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Process optimization for manufacturing of banana enriched ice cream by using response surface methodology (RSM)

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Abstract
Ice cream is a sweetened frozen product typically eaten as a snacks or desserts. The process for manufacturing a banana enriched ice cream was optimized. During the investigation, the effect of different level of Banana pulp and sugar on the sensory characteristics of Banana enriched Ice Cream was studied by employing central composite rotatable design. The best formulations with 10% banana pulp and 13.5% sugar yielded 48.5% of the product as a overrun. This formulations was found to be the most appropriate for manufacturing of banana enriched ice cream with predicted score of 8.4, 8.2, 8.5, 8.2, 7.8, 48.5% Body & Texture, Flavour, Colour and Appearance, Overall Acceptability (OAA) Sweetness and overrun respectively.

Keywords: Formulation, RSM, OAA, optimized

Introduction
Ice cream is a palatable, wholesome and nutritious frozen dairy food. It may be made from dairy milk or cream or soy, cashew, coconut or almond milk and is flavored with a sweetener, either sugar or an alternative, and any spices such as cocoa or vanilla. Colorings are usually added, in addition to stabilizers. The mixture is stirred to incorporate air spaces and cooled below the freezing point of water to prevent formation of detectable ice crystals. The result is smooth, semi-solid foam that is solid at very low temperatures (below -18 to -23 °C). Ice cream is also categorized as High fat ice cream, Medium fat ice cream and Low fat ice cream depending on the percentage of total solids, milk fat and milk protein used. Banana is one of the most important food crops in the world that can be used in ice cream. The most common types of sugar found in ripe bananas are sucrose, fructose and glucose. In ripe bananas, the total content of sugars can reach more than 16% of the fresh weight. Bananas are a significant source of several vitamins and minerals, especially potassium (A diet high in potassium can lower blood pressure in people with high blood pressure and has positive effects on cardiovascular health i.e. 1.3 to 1.4 grams of potassium is linked to a 26% lower risk of heart disease), vitamin B6 (One medium-size banana can provide up to 33% of the recommended daily intake of vitamin B6), and vitamin C. Like other fruits, bananas contain several healthy antioxidants, which are responsible for many of their health benefits. These include Dopamine and Catechin. In addition, bananas contain antioxidant flavonoids that have also been associated with a significant decrease in the risk of heart disease. It is true that bananas are high in starch and sugar, and therefore one might expect them to cause a large rise in blood sugar. But due to their low glycemic index, moderate consumption of bananas should not raise blood sugar levels nearly as much as other high-carbohydrate foods. In this regard, addition of banana pulp in ice cream could add value to the dairy desserts and help in product diversification. In view of growing importance of function food in our day to day foods, present research was undertaken to optimize production of banana enriched ice cream using a statistical software namely RSM. Validation of predicted and actual value was done in order to get the best quality of banana enriched ice cream.

Materials and Methods
Banana fruits, cream, sugar, skim milk powder were procured from local market. Milk was obtained from BHU dairy farm. Three levels of sugar (12-16 %) and five levels of banana pulp (6-14 %) were used in the investigation. Central composite rotatable design provides 13 trials,

which were concluded to obtain a combination of selected parameters for the production of the best quality banana enriched ice cream.

Preparation of ice cream mix

The milk, cream and skimmed milk powder (SMP) used in the manufacture of ice cream mix was analyzed for their composition, i.e. milk fat, MSNF, total solids. The quantity of milk, cream, SMP, sugar, stabilizer and emulsifier required was calculated by Pearson square method. The composition of Banana enriched ice cream was standardized by using milk, skim milk powder and fresh cream. There were two variables i.e. banana pulp (6 to 14 %) and sugar (12 to 16%), milk fat (4%), cream (25% fat), MSNF (11%) was constantly used in the preparation of experimental ice cream. The required quantities of various ingredients for each treatment were weighed, mixed and blended thoroughly. The cream (25.00 per cent fat) was added to the pre-heated (45 °C) whole milk. SMP was mixed with a part of sugar and added to the mix at a temperature of about 50 °C. The weighed amount of stabilizer and emulsifier was blended with about 20.0 parts of sugar and added to the mix pre-heated to 65 °C. The ice cream mix was pasteurized at 72 °C for 30 minutes as described by Marshall and Arbuckl (1996) to destroy pathogenic organisms. After pasteurization, the mix was homogenized in electric homogenizer as described by Berger and White (1976). The mix was heated to 70 °C and subjected to double-stage homogenization in a previously cleaned and sterilized homogenizer (Akshar industry Pvt. Ltd., Ahmedabad). Then the ice cream mix was subsequently aged overnight for 12 hours in ageing vat.

Freezing of mix in continuous freezer

For preparing ice creams, a direct expansion type continuous freezer was used for freezing of ice cream mix. The banana pulp was added to the aged mixes which were frozen in this freezer having a provision for air incorporation under pressure. The temperature of the circulating refrigerant was -25.0 to -30.0 °C. After freezing of the mix to a semi-solid consistency (Requiring 20.0-25.0 min) air was whipped in the freezer barrel by starting air compressor switch and maintaining a constant air pressure (i.e. 10 psi). Whipping was continued for about 2 min. till the desired overrun was attained. The ice cream was drawn from the freezer at -4.5 to -5.0 °C; the overrun of about 46.60-48.50 per cent. Storage of ice cream was done in a deep freezer (Voltas) maintained at –18±2 °C. The samples of each trials were evaluated for sensory attributes based on 9-point hedonic scale

Results and Discussion

Optimization of parameters

Using a CCRD, level of variables viz. banana pulp and sugar were selected through different experiments. The sensory and textural scores as influenced by different levels of banana pulp and sugar are presented in Table 1 and it shows the response surface plot for various sensory parameters. The sensory score were influenced by different levels of sugar and banana pulp.

The chemical composition of banana enriched ice cream by using 10% banana pulp and 13.50 % Sugar was determined and the optimized product was analyzed for proximate analysis. The composition of optimized Banana enriched ice cream showed 36.57% total solids, 63.43% moisture content, 13.50% sugar, 8.66% milk fat, 4.15 % total protein.

Table 1: Experimental runs and actual values of factors used in Central Composite Rotatable Design (CCRD)

Sensory scores								
Banana pulp (%)	**Sugar (%)**	**B & T**	**Flavour**	**C & A**	**Melting property**	**OAA**	**Sweetness**	**Overrun (%)**
10.0000	13.5000	8.4	8.2	8.5	7.95	8.2	7.8	48.5
12.0000	12.0000	7.1	7.8	8.1	7.80	8.0	7.6	47.8
10.0000	13.5000	8.4	8.2	8.5	7.95	8.2	7.8	48.5
12.0000	15.0000	6.8	7.2	7.8	7.10	6.9	6.8	47.6
8.0000	15.0000	8.0	7.4	7.9	7.85	7.2	7.1	47.4
12.8284	13.5000	7.2	7.3	7.7	7.20	7.0	7.3	47.5
10.0000	13.5000	8.4	8.2	8.5	7.95	8.2	7.8	48.5
10.0000	13.5000	8.4	8.2	8.5	7.95	8.2	7.8	48.5
10.0000	13.5000	8.4	8.2	8.5	7.95	8.2	7.8	48.5
10.0000	11.3787	7.3	7.1	7.6	7.60	7.2	7.2	47.8
8.0000	12.0000	6.5	6.9	7.1	7.75	6.8	6.4	47.5
10.0000	15.6213	6.7	7.0	7.4	7.40	6.6	6.9	47.7
7.1716	13.5000	7.4	6.8	7.3	7.90	7.1	6.5	46.7

Body and texture

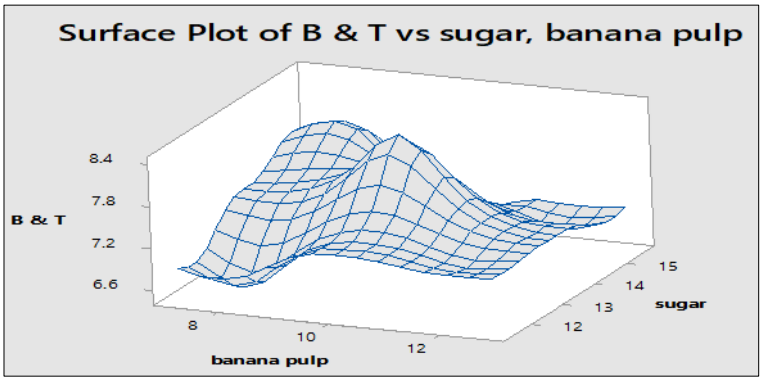

Fig 1: Effects of various levels of banana pulp and sugar on body & texture of Banana enriched ice cream

The Response Surface plots for body and texture score was presented in Fig 1 that is clearly depicts the effect of different level of banana pulp (8-12%) and sugar (12-16%) with their interaction. The coefficient estimates of body and texture model showed that the increased level of sugar and banana pulp had a positive effect on body and texture but only at the level of combination of banana pulp and sugar had significant effect. The texture score for banana enriched ice cream varied from 6.5 to 8.4 (Table 1). The values in fig. 1 shows that increasing the level of sugar (13.5%) and banana pulp (10%) increased the body and texture score for banana enriched ice cream. The findings of M. Guven and O. B. Karaca (2002) [5] showed that an increase in the amount of sugar in vanilla frozen ice cream softened the structure. Similarly the worker (Alvarez, 2009) explained that the ice cream should be judged for relative smoothness, coarseness, coldness, presence or absence of sandiness and relative size of ice crystals.

Flavour

Flavour is the single most important characteristic which can decide the acceptability of any food product. High quality ice cream should be pleasantly sweet, suggest a creamy background sensation, exhibit a delicate flavour and leave a most pleasant, but brief, rich after taste (Body felt *et al*., 1988).

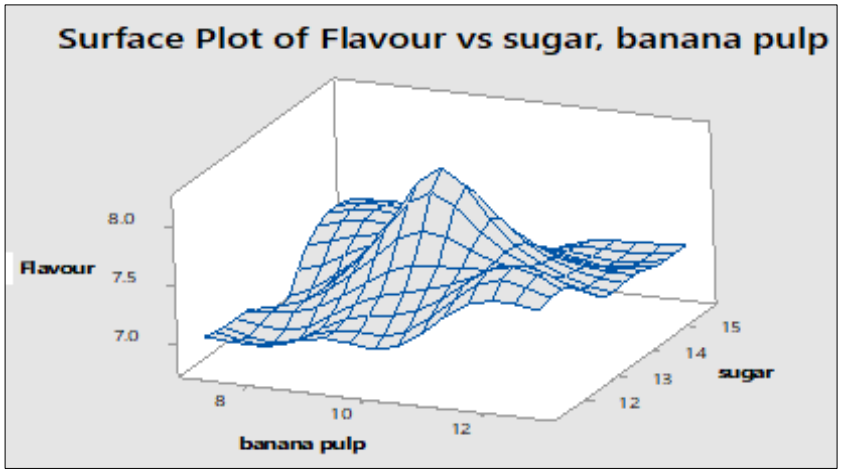

Fig 2: Effect of various levels of banana pulp and sugar on flavour of Banana enriched ice cream

The Response Surface plots for flavour score was presented in Fig 2. The coefficient estimates showed that quadratic model sugar^2, banana^2 and sugar - banana interaction had significant effect on flavour. The flavour score for banana enriched ice cream varied from 6.8 to 8.2 (Table 1). The values in Fig. 2 showed that increasing the level of sugar (13.5%) and banana pulp (10%) increased the score for flavour of banana enriched ice cream. A sharp convergence of the curve explains that addition of sugar and banana pulp above certain limit would not contribute to increase in sensory attributes. Earlier work of Guinard *et al*. (1997) [6] showed that too high or too low sugar was detrimental to the ice cream quality and the optimum level of sugar in vanilla ice cream was 14.1% for flavour liking. Guven, M. and Karaca, O. B. (2002) [5] also observed that high sugar and fruit concentrations are the most preferred type vanilla and fruit ice cream. (Martin and Swenson, 1969) also explained that higher levels of flavor particulate inclusion have been reported to enhance the flavor impact in peanut ice cream.

Colour & Appearance

The colour of ice cream, its intensity, patches of colour or colour migration and unevenness, if any, were considered while rating for color and appearance of the ice creams. The colour of ice cream should be attractive, uniform, pleasing and typical of the specific flavour declared on the label.

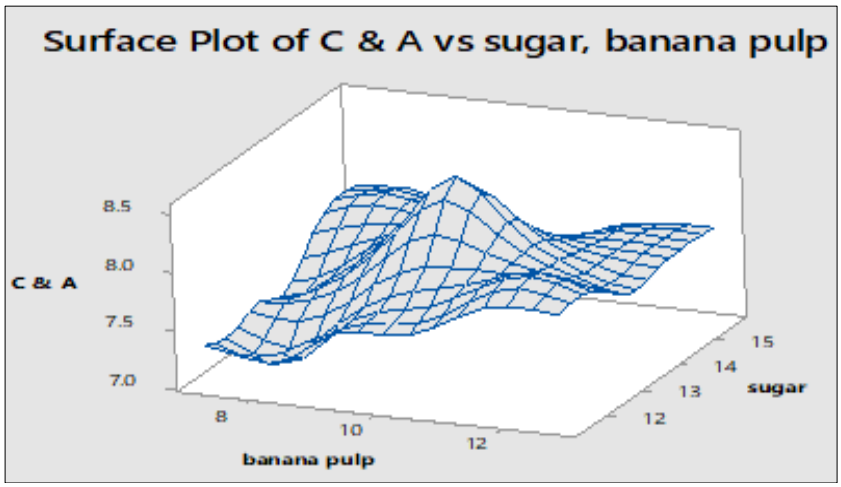

Fig 3: Effect of various levels of banana pulp and sugar on colour & appearance of Banana enriched ice cream

The Response Surface plots for colour and appearance score was presented in Fig 3. The coefficient estimates of colour & appearance score showed that quadratic model terms (Sugar^2 and Banana^2) were significant. However, the interactive effect of sugar and banana pulp was non-significant. The significant increase in score of colour & appearance rating appeared to occur with increase in all level of sugar and banana pulp. The colour & appearance score for banana enriched ice cream varied from 7.1 to 8.5 (Table 1). The values in Fig. 3 shows that increasing the level of sugar (13.5%) and banana pulp (10%) increased the score for banana enriched ice cream. These results are in conformity with finding of earlier worker (Alvarez, 2009), he was also reported that Ice cream flavours other than vanilla (usually colour is not added) should also exhibit a colour that is in harmony with and/or suggestive of the stated flavour on the package.

Melting property

During the melting phase, the mix should flow outward from the center portion of the scooped ice cream. The melted product should be expected to form a smooth, uniform and homogeneous liquid in the dish.

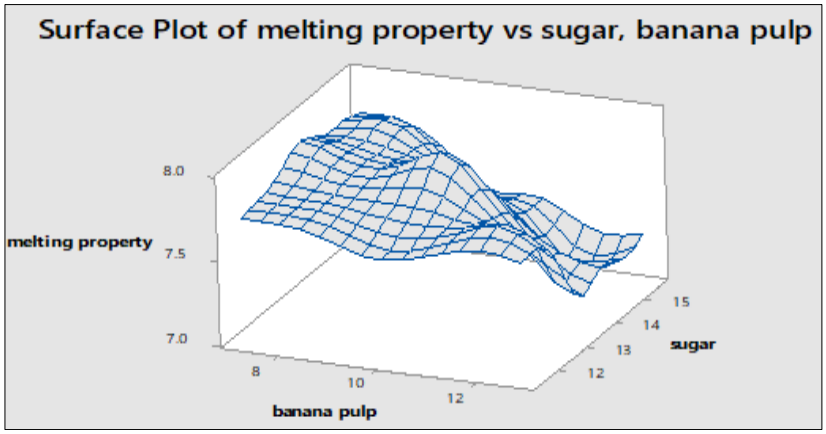

Fig 4: Effect of various levels of banana pulp and sugar on melting property of Banana enriched ice cream

The Response Surface plots for body and texture score was presented in Table 1 that is clearly depicts the effect of different level of banana pulp (8-12%) and sugar (12-16%) with their interaction. The coefficient estimates of sugar, banana pulp, their quadratic terms sugar^2 and Banana^2, their interaction sugar and banana had significant effect on melting property. The melting property score for banana enriched ice cream varied from 7.1 to 7.95 (Table 1). The values in Fig. 4 shows that increasing the level of sugar and banana pulp increased the score of melting property for banana enriched ice cream. The findings of Contori (1994) showed that sugar content affect the melting behavior of ice cream. Guinard *et al.*, (1996) also explained that Ice cream containing higher sugar level had lower melting resistance than the product containing lower levels.

Overall acceptability

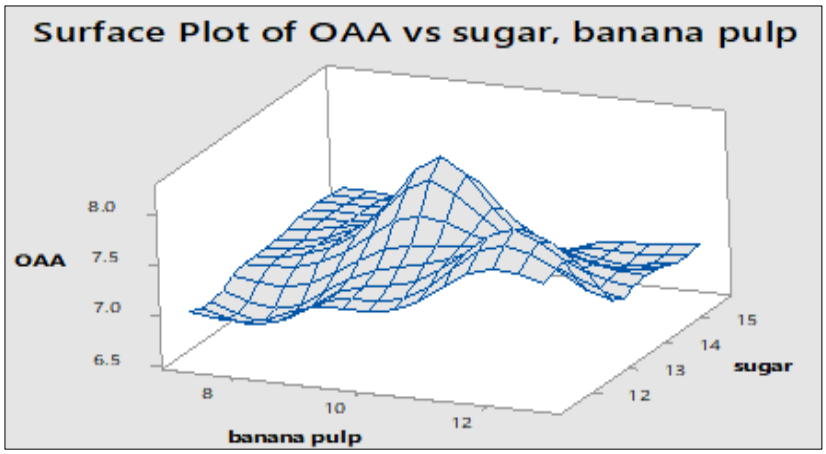

Fig 5: Effect of various levels of banana pulp and sugar on overall acceptability of Banana enriched ice cream

The Response Surface plots for OAA score was presented in Fig 5 that is clearly depicts the effect of different level of banana pulp (8-12%) and sugar (12-16%) with their interaction. The coefficient estimates that quadratic terms sugar^2 and banana^2 and the interaction of sugar and banana had significant effect on overall acceptability. The overall acceptability score for banana enriched ice cream varied from 6.9 to 8.2 (Table 1). The values in fig. 5 shows that increasing the level of sugar (13.5%) and banana pulp (10%) increased the score of OAA for banana enriched ice cream. The earlier analysis of Yadav, C. M.; Karanjkar, L. M.; Kashid, U. B. (2010) inferred that ice-cream prepared with incorporation of 15 per cent custard apple pulp and 15 per cent sugar level had overall acceptability of 8.05 scores of Hedonic scale.

Sweetness

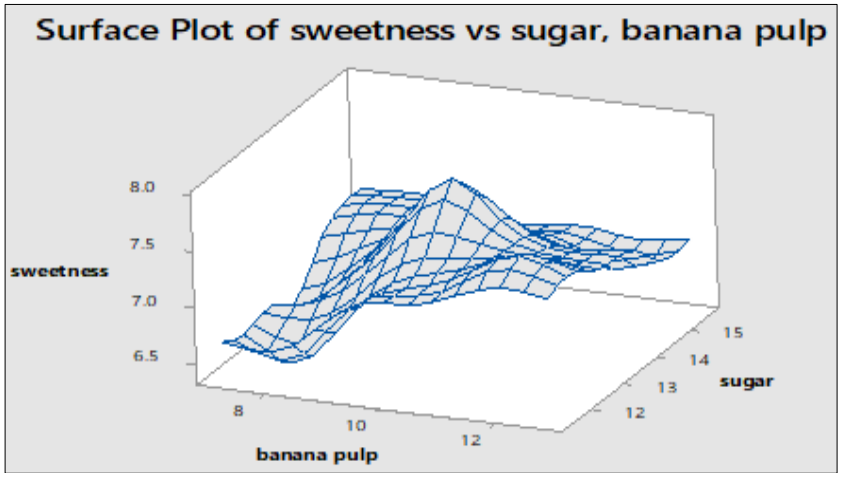

Fig 6: Effect of various levels of banana pulp and sugar on sweetness of Banana enriched ice cream

The Response Surface plots for sweetness score was presented in Fig 6 that is clearly depicts the effect of different level of banana pulp (8-12%) and sugar (12-16%) with their interaction. The sweetness score for banana enriched ice cream varied from 6.4 to 7.8 (Table 1). The values in fig. 6 shows that increasing the level of sugar and banana pulp increased the sweetness score for banana enriched ice cream. Earlier work of Stampanoni, *et al.* (1996) also reported that sweetness was significantly increased by addition of sugar level.

Overrun

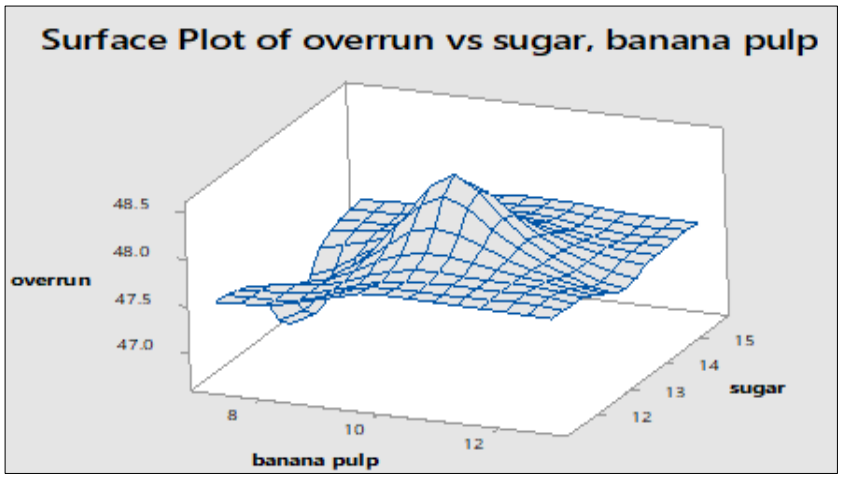

Fig 7: Effect of various levels of banana pulp and sugar on overrun of Banana enriched ice cream

The Response Surface plots for body and texture score was presented in Fig 7 that is clearly depicts the effect of different level of banana pulp (8-12%) and sugar (12-16%) with their interaction. The coefficient estimates of overrun score showed that banana pulp had significant effect but sugar had non-significant effect on overrun. The overrun% for banana enriched ice cream varied from 46.7 to 48.5 (Table 1). The findings of Arbuckle (1996) showed that the percentage of overrun for ice cream is between 30 and 60% depending on the total solids used in the formulation.

Conclusions

It is important to optimize the rate of addition of the flavour particulates in any ice cream variety. The minimal level of flavouring particulate that is able to impart the desired flavour and texture characteristics to the final product is desired. It was necessary to find out which level of banana pulp (out of 6.0, 8.0, 10.0, 12.0 and 14.0 % by weight of ice cream mix) and sugar levels (out of 12.0, 14.0, 16.0 %) would yield highly satisfactory quality 'banana enriched' ice cream. So, it was optimized by using Response Surface Methodology and then it was found that rate of addition of banana pulp (10 %) and sugar (13.5%) had a significant influence on all of the sensory attributes score viz., colour and appearance, flavour, body and texture, sweetness and overall acceptability. From these results, it could be concluded that banana enriched ice cream can be manufactured by dairy industry to promote value addition and product diversification.

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