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Process standardisation of fat replaced dietetic chhanakulfi using response surface methodology

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Abstract

Kulfi is an indigenous dairy product popular in northern part of India, often called the Indian ice-cream. It is a product that is relished by consumers of all ages and is gaining popularity in the current scenario. Kulfi's high calorific value and sugar content make it unsuitable for diabetics and diet-conscious people. The present study was to optimize the preparation of fat replaced dietetic chhanakulfi by response surface methodology (RSM). It was prepared by using skim milk, low fat chhana, inulin (as fat mimetic), sucralose (as low-calorie sweetener) and lutein ester (as colourant and antioxidant). Based on preliminary trials the range of addition of inulin, low fat chhana, sucralose and lutein ester were selected as 3.3-8 per cent, 15-22.5 per cent, 200-300 ppm and 1.3-2.0 mg per 100gof the mix respectively. Computation of the optimised composition was done with these four variables and four responses consisting of sensory characteristics. The responses studied were flavour, body and texture, colour and appearance, overall acceptability using Central Composite Rotatable Design (CCRD) of RSM. The composition with highest desirability of 89 per centwas obtained for 6.34 per cent of inulin, 22.5 per cent, of low fat chhana, 243ppm of sucralose and 1.65mg lutein ester per 100g of the mix. The standardised product was analysed for its proximate composition which were, 1.22±0.25% fat, 9.26±0.66% protein and an energy value of 152±0.32kcal/g.Kulfi thus prepared had low calorie and was protein rich.

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Response surface methodology is a set of mathematical and statistical approach focused on fitting a polynomial equation to experimental data in order to understand the behaviour of a data set and make statistical predictions.The goal is to get the greatest system performance by simultaneously optimising the levels of variables (Bezerra*et al.,* 2008). It is widely used in the optimisation of products with various ingredients. About half of the total milk produced in India is converted into traditional and value-added products by using various methods like fermentation, heat desiccation, freezing, concentration. Frozen dairy products constitute about 0.7 per cent of the total milk (Naik and Londhe, 2011).*Kulfi,* the Indian ice cream also known as Malai*kulfi* or Malaikabaraf, is an extremely popular traditional dairy product especially in Northern India. The term *"kulfi"* is derived from the Hindustani word "kulaf," that means "lock" or "a container that must be unlocked". *Kulfi*is similar to ice cream except that it lacks air and hence has more solids. It is characterised as a frozen combination of milk, cream, dried milkand condensed milk that has been sweetened, stabilisedand flavoured with non-milk ingredients (Yerriswamy *et al.,* 1983).As per the Food Safety and Standards (Food Products Standards and Food Additives) Regulations (FSSR,2016) *kulfi* is categorised as low, medium and high fat with a fat content of 2.5 per cent (max), 2.5 to 10 per cent and 10 per cent (min), respectively.

Recent food consumption pattern indicates that consumers are not looking for anything that can only halt their hunger but are nutritious. Milk and milk products are highly nutritious andcan act as an effective vehicle for addition of functional ingredients. Numerous researchworks have been carried out on frozen dairy products like substitution of buttermilk powder in ice-cream (Shibu*et al.,* 2000).Sugar is one of the key ingredients in the manufacture of *kulfi*which imparts the characteristic sweetness,caramelised flavour and colour, but people restrict its use due to its high calorie content. The high fat content in kulfi also contributes to its calorie content. This study attempts to reduce the calorie content in *kulfi*by the replacement of fat and sugar.

The sugar content in *kulfi* can be partially or completely replaced by the use of non-calorie sweeteners like aspartame, saccharin, sucralose and acesulfame K which have been permitted in dairy products (FSSR, 2016). Fat content can be reduced by replacing it with inulin, a linear non-digestible polysaccharide which acts as a fat mimetic. It formsparticulate gel, modifying the product texture and gives a fat like mouth feel. It is also found that inulin is ten times less sweet thansucrose.It is a dietary fibre that promotes the growth of healthy bifidobacteria, enhances calcium absorption and lowers cholesterol levels. Rasagolla was prepared using skim milk filled with coconut milk with 4 percent fat and was found similar to control with 3 days shelf life (Mini *et al.,* 1995). Lutein is a carotenoid widely found inmarigold flowers and green vegetables. It acts as an antioxidant and natural colouring agent when incorporated in food products. Chhana obtained from the coagulation of milk with organic acid owes excellent nutritional profile and is used in the preparation of various traditional sweetmeats.Various research works have been carried out using chhana other than traditional preparations like low fat rasogolla, chhanakheeretc (Chavan*et al.,* 2011,Gautham*et al.,* 2012). The moisture and milk fat content in low fat chhana must be less than 65 per cent and 15 per cent respectively on dry matter (DM) basis (FSSR, 2017).

The objective of this study was to use RSM tooptimisethe level of ingredients viz., low fat chhana, inulin, sucralose and lutein ester in the preparation of fat replaced dietetic chhanakulfi.

Materials and methods

The study was carried out in the Department of Dairy Technology,VergheseKurian Institute of Dairy and Food Technology, Mannuthy during the period 2020-21.

Preliminary trials

Inulin, sucralose, lutein ester and low fat chhanawere added at the levels between

1-8% (Mittal, 2011), 200-400 ppm (FSSAI, 2016), 0.5 -3.0 mg/ 100g(Tokusoglu,2013) and 15-30% (Nigam *et al.,* 2016) by weight of kulfi mix respectively. *Kulfi*was prepared and minimum and maximum levels of incorporation of additives were selected by varying the levels of each ingredient within the range. The selection of the levels of addition of all the additives were based on sensory attributes and the scores obtained were statistically analysed by KruskalWallis test.

Optimisation using RSM

Preparation of fat replaced dietetic chhana*kulfi* was optimised by Central Composite Rotatable Design (CCRD) of RSM software. Based on the different combinations suggested in RSM software, trials were conducted and the products were subjected for sensory evaluation. The sensory results were then fed to the RSM software to optimise the level of addition of the ingredients. The optimised levels of all the ingredients and magnitude of the responses were then validated using sensory analysis (Fig. 1-4).

Preparation of fat replaced dietetic chhanakulfi

Skimmed cow milk with0.5 per cent fat (max) and 8.7 per cent milk solids not fat (MSNF) was used for the preparation. Inulin was added to a part of the skim milk and then pasteurized (72°C/15sec). The pasteurised skim milk was then kept for ageing under refrigeration (5°C) overnight. The other part of the skimmed cow milk was heated to boiling and held for five minutes under boiling conditions, then cooled to 80±2ºC and one per cent citric acid solution heated to 80ºC was added slowly into the milk (@200 ml per litre milk) with slow stirring. Coagulation was accomplished within a minute. The coagulated mass was kept undisturbed (for five minutes)and whey was removed by passing through a muslin cloth. The coagulated mass was then hung to drip the excess whey. Low fat chhana thus obtained was shredded and kept aside.The other part of skimmed milk that was kept for ageing was concentrated toone third volume with the addition of lutein ester. To this, sucralose and low fat chhana were added in required amount. The mixture was then blended (for 10-15 s) with the help of a mixer grinder (Panasonic MX-AC 3005) to obtain the *kulfi* mix, which was filled into moulds and sealed.Hardening was done in a deep freezer (-18°C) for overnight. The *kulfi* was stored under refrigerated condition temp (5ºC) until served.

Chemical composition of fat replaced dietetic chhanakulfi

The chemical composition of fat replaced dietetic chhanakulfi was analysed as per BIS procedure IS:SP:18 (Part XI), 1981. Energy value of the product was analysed using bomb calorimeter.

Results and discussion

Fat replaced dietetic chhana*kulfi*was prepared and optimised using RSM, which was carried out in two stages i.e., preliminary and optimisation trials. A four factor CCRD was adopted employing quadratic model. The levels of four factors were optimised at maximum levels of the sensory responses.

Preliminary trials

Preliminary trials were conducted to select the minimum and maximum level of ingredients that can be incorporated in the product. The selections were based on sensory responses which were further analysed byKruskalWallis test. The addition of inulin to obtain the texture of *kulfi*prepared using skim milk was done at the levels between 1-8 per cent. *Kulfi*with textural properties similar to control was obtained with the levels between 3.3 to 8 per cent.El- Nagar *et al.* (2002) reported that addition of 5 per cent inulin in yog-icecream as a fat replacer improved the melting properties of the product. Low fat chhana prepared using skim milk was added in the range of 15-30 per cent of concentrated skim milk aged with inulin and the sensory responses obtained for 15-22.5 per cent was similar to the control. This range of addition attributed lesser grainy texture and better mouthfeel to the final product. Kumar*et al.* (2018) reported that low fat chhana prepared using a blend of soymilk and skim milk had good overall acceptability. Level of sucralose selected was based on the required sweetness

Figures are the Mean ± Standard error of six replications, ns-non significant ($p \geq 0.05$)

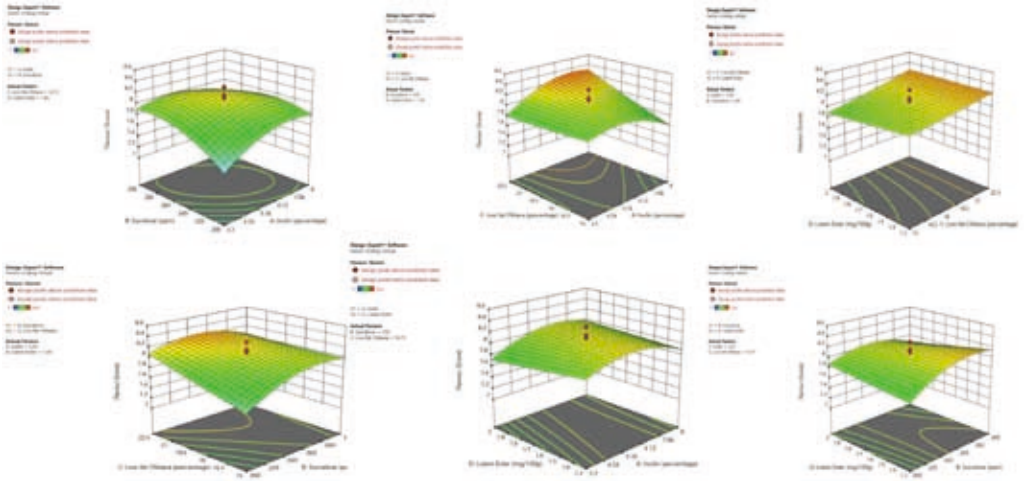

Fig 4: Response surface plot relating to flavour score as influenced by level of Inulin, low fat chhana, sucralose and lutein ester

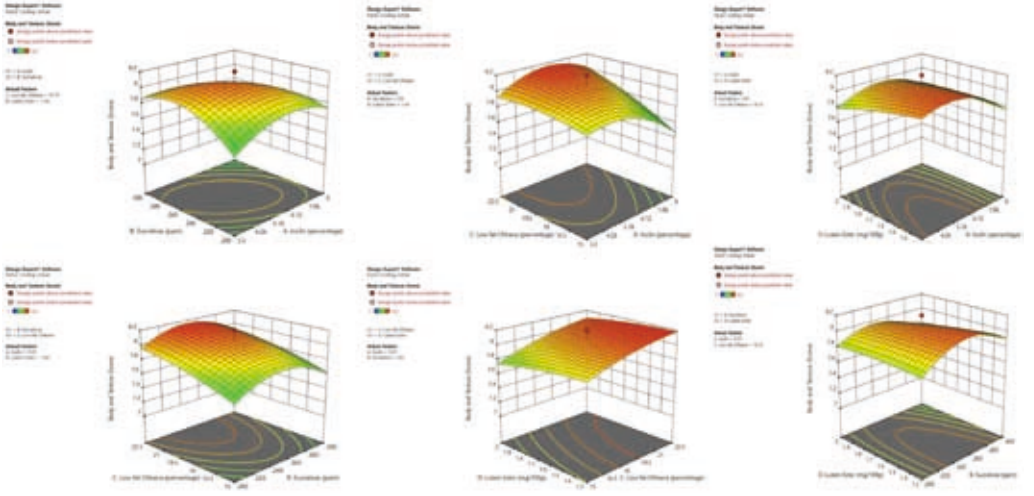

Fig 2 : Response surface plot relating to body and texture score as influenced by level of Inulin, low fat chhana, sucralose and lutein ester

and little or no aftertaste in fat replaced dietetic chhana*kulfi* and 200 to 300ppm sucralose was the acceptable range. Lutein ester imparts colour and appearance to the product and a level of 1.3-2mg per 100g was selected based on the sensory responses. Tokusoglu*et al.* (2013) incorporated 1.5mg/100ml lutein to cream cheese and it showed intense a* value in Hunter Colorimetric analysis (Table 1).

RSM optimisation of fat replaced dietetic chhanakulfi

The central values of the four factors i.e., inulin, sucralose, low fat chhana and lutein ester were coded as A, B, C and D. The model's F-value for all aspects was greater than the stated F-value ($p<0.01$), indicating that the test is significant. Flavour, body and texture, colour and appearance and overall acceptability all had coefficients of determination (R^2) of 0.91, 0.94, 0.92 and 0.95 respectively, indicating that the fitted quadratic model explained more than 80% of the variation in the experimental data (Table 2).

The model is satisfactorily accurate for forecasting the sensory properties of fat replaced dietetic chhana*kulfi* made with any

combination of the variables within the range estimated, according to the non-significant lack of fit test. In terms of all responses, the adequate precision, which measures the signal-to-noise ratio, is more than four, which is extremely acceptable, implying that the model is right in directing the design. The levels of four factors were optimised by maximising the sensory responses through fitting of quadratic models by numerical optimisation. Table 4 presents the suggested solutions for the preparation of fat replaced dietetic chhana*kulfi*. The solution that got a desirability of 0.897 was selected. The optimum composition selected was at 6.34 per cent inulin, 22.5 per cent low fat chhana, 243.55 ppm sucralose and 1.65mg per 100g lutein ester. Nigam *et al.,* (2016) reported that addition of chhana to *kulfi* at 24.66 per cent showed good sensorial properties and did not affect the flavour score of the optimised product.(Table 3).

Verification of optimum solution

The fat replaced dietetic chhanakulfi prepared at desired optimum level of ingredients were statistically analysed for sensory attributes as depicted in Table 4 and it is evident that the observed values were not significantly ($p<0.05$) different from the predicted values.

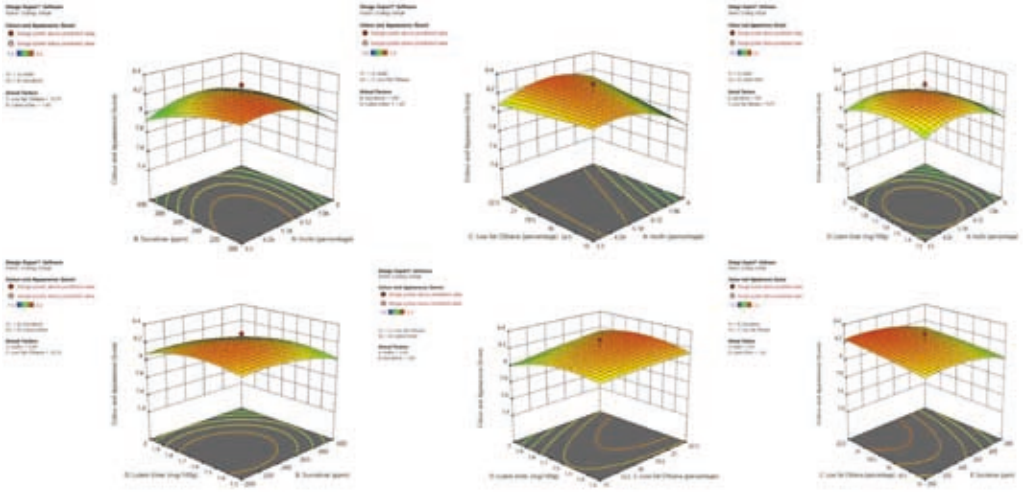

Fig 3: Response surface plot relating to colour and appearance score as influenced by level of Inulin, low fat chhana, sucralose and lutein ester

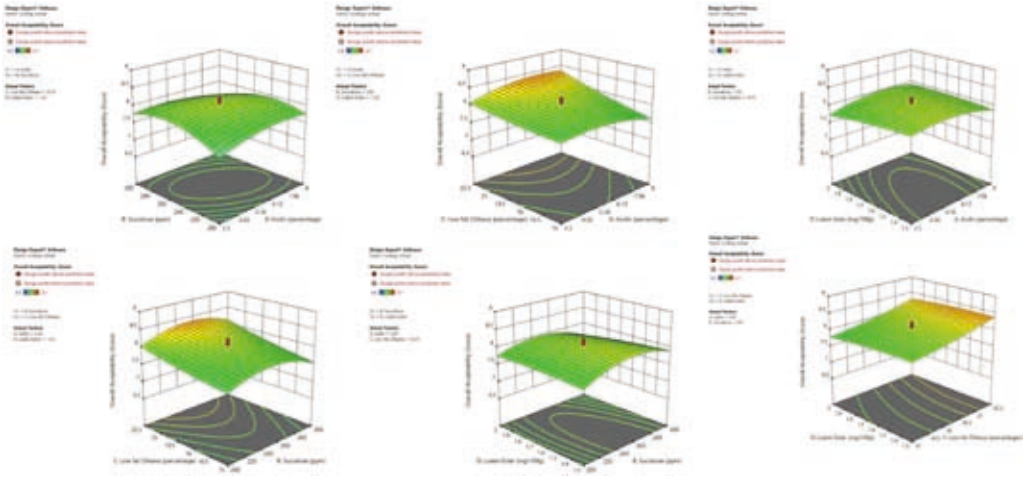

Fig 4: Response surface plot relating to overall acceptability score as influenced by level of Inulin, low fat chhana, sucralose and lutein ester

Table 1. The coded and actual levels of Inulin, low fat chhana, sucralose and lutein ester

Coded level Factor	Lower limit	Factorial point	Centre coordinate	Factorial point	Upper limit
	-2	-1	0	+1	+2
A: Inulin (%)	0.95	3.3	5.65	8	10.35
B: Sucralose (ppm)	150	200	250	300	350
C: Low fat chhana (%)	11.25	15	18.75	22.5	26.25
D: Lutein ester (mg/100g)	0.95	1.3	1.65	2	2.35

Table 2. Regression coefficients and ANOVA of fitted quadratic model

Partial Coefficients	Sensory characteristics			
	Flavour	Body and Texture	Colour and Appearance	Overall Acceptability
Intercept	8.09	8.05	8.2	8.08
A- Inulin	0.058^{ns}	-0.067*	-0.0625**	0.0208^{ns}
B- Sucralose	0.11^{**}	-0.008^{ns}	-0.0542^{**}	0.0208^{ns}
C- Low fat chhana	0.15^{**}	0.1583**	0.0458*	0.2458**
D- Lutein ester	-0.033^{ns}	-0.0583^{*}	-0.0292^{ns}	-0.0542^{ns}
AB	-0.162^{**}	-0.162^{**}	0.0812^{**}	-0.1437^{**}
AC	0.1875^{**}	0.1125^{**}	0.0813^{**}	0.1188^{**}
AD	0.075^{ns}	0.0625^{ns}	-0.0063^{ns}	0.0813^{*}
BC	-0.125^{*}	-0.0125^{ns}	-0.0063^{ns}	0.0313^{ns}
BD	-0.112^{*}	-0.0625^{ns}	-0.0063^{ns}	-0.0812^{**}
CD	0.0375^{ns}	0.0125^{ns}	0.0312^{ns}	0.0063^{ns}
A^2	-0.21^{**}	-0.19^{**}	-0.13^{**}	-0.16^{*}
B^2	-0.20^{**}	-0.225^{**}	-0.06^{**}	-0.30^{**}
C^2	0.0146^{ns}	-0.05^{ns}	-0.0094^{ns}	0.049^{ns}
D^2	0.0021^{ns}	-0.025^{ns}	-0.0844^{**}	-0.0385^{ns}
Lack of fit	2.84^{ns}	0.39^{ns}	0.35^{ns}	4.49^{ns}
Model F value	10.37^{**}	16.15^{**}	11.71^{**}	21.03^{**}
R^2	0.91	0.94	0.92	0.95
Press	2.47	0.804	0.3312	1.5
Adeq.Press	10.91	13.07	12.26	19.92

*- significant at 5%level ($p<0.05$), **- significant at 1% level ($p<0.01$),
ns - non significant ($p\geq0.05$)

Table 3. Suggested solutions from RSM

Solution	Inulin (%)	Low fat chhana (%)	Sucralose (ppm)	Lutein ester (mg/100g)	Desirability
1	6.34	22.5	243.55	1.65	0.897
2	6.25	22.5	243.55	1.65	0.856
3	6.25	20	243.55	2.00	0.854

Table 4. Verification of optimum solution from RSM

Attributes	Predicted value by RSM	Observed value	t-value
Flavour	8.32	8.20±0.09	1.28^{ns}
Body and Texture	8.16	8.05±0.05	2.20^{ns}
Colour and Appearance	8.23	8.20±0.09	0.32^{ns}
Overall Acceptability	8.4	8.35±0.06	0.81^{ns}

Chemical composition of fat replaced dietetic chhanakulfi

The proximate composition of the optimised product contained 1.22 per cent fat, 9.26 per cent protein, 36.90 per cent total solids and 22.97 per cent carbohydrates. The addition of sucralose along with the use of skim milk for the preparation of optimized product contributed to its low energy value of 152 kcal. Hence, the developed product contained 84.45 per cent less fat, 75 per cent more protein and 31 per cent less calorie than its conventional counterpart.

Conclusion

According to the findings of this study, *kulfi* with 84.45 per cent less fat content and 31 per cent less calorie could be prepared using low fat chhana, sucralose, inulin and lutein ester utilising optimum components identified by response surface technique. The sensorial qualities of the optimised product could be correctly simulated and the models developed were suitable for predicting the formulation with about 89 per cent desirability. The RSM also assured an acceptable sensory score for fat replaced dietetic chhana*kulfi* similar to that of control.

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Conflict of interest

The authors declare that they have no conflict of interest.

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