Studies on sensory and textural properties of milk cake using response surface methodology

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Received: 25-10-2017 Accepted: 29-08-2018 DOI: 10.18805/ajdfr.DR-1316

ABSTRACT
Milk cake is one of the most popular traditional sweets of India especially popular in Northern and Central part of India. High sugar content in milk cake poses severe restriction in its consumption. Sucrose was successfully replaced with artificial sweetener sucralose along with addition of bulking agent maltodextrin to provide a characteristic texture to the product. The level of milk fat and sucralose were optimised using response surface methodology. Central composite rotatable design was used with two independent variables i.e. milk fat (3-6%) and sucralose (0.03-0.07%). The optimisation was done on the basis of sensory profile assessment and important textural parameters i.e. hardness and adhesiveness. Milk cake prepared with 6% milk fat and 0.07% sucralose level gave optimised product.

Key words: Milk cake, Response surface methodology, Sucralose, Traditional milk sweets.

INTRODUCTION
Among the various traditional dairy products, khoa and khoa based milk sweets are very popular in India. According to an estimate out of total milk produced about 55 percent is utilized for the manufacture of traditional Indian milk products (Khan, 2006). Milk cake is one of the most popular khoa based traditional Indian delicacies prepared preferably from buffalo milk (Aneja et al. 2002). Varma et al. (2005) found that as the fat level in milk increases the body and texture score of milk cake prepared from cow milk also increases. Kumar et al. (2014) observed that the level of fat in the milk, sugar concentration, corn syrup level and the temperature-time of thermization had significant effect on the sensory properties of the product The product is a rich source of energy, milk proteins, minerals and other growth promoting factors and is characterized by well-defined grains having more pronounced caramelized flavour and comparatively more intense colour than that of kalakand (Varma et al. 2005). The brown colour is darkest at the center of the milk cake which spreads outward and then fades toward peripheral regions. Proximate composition of a good quality milk cake is as follow: 19% fat, 10% protein, 13% lactose, 42% sucrose, 1.9% ash and 17% moisture (Landge et al. 2012).

In 2005, an estimated 1.1 million people died from diabetes, with the number likely to be doubled by the year 2030 (WHO, 2009). As a result of growing consumer awareness about the adverse effect of sugar on health, modern health conscious consumers are looking for the low-sugar or sugar-free Indian traditional dairy products. The use of low calorie sweeteners like sucralose, saccharin, aceulfame-K and aspartame in traditional Indian milk products have been permitted first time in the year 2004 (PFA, 2004). Sucralose is 600 times sweeter than sucrose (Varzakas et al., 2012) but the human body does not recognize it as a sugar and does not metabolize it, thus provides sweetness but no calories (Morlock and Prabha, 2007).

The objective of this study was to investigate the influence of varying level of milk fat and sucralose on the sensory and textural properties of milk cake and also to standardize the optimum percentage of various ingredients.

MATERIALS AND METHODS
Raw materials: Raw milk was procured from the experimental dairy plant, College of Dairy Science and Technology (CODST), GADVASU Ludhiana. Sucralose (Natura) was purchased from Zydus Wellness Ltd., Sikkim, India and bulking agent maltodextrin from Sukhjit Starch and Chemicals Ltd., Phagwara, Punjab, India.

Experimental design: The Central composite rotatable design (CCRD) of Response Surface Methodology was used to design the experimental combinations (Modha and Pal 2011). The experiment was designed using software Design Expert version 8.0.3. Response surface methodology was used to study the effect of two variables i.e. fat percent of milk (3-6%) and sucralose level (0.03-0.07%) in each experiment. The range of variables were selected based on preliminary trials. Experiments were planned using CCRD which gave 13 designed runs with 4 factorial, 4 axial and 5 center point (Table 1). For analysis of experimental data, it was assumed that k-mathematical functions,
was $ij^{th}$ interaction coefficient and $XiXj$ were independent variables. Maximization and minimization of the polynomials thus fitted was done using the numerical optimization technique as given in software package (Design Expert® Version 9.0.3.1). The goals are combined into an overall desirability function. The mapping of the fitted response was achieved using software. The response surfaces for the models were plotted as a function of the two given variables.

RESULTS AND DISCUSSION

The minimum and maximum values of the responses representing different combinations of level of milk fat and sucralose used for milk cake preparation are marked in Table 2.

Diagnostics checking of fitted data: The linear, quadratic and interactive effects were calculated for each model. The adequacy of the model was analyzed using F-value, coefficient of correlation ($R^2$) and lack of fit test (LoF) (Table 3). The models were considered adequate when the $R^2$ value was more than 80%, and LoF was non-significant (Henika 1982, Khuri and Cornell 1987). The coefficient of correlation for the responses, i.e. sweetness, texture, flavour, overall acceptability, hardness and adhesiveness were 0.9305, 0.8150, 0.9352, 0.9447, 0.9988 and 0.9552 respectively. As all these values were more than 80% and the LoF test was non-significant therefore, it was concluded during diagnostic checking of data that the developed model appropriately explained the variability in responses due to change in level of independent variables.

Effect of variables on sensory properties of milk cake

Sweetness: The sweetness scores varied from 6.7 to 8.4 (Table 2). Fig 2(a) clearly indicates that with increase in level of milk fat and sucralose the sensory scores for sweetness increased. The positive value of regression coefficient also endorses the above statement. Effect of variables on sensory score of sweetness could be appropriately explained by the following equation:

$$\text{Sweetness} = 7.28 + 0.23X_1 + 0.51X_2 + 0.33X_1X_2$$

Table 1: Experimental design matrix for milk cake preparation and levels in coded and uncoded form.

| Exp No. | Coded Variables | Uncoded Variables |
|---------|-----------------|-------------------|
|         | $X_1$           | $X_2$            | Milk Fat % | Sweetener % |
| 1       | -1.141          | 0                | 2.4        | 0.05        |
| 2       | 1.414           | 0                | 6.6        | 0.05        |
| 3       | 0               | 0                | 4.5        | 0.05        |
| 4       | 1               | -1               | 6          | 0.03        |
| 5       | 1               | 1                | 6          | 0.07        |
| 6       | 0               | -1.141           | 4.5        | 0.02        |
| 7       | 0               | 0                | 4.5        | 0.05        |
| 8       | 0               | 0                | 4.5        | 0.05        |
| 9       | -1              | 1                | 3          | 0.07        |
| 10      | 0               | 1.414            | 4.5        | 0.08        |
| 11      | -1              | -1               | 3          | 0.03        |
| 12      | 0               | 0                | 4.5        | 0.05        |
| 13      | 0               | 0                | 4.5        | 0.05        |
Table 2: Sensory and textural properties of milk cake.

| Exp No. | Sweetness | Texture | Flavour | Overall acceptability | Hardness(Kg) | Adhesiveness(g.s.) |
|---------|-----------|---------|---------|-----------------------|--------------|-------------------|
| 1       | 7.3       | 6.8     | 7       | 7                     | 4.5          | 0.58              |
| 2       | 7.7       | 7.5     | 8       | 7.7                   | 6.8          | 0.732             |
| 3       | 7.3       | 7.6     | 7.5     | 7.5                   | 5.9          | 0.69              |
| 4       | 6.7       | 7.7     | 7.3     | 7.2                   | 6.5          | 0.706             |
| 5       | 8.4       | 8.2     | 8.5     | 8.4                   | 6.55         | 0.713             |
| 6       | 6.6       | 8.1     | 7.2     | 7.3                   | 5.77         | 0.623             |
| 7       | 7.3       | 7.6     | 7.6     | 7.5                   | 5.89         | 0.68              |
| 8       | 7.2       | 8.1     | 7.3     | 7.5                   | 5.86         | 0.687             |
| 9       | 7.1       | 7.6     | 6.7     | 7.1                   | 4.9          | 0.6               |
| 10      | 8         | 8.1     | 8       | 8                     | 5.78         | 0.692             |
| 11      | 6.7       | 7.3     | 7.3     | 7.1                   | 4.8          | 0.599             |
| 12      | 7.3       | 8       | 7.4     | 7.6                   | 5.85         | 0.688             |
| 13      | 7.1       | 8.1     | 7.3     | 7.5                   | 5.87         | 0.67              |

^Minimum ^Maximum

Fig 1: Flow chart for preparation of milk cake.
Here $X_1$ and $X_2$ are the coded values of both variables under study. The equation in terms of coded factors using regression coefficient (Table 3) can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors are coded as +1 and low levels of factors are coded as -1. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficients. F-value was determined to examine the goodness of fit for the developed model in Table 3. The F value for sweetness was significant (p<0.0001). The coefficient estimates of sweetness showed that the linear model terms ($X_1$, $X_2$) and interactive model ($X_1X_2$) had a significant effect (p<0.0001) on sweetness of the product (Table 3). However, sweetness does not depend upon the higher powers of $X_1$ and $X_2$, which may be attributed to adverse effect of higher level of sucralose on the sensory scores for sweetness. The Model F-value was 40.32 which was greater than table F-value (3.86) which implies that the model is significant (Table 3). R² was found to be 0.9307, indicating that 93.07% of the variability in the response could be explained by the model. The 'Pred R-squared' of 0.8086 is in reasonable agreement with the 'Adj R-squared' of 0.9077 which demonstrated that this model could be used to navigate the design space.

**Texture:** Texture is another important sensory parameter for milk cake. Figure 2(b) depicts that with the increase in milk fat, sensory texture score increased at linear level but at quadratic it had adverse effect while, the effect of sucralose was found to be positive on the textural properties of milk cake both at the linear and quadratic level. Regression coefficient was positive for milk fat and sucralose at linear level while an adverse effect of higher level of sucralose at linear level while an adverse effect was reported at higher level.

Flavour: Flavour is one of the most important sensory parameters which affects the overall acceptability of milk cake. Figure 2(c) brings out the fact that with increased levels of milk fat and sucralose, sensory score for flavour also increased. Ramesh (2000) also observed with increase in fat level the score of flavour and overall acceptability of milk cake was affected significantly (p<0.01). Effect of level of milk fat and sucralose on flavour score could be described by the following equation:

**Flavour = 7.47+0.40\times X_1 +0.22\times X_2 +0.45\times X_1X_2**

The coefficient estimates of flavour showed that the linear model terms and interactive model terms ($X_1$, $X_2$) had significant effect (P < 0.0001) on flavour of the product. Flavour does not depend upon the higher powers of $X_1$ and $X_2$. F-value was determined to examine the goodness of fit for the developed model (Table 3). The F-value of model for flavour as calculated by model was 43.29 which was greater than tabulated F value (3.86). R² was found to be 0.9352, indicating that 93.52% of the variability in the response could be explained by the model. The 'Pred R-squared' of 0.8519 is in reasonable agreement with the 'Adj R-squared' of 0.6909.

**Table 3:** Regression coefficient for sensory and textural properties and their significance.

| Coefficients | Sweetness | Texture | Flavour | Overall acceptability | Hardness | Adhesiveness |
|--------------|-----------|---------|---------|-----------------------|----------|--------------|
| $\beta_0$    | 7.28      | 7.88    | 7.47    | 7.52                  | 5.87     | 6.8          |
| $\beta_1$    | 0.23*     | 0.24*   | 0.40*   | 0.40*                 | 0.30*    | 0.30*        |
| $\beta_2$    | 0.52*     | 0.096   | 0.22*   | 0.27*                 | 0.021    | 0.013*       |
| $\beta_{12}$ | 0.33*     | 0.057   | 0.45*   | 0.30*                 | -0.013   | 0.0015       |
| $\beta_{11}$ | -0.34*    | -0.34*  | -0.34*  | -0.098*               | -0.12    | 0.014*       |
| $\beta_{22}$ | -0.13     | -0.13   | -0.13   | 0.053                 | -0.056*  | 0.013*       |
| $R^2$        | 0.9305    | 0.8150  | 0.9352  | 0.9447                | 0.9988   | 0.9552       |
| Pred $R^2$   | 0.8086    | 0.4641  | 0.8519  | 0.8692                | 0.9935   | 0.7331       |
| Adj $R^2$    | 0.9077    | 0.6909  | 0.9136  | 0.9625                | 0.9980   | 0.9231       |
| Model F-value| 40.32 (table value 3.86) | 6.36 (table value 3.86) | 43.29 (table value 3.86) | 62.67 (table value 3.97) | 1205.29 (table value 3.97) | 29.82 (table value 3.97) |

* Significant at 5% level of significance, NS: Not Significant
R-squared’ of 0.9136 (Table 3). It was demonstrated that this model could be used to navigate the design space. Similar observations were also reported by Gautam et al. (2013) where with the increase in sucralose level the flavour scores of chhana kheer increased.

Overall acceptability: The average overall acceptability scores for milk cake varied between 7.0 and 8.4 (Table 2). Figure 2(d) suggests that with increase in levels of milk fat and sucralose, overall acceptability score also increased.

\[
\text{Overall acceptability} = 7.52 + 0.30X_1^1 + 0.27X_2^2 + 0.03X_1^1 X_2^2 - 0.98X_1^1 + 0.053X_2^2
\]  

The coefficient estimates of overall acceptability showed that the linear, interactive, and quadratic model terms \((X_1, X_2, X_1^2, X_2^2)\) had significant effect \((p<0.0001)\) at on overall acceptability of the product. However, effect of sucralose was insignificant at higher levels. F-value was determined to examine the goodness of fit for the developed model (Table 3). The F-value for model of overall acceptability was 62.67 which was greater than tabulated F value (3.97). \(R^2\) was found to be 0.9781, indicating that 97.81\% of the variability in the response could be explained by the model. The ‘Pred R-squared’ of 0.8692 is in reasonable agreement with the ‘Adj R-squared’ of 0.9980 (Table 3). It was demonstrated that this model could be used to navigate the design space. The ‘Pred R-squared’ of 0.8692 is in reasonable agreement with the ‘Adj R-squared’ of 0.9980 (Table 3). Jha et al. (2007) for burfi made with artificial sweeteners, tested under same conditions.

Adhesiveness: Adhesiveness is the negative force area for the first bite and represents the work required to overcome the attractive force between the surface of a food and the surface of other materials with which the food comes into contact. Hardness and adhesiveness gives an idea of the force required by the jaw to break and chew the food in oral cavity. The figure 2(f) depicts that with increasing milk fat and artificial sweetener, the adhesiveness of milk cake increases. Effect of milk fat and sucralose on adhesiveness could be described by the following equation:

\[
\text{Adhesiveness} = 6.8 + 0.054X_1^1 + 0.013X_2^2 + 0.0015X_1^1 X_2^2 - 0.013X_1^1 + 0.053X_2^2
\]

The coefficient estimates of adhesiveness showed that the linear and quadratic model terms \((X_1, X_2, X_1^2, X_2^2)\) had significant effect \((p<0.0001)\) on adhesiveness of the product. F-value was determined to examine the goodness of fit for the developed model (Table 3). The F-value for model of adhesiveness as calculated by model was 29.82 which was greater than tabulated F value (3.97). \(R^2\) was found to be 0.9552, indicating that 95.52\% of the variability in the response could be explained by the model. The ‘Pred R-squared’ of 0.7331 is in reasonable agreement with the ‘Adj R-squared’ of 0.9231 (Table 3). It was demonstrated that this model could be used to navigate the design space. Jha (2003) reported that sugar had a positive linear effect on adhesiveness of doda burfi during storage.

OPTIMIZATION

All the responses were affected significantly by the variables so all responses i.e., sweetness, texture, flavour, overall acceptability, hardness and adhesiveness were taken into account for optimization. These responses were used for the numerical as well as graphical optimization of the variables, and the criteria used along with predicted responses have been presented in Table 4. The overlay contour plots were plotted to see the area of optimization Fig. (3). In overlay plot the optimized product lies at the upper right side. The RSM suggested six results (given in Table 5) out of which first result had highest desirability (0.954) and overall acceptability score (8.347) as compared to other solutions. Therefore, the first result given by software i.e. 6\% milk fat and 0.07\% sucralose was selected as optimized product. The optimized milk cake had predicted scores 8.353 for sweetness, 8.061 for texture, 8.537 for flavour and 8.347 for overall acceptability, 6.533 Kg for hardness and 0.725 g.s. for adhesiveness. The milk cake was prepared using recommended set of conditions and again responses of the panelists were recorded for the optimized product.

Effect of variables on textural properties of milk cake

Hardness: Hardness or firmness is an important textural attribute of the milk cake. It implies the maximum force required fracture or cut the product. The figure 2(e) depicts that with increasing milk fat and level of sucralose, the hardness of milk cake increases. Effect of milk fat and sucralose on hardness could be described by the following equation:

\[
\text{Hardness} = 5.87 + 0.83X_1^1 + 0.021X_2^2 - 0.013X_1^1 X_2^2 - 0.12X_1^2 - 0.056X_2^2
\]  

The coefficient estimates of hardness showed that the linear and quadratic model terms \((X_1, X_2, X_1^2, X_2^2)\) had significant effect \((p<0.0001)\) on hardness of the product. F-value was determined to examine the goodness of fit for the developed model (Table 3). The F-value for model of hardness as calculated by model was 1205.29 which are greater than tabulated F value (3.97). \(R^2\) was found to be 0.9998, indicating that 99.88\% of the variability in the response could be explained by the model. The ‘Pred R-squared’ of 0.9935 is in reasonable agreement with the ‘Adj R-squared’ of 0.9980 (Table 3). It was demonstrated that this model could be used to navigate the design space. The hardness of milk cake was ranged between 4.5Kg to 6.8Kg which was in tune with the values reported by Arora et al. (2007) for burfi made with artificial sweeteners, tested under same conditions.

Overall acceptability of the product. However, effect of sucralose was insignificant at higher levels. F-value was determined to examine the goodness of fit for the developed model (Table 3). The F-value for model of overall acceptability was 62.67 which was greater than tabulated F value (3.97). \(R^2\) was found to be 0.9781, indicating that 97.81\% of the variability in the response could be explained by the model. The ‘Pred R-squared’ of 0.8692 is in reasonable agreement with the ‘Adj R-squared’ of 0.9980 (Table 3). Jha et al. (2007) for burfi made with artificial sweeteners, tested under same conditions.

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Fig 2: Response surface plots showing effect of variables on sensory parameters of milk cake.
Table 4: Criteria for optimization, solution along with predicted response value.

| Constraints          | Target   | Lower limit | Upper limit | Importance | Predicted solution |
|----------------------|----------|-------------|-------------|------------|--------------------|
| Sweetness            | Maximize | 6.6         | 8.4         | 5          | 8.353              |
| Texture              | Maximize | 6.8         | 8.2         | 5          | 8.061              |
| Flavour              | Maximize | 6.7         | 8.5         | 3          | 8.537              |
| Overall acceptability| Maximize | 7           | 8.4         | 5          | 8.347              |
| Hardness             | In range | 4.5         | 6.8         | 3          | 6.533              |
| Adhesiveness         | In range | 0.58        | 0.732       | 3          | 0.725              |

Table 5: Results suggested by the software.

| S.No. | Milk fat | Sweetener | Sweetness | Texture | Flavour | OA | Hardness | Adhesiveness | Desirability |
|-------|----------|-----------|-----------|---------|---------|----|----------|--------------|--------------|
| 1     | 6.000    | 0.070     | 8.353     | 8.061   | 8.537   | 8.347| 6.533    | 0.725        | 0.954        |
| 2     | 5.959    | 0.070     | 8.338     | 8.072   | 8.514   | 8.336| 6.518    | 0.724        | 0.952        |
| 3     | 5.943    | 0.070     | 8.331     | 8.076   | 8.505   | 8.332| 6.511    | 0.723        | 0.951        |
| 4     | 5.925    | 0.070     | 8.325     | 8.080   | 8.495   | 8.327| 6.504    | 0.722        | 0.949        |
| 5     | 5.854    | 0.070     | 8.298     | 8.096   | 8.454   | 8.307| 6.476    | 0.720        | 0.941        |
| 6     | 5.595    | 0.070     | 8.202     | 8.142   | 8.307   | 8.231| 6.369    | 0.718        | 0.906        |

Table 6: Model verification using the $\chi^2$ test.

| Constraints          | Predicted solution (E) | Actual experimental response value (O) | (O-E)$^2$/E |
|----------------------|------------------------|---------------------------------------|-------------|
| Sweetness            | 8.353                  | 8.2                                   | 0.002802466 |
| Texture              | 8.061                  | 8                                     | 0.000461605 |
| Flavour              | 8.537                  | 8.3                                   | 0.006579478 |
| Overall acceptability| 8.347                  | 8.16                                  | 0.004189409 |
| Hardness             | 6.533                  | 6.46                                  | 0.000815705 |
| Adhesiveness         | 0.725                  | 0.728                                 | 0.0000124   |

$\chi^2 = \sum ((O-E)^2)/E$

Where $\chi^2 = \frac{\sum ((O-E)^2)}{E}$

Fig 3: Overlay plot
Verification of models: To verify the model as described by Maduko et al. (2007) $\chi^2$ test was employed. The $\chi^2$ value indicated (Table 6) that there is no significant ($p\geq0.05$) difference between the observed and predicted values. The $\chi^2$ value (0.0148) was smaller than the cut-off point (11.07) at $\alpha_{0.05}$ and 5 degree of freedom. The measured responses were very much close to the predicted ones reconfirming the adequacy of the models.

CONCLUSION

From the present investigation it was concluded that acceptable quality milk cake can be prepared from buffalo milk using sucralose as intense sweetener. Sucrose was successfully replaced with artificial sweetener sucralose. To simulate the colour and texture of the conventional product, bulking agent maltodextrin was added. For optimization of milk cake, milk fat level (3-6%) and sucralose level (0.03-0.07%) was taken in each experiment using central composite rotatable design. Optimization was done on the basis of sensory profile and important textural parameters i.e. hardness and adhesiveness. The measured responses of optimized milk cake are shown in Table 6. The production of milk cake with artificial sweeteners could be highly beneficial for consumers who require such dietetic foods.

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