For example, an ice cream shop is often faced with a dwindling number of customers during the winter season. When sub-zero temperatures start creeping in, ice cream shops tend to see fewer and fewer customers walking through the door (RMagazine, 2017). People tend to crave hot or warm food instead of ice cream during winter. When the weather is cold, eating or drinking something hot increases the sensation of being warm (Styles, 2018). Thus, the possibility of ice cream not being consumed by customers in the winter season is high and at the end of the night shift, the shops face ice cream leftover. Another important issue to be considered is the occurrence of power shutdown at the shop which leads to the melting of ice cream.

The breakdown of ice and air bubble structures in melted ice cream causes a major change in ice cream quality. The fat droplets eventually melt and if the melted ice cream is directly reused again to make ice cream, the ice cream produced becomes hard as the fat droplets are not well distributed in the matrix and do not hold the air bubbles properly. This compromises the texture and causes the ice cream to melt faster. In some cases, the leftover is reused again for the next production where it is combined with a new batch of ice cream mixture and processed in an ice cream machine.

Reusing the leftover ice cream for the next day may lead to an unpleasant taste of ice cream which may affect the shop's reputation. There are several articles on the general practices of reusing the ice cream leftover. In dessert kitchens, there are special ice cream machines for "reworking" yesterday's ice cream, whereby, in other words, melting it down, remixing and refreezing the ice cream without it forming ice crystals (Professional Secrets, 2021). A forum on the internet shared how gelato shops handled leftover ice cream. One of the gelato shops' practices is to resell the leftover ice cream the next day but this can be done not more than two days. At the end of the second day, any unsold gelato is given to employees to be taken home or thrown out (Quora, 2021).

However, there is another interesting method that can be done for the leftover ice cream. The leftover ice cream in melted form can be innovatively reformulated with other ingredients to produce bakery products. Ice cream leftover seems to have a huge potential to be converted into value-added baked goods such as cookies, cake, muffins and bread (Wheeler, 2020). It can also be converted into custard, mousse and glaze. Even though there is no available research study made on the treatment and handling method of leftover ice cream, the availability of various articles and online websites on how to creatively innovate the leftover ice cream into amazing food products are helpful in understanding the handling of its by-product. Most of the applications suggested are usually practical for small-scale ice cream parlour businesses that would help them to generate profit from the conversion of leftover food or food waste into the new food products.

Ice cream consists of ingredients that are similar to the ones in cake i.e., fat, protein, sugar, emulsifier, stabilizer and water. The melted ice cream cake needs further addition of emulsifier i.e., eggs to produce cakes of similar quality as the conventional cakes. In this study, the outcomes of the innovative formulation that relates to science and gastronomy i.e. the product's physical and textural properties and acceptance of its taste are observed. Hence, the objectives of this work were to investigate the effects of different leftover ice cream-cake formulations on the physical, textural and sensorial qualities of cakes produced from melted leftover ice cream.

eISSN: 2550-2166

2. Materials and methods

2.1 Ice cream preparation

The ice cream formulation was prepared and adjusted based on the formulation reported by Rahman *et al*. (2019) i.e., 60.9% w/w of water, 14.5% w/w of skimmed milk, 16.3% w/w of sugar, 3.6% w/w of whey powder, 3.6% w/w of creamer, 0.4% w/w of emulsifier, 0.3 w/w of stabilizer and 0.4 w/w of vanilla flavouring. Full cream milk, sugar, whey powder, creamer and flavouring were obtained from local suppliers. The emulsifier used was Olein PK-10 (BIS Chemicals, Shah Alam, Malaysia) and the commercial stabilizer was purchased from Warisnove Sdn. Bhd.

All the ingredients were weighed and blended together into a liquid mix by using a commercial mixer (Model 5K5SS, KitchenAid, St Michigan, USA) for five minutes until an apparent homogenous mixture was obtained. The dry ingredients were dispersed under agitation into wet ingredients at room temperature by manual stirring. The mixture was then batch pasteurized at 80ºC for 15 s and consequently made to go through the two-stage homogenization process using a laboratory -scale homogenizer. Then, the liquid ice cream mixture was rapidly cooled at a constant temperature of 4ºC overnight for ageing. The aged mixture was then freeze-churned using a home-style batch ice cream machine (Breville, Model BC1600, Australia) which has a maximum capacity of 1 L. The fat, milk solids-non-fat (MSNF) and total solid contents of the final ice cream are 3.0%, 7.4%, and 30.3%, respectively.

2.2 Melted ice cream preparation

To imitate the situation that happens in an ice cream store or shop, after the freezing process had been completed, the ice cream was taken out from the batch ice cream freezer. The vanilla ice cream was then allowed to melt in a chiller which was about 4°C for 12 hrs. The ice cream was expected to melt completely during this period whereby a complete breakdown of the ice cream structure takes place. Since the ice cream shops typically close at 10 PM and open at 10 AM on the next day, thus, this period was chosen as the control period to keep the leftover ice cream until it is reused on the next day.

2.3 Preparation of cake samples

The recipe used for making a cake from melted leftover ice cream was adapted from (Brandie, 2019). The ingredients used to make the formulated cakes were instant sponge cake mix (Dr Oatker by Nona, Malaysia), melted leftover vanilla ice cream and eggs. The instant cake mix was used to get the simplest cake made from melted ice cream that is convenient for anyone to do. Four suggested formulations for making cakes are listed in Table 1. A cake made from instant cake mix without the addition of leftover ice cream was used as a control sample in this study. The control sample required 5 eggs, 100 g butter and 100 ml water as written on the package. The number of eggs used in the formulated cake varied between 0-3 eggs. From the preliminary work conducted beforehand, adding 4 eggs into the formulation will cause the cake batter to become runny and the cake does not form well after baking.

Table 1. Formulations of cake from melted leftover ice cream

Formulation	Ingredients
A	1 box of instant cake mix 2 cups of melted ice cream 3 eggs
B	1 box of instant cake mix 2 cups of melted ice cream 2 eggs
C	1 box of instant cake mix 2 cups of melted ice cream 1 egg
D	1 box of instant cake mix 2 cups of melted ice cream 0 eggs

1 box of instant cake mix is equivalent to 400 g while 2 cups of melted ice cream equal to 445 g.

For each cake from the melted leftover ice cream formulations, the instant cake mix and melted ice cream were weighed using an electronic balance. Instant cake mix and melted ice cream were poured into a mixing bowl and mixed for 4 to 5 mins. Eggs were gradually added and mixing continued for another one minute at the slowest speed to minimize gluten formation. After all the ingredients were mixed, the mixture was poured into a tray and baked at 180°C for 45 mins as per the instruction on the packaging. The pan used for the cake sample was square in geometry with the dimension of 6.5 cm (height) × 21 cm (length) × 21 cm (width). The baked cake was then allowed to cool for 30 mins in the oven before it was taken out. The control sample was produced in a similar manner.

2.4 Physical, textural and sensorial analyses of cakes

The characteristics of a well-baked cake are a uniform shape, large volume, tender crust, fine texture, delicate taste, and a well-blended flavour. Analyses were conducted to relate the gastronomic criteria to the scientific data obtained from the study. The moisture content of all cakes was determined using a moisture analyzer (AND MX-50, A and D Weighing, Japan). The volume index of cakes was measured according to the method explained by Rahmati and Tehrani (2014). Cakes were cut vertically through their centre and the heights of the samples were measured at three points (B, C, D) along the cross-sectioned cakes using the template as shown in Figure 1. C is the height of the cake at the centre and B and D are the heights of the cake sample at points 2.5 cm away from the centre towards the left and right sides of the cake, respectively.

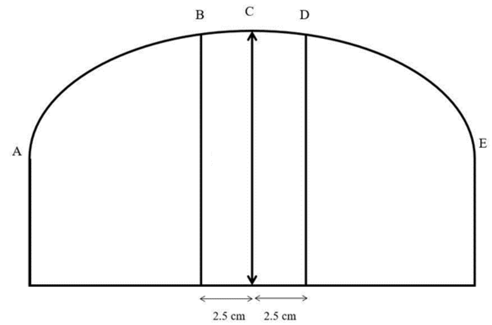

Figure 1. The position of points on cake to enable calculation of cake morphology

Volume index was calculated by the following equation:

Volume index = B + C + D (1)

Contour and symmetry indices were calculated using the following equations:

Contour = 2C−B−D (2)

Symmetry = B−D (3)

A positive symmetry index shows that the cake rises more in the central area, while a negative symmetry index indicates that the central area of the cake has fallen during the final part of baking or during cooling. The volume of the cake was calculated based on the dimension of the pan except for the height. The equation used was as follows:

Cake volume = height of cake (h_{cake}) × length of pan (4)

The cake height was calculated by taking the average 5-point height (ABCDE) of the cake as shown in Figure 1 previously:

Cake height = [$h_{cakeA} + h_{cakeB} + h_{cakeC} + h_{cakeD} +$ (5)

Cake density was measured by dividing the mass of the cake by its volume.

Cake density, ρ (g/cm^3) = m_{cake} / V_{cake} (6)

Where, m represents mass (g), V represents volume (cm^3), and ρ represents density (g/cm^3).

Specific volume is the amount of air that remains in the final product. High gas retention and high gas expansion of the product lead to a high specific volume. Cake specific volume was calculated by dividing the volume of the cake by its mass:

Specific volume = V_{cake} / m_{cake} (7)

A texture analyser (TA.XT Plus, Stable Micro System, England) was used for obtaining the texture profile analysis (TPA) of the samples. The dimension of the samples used was 25 × 25 × 25 mm. The penetration depth at the geometrical centre of the samples was 50 mm and the penetration speed was set at 1.0 mm.s^{-1}. For each sample, three measurements were carried out using a 36 mm diameters cylindrical probe. The texture parameters taken for this study were firmness, springiness, chewiness and cohesiveness.

For sensory evaluation, a hedonic test (5-point scale) was carried out by twenty untrained panellists. All cake samples made from melted leftover ice cream including the control sample were evaluated. The samples were labelled as A, B, C, D and E (control). The sensory characteristics evaluated were crust colour, aroma, softness, sweetness, taste and overall acceptability of the innovative cake. The output obtained from the evaluation would enable us to get ideas on the acceptance of the innovative cake and how we could improve its quality.

3. Results and discussion

3.1 Physical qualities of cakes

Table 2 shows the physical characteristics of the cake produced from melted leftover ice cream and the control sample. Sample A had the highest moisture content while sample D displayed the lowest moisture content which was 39.09% and 32.54%, respectively. Eggs and sugar are known to influence moisture retention during mixing and baking. The egg yolk itself contributes protein, some fat, flavour, and emulsifying lecithin. Emulsifiers are one of those agents that hold together water and fat. Thus, adding more eggs to the batter enables the batter to hold extra liquid and consequently extra sugar.

All the formulations containing melted ice cream possessed high moisture content with about the same amount as in the control sample. This is mainly due to the availability of stabilizers in melted ice cream composition. A stabilizer has the ability to bind and retain water in food. Sample D had the lowest moisture content due to the eggless formulation. Although the amount of sugar in the ice cream was the same for all cakes made from melted ice cream, the absence of eggs may have a high effect on the water absorption. The presence of sugar in the cake alone without eggs was not strong enough to hold the water and caused high water losses during baking. This result is supported by Lin *et al*. (2017) who stated that eggless cakes showed lower moisture contents.

The volume index of the cake indicates the amount of air entrapped in the cake. Although high volumes do

Table 2. Physical quality parameters of cake produced from melted leftover ice cream and control sample.

Physical characteristics	Types of Formulations				
	Control	A	B	C	D
Moisture (%)	35.32±0.47	39.09±0.31	33.18±0.52	34.20±0.30	32.54±0.75
Volume index (cm)	22.53±0.91	17.92±0.60	16.42±0.10	16.78±0.70	13.77±0.58
Contour (cm)	0.77±0.06	0.38±0.19	0.88±0.38	0.62±0.11	-0.47±0.15
Symmetry index (cm)	0.17±0.06	0.15±0.05	0.12±0.03	0.08±0.03	-0.13±0.06
Density (g/cm^3)	0.34±0.02	0.48±0.01	0.47±0.01	0.43±0.03	0.45±0.02
Specific volume (cm^3/g)	2.99±0.16	2.09±0.05	2.14±0.04	2.32±0.17	2.22±0.11
Texture Physical Analysis					
Firmness (N)	4.13±0.24	3.66±0.45	4.11±0.16	4.14±0.83	3.35±0.54
Springiness (mm)	0.92±0.02	0.90±0.03	0.94±0.03	0.92±0.01	0.71±0.08
Chewiness (N.mm)	2.67±0.07	2.03±0.26	2.63±0.14	2.57±0.53	1.49±0.38
Cohesiveness (-)	0.69±0.01	0.61±0.02	0.68±0.01	0.67±0.01	0.62±0.04

A: Cake produced from melted ice cream with 3 eggs, B: Cake produced from melted ice cream with 2 eggs, C: Cake produced from melted ice cream with 1 egg, D: Cake produced from melted ice cream with no eggs

not always indicate a desirable cake, low volumes generally indicate a heavy and less desirable crumb (Zhou *et al*., 2011). Higher egg content in the control sample caused the volume index to be higher than all the formulated samples. Sample D has the lowest volume index since there was no egg used in the formulation.

Generally, cakes with higher volume exhibited higher central loaf height. Normally, a high contour value indicates a peaked cake while a flat cake would have a low value of contour. Even though Sample A had the highest volume index among all formulated cakes made from melted ice cream, however, it had a lower contour index value (among cakes made using eggs) due to its flatter top surface. Sample D had a negative contour value of -0.47cm which indicated that the top surface had sunken in the middle. The symmetry index was inversely proportional to the number of eggs added. The control sample which contained the highest amount of eggs had the highest symmetry index of 0.17 cm. Sample D which contained no egg had a negative symmetry index of -0.13 cm. The negative value of sample D corresponds to the sunken central area of the cake at the end of the cooling process. Figure 2 illustrates how the cake behaved after the baking process ended.

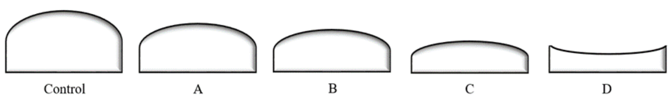

Figure 2. The body formation of cake samples after baking

The addition of egg is important in cake-making as the whipping of egg entraps air bubbles which help in building up the structure of the cake. The exclusion of egg from cake formulation would compromise its structure. The air incorporated by whipping the eggs adds volume to those cakes, making them springy and elastic. It is also necessary to consider the period of whipping eggs to prevent the batter from reaching its limits. Once the limit is reached, the matrix of protein will begin to break down and the foam will collapse (Moncel, 2019). The egg whites will become grainy, watery, and flat. Proper egg whipping technique and time consideration thus affect the batter structure. In addition, an egg is also a rich source of emulsifying agent which facilitates the incorporation of air and inhibits wheat starch gelatinization. Without eggs, the batter's structural framework may become dense as less air is incorporated during the mixing process and the ingredient does not fold together.

It can be seen from the data in Table 2 that the addition of melted ice cream increased the density of the cake with sample A having the highest density. This must be due to its higher ability to retain water. Melted ice cream also contained an emulsifier inside which readily contributed to the increased ability of cakes with melted ice cream to retain water. The specific volume of the control sample showed the highest value of 2.99 cm^3/g as compared to other samples. Cakes produced from melted ice cream displayed significantly lower specific volume than the control sample. The addition of melted ice cream made the formulated cakes denser and led to lower volume expansion.

3.2 Cake texture

The results for textural profile analysis (TPA) for all cake samples are shown in Table 2. The parameter tested were firmness, springiness, chewiness and cohesiveness of the cakes. The firmness of all the formulated cakes of samples B and C were comparable with the one of the control samples. Sample A and D had about the same values i.e., 3.66 N and 3.35 N, respectively. The increase in the softness i.e., the reduction in the firmness was attributed to both an increase in the cake volume and the anti-firming effect of emulsifiers (Zhou *et al*., 2011). The decrease in the number of eggs in melted ice cream

eISSN: 2550-2166

(except for eggless formulation) led to the increase in firmness due to the decrease in porosity. In this case, sample C which contained only one egg had the highest firmness value i.e., 4.14 N. The sugar-egg ratio in the formulation of sample C may not be balanced between them, resulting in excess sugar content. Thus, the cake became firmer as compared to other samples. Sample D with no egg at all had the least firmness value. The lowest value of firmness did not mean that the texture of the cake was soft but it was rather squishy. This may probably be due to the lack of emulsifiers in the cake. The amount of emulsifier inside the leftover ice cream was too little, so it could not retain the structure of the cake strong enough. The egg acts as an emulsifier to combine and bind two substances that normally would not adhere (fat and liquid). Without the presence of eggs, the batter might not have mixed well with other constituents, which leads to the cake structure sinking in the middle (as explained in the previous section) and the cake becomes squishy.

Springiness is a textural parameter related to the elasticity of the sample. Springiness is related to the height that food recovers during the time that elapses between the end of the first bite and the start of the second bite. If springiness is high, it requires more mastication energy in the mouth (Rahman and Al-Mahrouqi, 2009). There were no significant differences in springiness values for each sample which range between 0.90 and 0.94 except for sample D. Thus, this shows that as long as the egg is present in the cake, the varying amount of eggs did not significantly affect the springiness value. Sample D showed the lowest springiness value as compared to other samples. This was due to its low porosity which caused the cake to not expand well.

There is a strong correlation between chewiness and springiness. Low springiness results in little chewiness. Chewiness is defined as the energy required to masticate solid food to a state of readiness for swallowing (Karaoglu and Kotancilar, 2009). The chewiness value of all cake samples varied from 1.49 N.mm to 2.67 N.mm. The data obtained shows that the varying amount of eggs used slightly affects the value of chewiness. Sample D had the lowest chewiness value as compared to other samples. Since no egg was presented, sample D lacked elasticity and therefore required less energy to chew. This relates to its lowest firmness value. However, chewiness is the most difficult parameter to measure precisely, because mastication involves compressing, shearing, piercing, grinding, tearing, and cutting along with adequate lubrication by saliva at body temperature (Bhale, 2004). Chewiness is highly associated with firmness (Rahmati and Tehrani, 2014). A plot of chewiness as a function of firmness (Figure 3) with an R^2 value of 0.9887 confirms the positive correlation between firmness and chewiness. A similar result was reported by Gomez *et al.* (2007) who stated that chewiness is a parameter dependent on firmness.

There was no statistical difference among the data obtained for springiness and cohesiveness of samples and all samples showed satisfactory springiness and cohesiveness values. Cohesiveness means the ability of the material to stick to itself. All samples showed comparable cohesiveness values ranging from 0.61 to 0.69. The control sample had the highest value of cohesiveness as it contained the highest amount of eggs. This is expected for the control sample due to the availability of eggs to hold and retain the structure of the cake during the baking and cooling process.

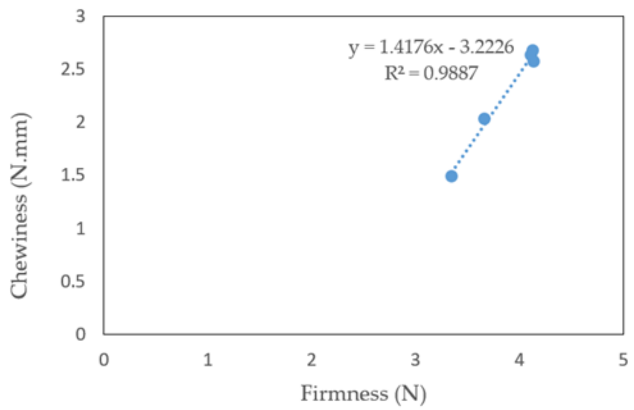

Figure 3. The chewiness is highly correlated with firmness

3.3 Sensory evaluation

The sensory scores are presented by the spider web chart in Figure 4. According to the results obtained, the control sample had maximum overall acceptability. The control sample also obtained the highest scores for aroma, softness, sweetness and taste. This preference by the panelists reflected the physical and texture quality that the sample possessed.

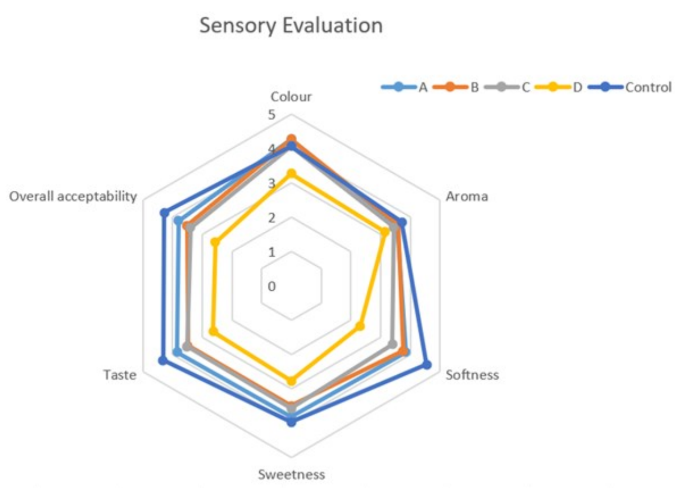

Figure 4. Sensory evaluation results for all cake samples

Sample D obtained the lowest score of overall acceptability (2.56). This was expected due to its lowest score of taste (2.64) as compared to the other cake samples. Sample D also had the lowest score for every sensory characteristic. Besides, the panellists found that the texture of sample D cake was fragile to touch. Its eggless formulation contributes to the least favourable quality due to the low content of emulsifiers in the cake. Sample A obtained the second-highest overall acceptability which reflected its highest score on colour (4.28) and good scores on other criteria (>3.5). Samples B and C had acceptable qualities with scores >3.0 for each criterion. This shows that cake made using melted leftover ice cream has high acceptance quality (except for the eggless formulation). It can be seen from the physical, texture and sensory qualities data, that melted ice cream is able to replace butter and be the source of emulsifier and liquid (that forms batter) in cake formulation.

4. Conclusion

In this study, we were able to innovatively re-formulate leftover ice cream to be converted into the cake. The formulation enables the elimination of butter and water as the melted ice cream already contributes to the fat and water content of the batter. Eggs are required to be added to the formulation as the amount of emulsifier in the melted ice cream is not high. The formulated cake has good moisture content as the melted ice cream contains a stabilizer that helps to bind water and retain moisture. The formulated cake produced has good quality and acceptance level as rated by the panellists. This would be beneficial to any ice cream business to expand their ice cream-based product by innovatively reusing the by-product or leftover off the processing or selling stage.

There are no other studies conducted on the conversion of by-products from ice cream manufacturing into other food products which would lead to possible profit gain for the business. Many factors can affect the characteristics of the cake produced from melted ice cream. For future research on this, apart from varying the number of eggs added, the amount of melted ice cream added to the cake batter could be varied as well to get cakes with improved taste and texture. Besides, the parameters during the baking process i.e., temperature and time of baking could also be varied to get the optimum baking conditions of the formulated cake. Furthermore, studies could be conducted to relate the gastronomy and science of other converted food products derived from melted ice cream such as cookies, custard and glaze; and possibly other frozen desserts.

Conflict of interests

The authors declare no conflict of interest.

Acknowledgements

The authors were grateful for the support from the laboratory staff who helped in handling the equipment for the analyses involved in the research. This study was conducted in the laboratory of the Department of Process and Food Engineering, Faculty of Engineering, Universiti Putra Malaysia.

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