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Physical characteristics of optimized jaggery nuggets

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ABSTRACT : Chocolate products are the most important products that are popular with a lot, especially children and as a source of energy in addition to its high nutritional value. In chocolate industry, many of ingredients such as cocoa, sugar, cocoa butter, fats, emulsifiers and flavorings play an important role in product quality. This research aims to produce chocolate nuggets using jaggery powder, which contains enormous wealth of minerals, protein, vitamins and useful sugar as compared to sugar. Chocolate nugget is formulated using jaggery powder, cocoa powder, cocoa butter, nuts and spices. Physical characteristics (Hardness and Color) of jaggery based nuggets were optimized using Response Surface Methodology (RSM).

KEY WORDS : Jaggery, Chocolate nugget, RSM, Cocoa emulsifier

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The knowledge of chocolate manufacturing has evolved hugely since the introduction of plain chocolate tablets in 1847 by Joseph Fry, the first solid milk chocolate in 1876 by Daniel Peter, and the production of smoother and better tasting chocolate in 1880 by Rodolphe Lindt (Beckett, 2008 and Nelson, 1999). Since then, the chocolate manufacturing process has undergone various changes for the purposes of either improved oral experience (flavour and texture) or increased productivity to meet increasing demands for chocolate products. With ever increasing product output, it is essentially important to have a good understanding of the influences of chocolate manufacturing process, as well as the processing conditions, on the quality of the final product.

Sugar contains various types of carbohydrates like glucose, fructose, galactose, lactose, ribose, maltose and sucrose. Sucrose is further converted into glucose which provides energy to the body. Insulin, which is secreted by the pancreas, converts sucrose into useful sugar. In diabetics, the insulin secretion doesn't take place, so the sugar which is not useful gets accumulated in the body. Jaggery is a natural sweetener made from sugarcane juice simply by evaporation. It contains an enormous wealth of minerals, protein, vitamins and useful sugar (Makde, 2006).

Jaggery is an important sugarcane product used widely in India. It occupies an important place in agriculture economy and diet of rural people. It has been used since ages for various kinds of products like *reori*, *gazak* and *patti*. Being a nutritive sweetener, it has a potential use in developing energy foods on large scale. It has been used as sweetener in many traditional confectionaries in India.

If we examine the modern confectionary products available in the market, for the incorporation of jaggery as sweetener, chocolate emerges as a potential choice. It seems that the nature of jaggery in terms of its color, texture and sweetness would make it very suitable for a chocolate like product. Chocolate confectionary has been a novelty food item over the years. Consumers of all ages and social classes have been enjoying it in various forms. Once seen as an item meant for children only, adults now savor chocolates as well.

RSM is a statistical technique which consists of a group of mathematical and statistical procedures that uses quantitative sensory data to determine and simultaneously solve multivariate equations which specify the optimum product for a specified set of factors. This considers interaction among the test factors and can be used to determine how the product changes with changes in the factor level (Thompson, 1982).

The aim of current study to optimize the physical characteristics [hardness and lightness(L*)] of jaggery based chocolate nuggets using Response Surface Methodology (RSM).

METHODOLOGY

Powder jaggery, cocoa powder, skim milk powder, cocoa butter, nuts (almond) and spices black pepper powder were the main ingredients for jaggery chocolate nugget.

The powder jaggery was purchased from the local market of Rudrapur, dist. U.S. Nagar, Uttarakhand. Cocoa butter and cocoa powder was procured from Laxmi treading company, Lucknow.

Process for making jaggery chocolate nugget :

All ingredients such as jaggery powder, skim milk powder, cocoa powder and cocoa butter were mixed in concher.

Conching:

Conching involves two stages, firstly conched in dry state called dry conching process for150min. Then cocoa butter is added and further conched for 30min, there after emulsion is added. After that it is conched for 60min. During this process the temp of the material in the concher is kept at 40-50^{0}C by mean of hot air blower. The total time of conching process is about 4h (Ziegleder, 2004).

Tempering:

The molten chocolate mass at temp 40-45^{0}C is lower down to 28^{0}C and increased to temp. of 32^{0}C (Baichoo, 2007). After the above steps, the adequate quantity of almond and black pepper powder was added and final mixing was completed.

Moulding:

The molten mass was then poured in plastic moulds and allowed to cool for 30 min (Baichoo, 2007).

For the physical characters study hardness by using texture analyzer was determined.

Design of experiments:

Independent variables were defined as cocoa powder, cocoa butter, skim milk powder, black pepper powder. Experiments were designed using Response Surface Methodology. The RSM design was chosen as it allows reduction in number of experiments without affecting the accuracy of results and to decide interactive effects of variables on the responses (Myers, 1987**)**. A Central Composite Rotatable Design based on 5 levels for 4 factors.

Table A : Response surface design of experiments

Independent variables per 100g of jaggery powder		Coded variables				
		-2	-1	0	1	2
Cocoa powder, g	X_1	15	20	25	30	35
Cocoa butter, g	X_2	50	55	60	65	70
SMP, g	X_3	40	45	50	55	60
Black pepper powder, g	X_4	1	1.5	2	2.5	3

Physical characteristics:

Hardness analysis:

Hardness of chocolate nugget samples during optimization and storage was measured on texture analyzer (Stable Microsystem Model TA- XTZi, UK) using 2 mm dia cylindrical stainless steel probe (Probe code- P/2). All the samples in cubical form (2.5x2.0x1.0 cm) were analysed. Force calibration was carried out by using 25 kg load cell and the texture analyzer settings were fixed (return to start option, pre test speed – 2.0 mm/sec, test speed - 0.5 mm/sec, post test speed - 5.0 mm/sec, rupture test distance - 1.0 mm, distance - 10.0 mm, force - 0.98 N, time - 5.00 sec, count - 5). The hardness was calculated using the software provided with the texture analyser (Szczesniak, 2002).

Colour analysis:

Colour of sample was determined by combination of digital camera, computer and graphic software for defining the color of chocolate nugget the L*, a* and b* values where are determined. L* is luminance or lightness component which ranges from 0 to 100, a*(from green to red) and b*(from blue to yellow) are chromatic components and ranges from -120 to 120. Photographs of freshly prepared chocolate nugget were used as the basis for determining L*, a* and b* values in adobe Photoshop. The color picker tool with sample size of 5X5 was used for determining the L*,a* and b* values. Four replications were taken for each sample **(**Papadakis *et al.*, 2000**)**.

RESULTS AND DISCUSSION

The experiments were conducted to develop chocolate nuggets using jaggery as sweetener. The experiments were planned using center composite rotatable design in 4 variables and response surface methodology was used for data analysis.

Hardness:

The hardness of the fresh chocolate nugget ranged from 12.1978-38.2536N (Table 1). A minimum hardness was found in chocolates containing 8.99% cocoa powder, 22.49 % cocoa butter, 22.49% SMP and 0.89% black pepper powder. Maximum taste score was found in nuggets containing 8.23% cocoa powder, 26.77% cocoa butter, 22.65 % SMP, 1.02% black pepper powder.

$$\text{Hardness} = 30.00 - 1.40250 X_1 + 3.35500 X_2 + 1.4917 X_3 - 0.48250 X_4 - 2.55875 X_1 X_2 - 1.88125 X_1 X_3 - 0.80875 X_1 X_3 + 1.58625 X_2 X_3 + 0.97625 X_2 X_4 - 0.53125 X_3 X_4 - 2.00042 X_1^2 - 2.96417 X_2^2 - 2.64042 X_3^2 - 1.84792 X_4^2 \quad \ldots\ldots (1)$$

Table 1 : Response for physical characteristics of fresh chocolate nugget

Expt No.	Hardness	L*	Expt No.	Hardness	L*
1	15.05	18.24	16	21.27	31.06
2	18.28	21.24	17	23.34	22.21
3	19.14	21.25	18	18.12	31.34
4	22.06	25.25	19	12.19	18.16
5	18.67	16.28	20	21.56	22.21
6	24.21	18.26	21	18.77	17.33
7	37.46	26.49	22	17.57	21.38
8	20.63	24.34	23	21.21	26.05
9	16.36	21.28	24	21.47	27.25
10	14.84	16.06	25	30	26.08
11	21.36	21.14	26	30	26.08
12	20.17	23.06	27	30	26.08
13	14.77	30.14	28	30	26.08
14	16.38	29.03	29	30	26.08
15	38.25	29.51	30	30	26.08

The lack of fit for the response surface model developed for hardness was not significant at 1% level of significance and the calculated adequate precision was greater than 4 and is desirable (Table 2). R^2 was found to be 84.35%. Therefore, the model was acceptable. The ANOVA for the response indicated that the model was adequate and explained more variability. The model was significant on the basis of model 'F_{cal}' value (Table 2). The equation (1) shows the multiple regression equation for hardness.

The effect of cocoa butter and SMP was significant at linear level ($P<0.01$) and ($P<0.05$), respectively. The cocoa butter and cocoa powder at quadratic level was found significant ($P<0.01$) and ($P<0.05$), respectively. The negative sign of coefficient of estimastion of cocoa butter and cocoa butter in quadratic level indicating hardness was in range at centre point and it decreased with increase or decrease of the levels cocoa butter and cocoa powder from centre point (Table 2). Contours shown in Fig.1 indicated that the maximum hardness was obtained at lower level of cocoa powder with SMP and cocoa butter and at higher level cocoa butter with cocoa powder and SMP. The shaded portion shown in Fig.1 indicated in range value for hardness.

Color (L*) :

The L* value of the fresh chocolate nugget ranged from 16.063-31.344. A minimum L* value was found in nuggets containing 12.35 % cocoa powder, 22.65 % cocoa butter, 22.65% SMP and 1.02% black pepper powder. Maximum taste score was found in chocolates containing 13.60% cocoa powder, 23.31% cocoa butter, 23.31 % SMP and 0.77% black pepper powder.

$$L^* = 26.08000+0.92625*X_1+1.65292*X_2+1.90375*X_3+1.34708*X_4+0.41688*X_1*X_2-0.21437X_1*X_3-0.60562*X_1*X_4+0.23813*X_2*X_3-0.94062*X_2*X_4+2.42563*X_3*X_4+0.18177X_1^2-1.46573X_2^2-1.67323X_3^2+0.15052X_4^2 \quad .....(2)$$

The lack of fit for the response surface model developed for L* value was not significant at 1% level of significance and the calculated adequate precision was greater than 4 and is desirable (Table 3). R^2 was found to be 84.39%. Therefore, the model was acceptable. The ANOVA for the response indicated that the model was adequate and explained more variability. The model was significant on the basis of model 'F_{cal}' value (Table 3). The equation (2) shows the multiple regression equation for hardness.

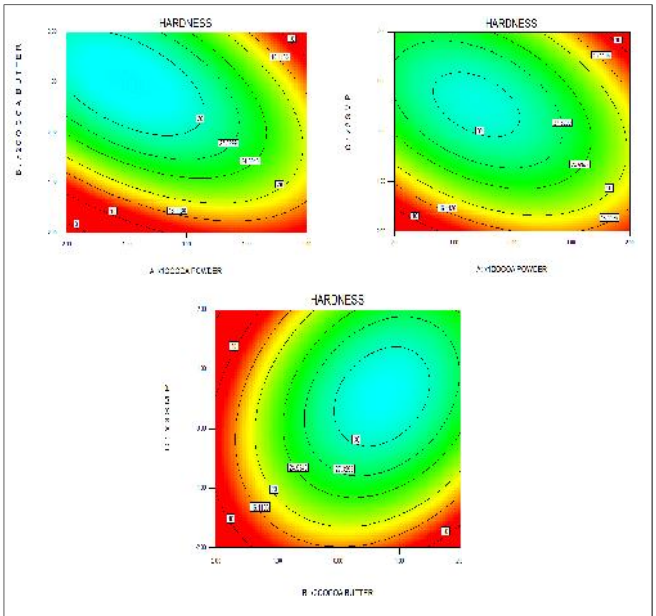

Fig. 1 : Effect of independent variable on hardness score of nugget

The effect of cocoa butter and SMP was significant at linear level (P<0.01). The quadratic effect was negative indicating L* value was in range at centre point and it decreased with increase or decrease of the levels SMP and cocoa butter from centre point (Table 3). Contours shown in Fig. 2 indicated that the maximum L* value was obtained at lower level of cocoa powder with SMP,cocoa butter and at higher level of SMP with cocoa butter and black pepper powder. The shaded portion shown in Fig.2 indicated in range value for L*.

Optimization of nugget ingredients :

Numerical optimization was carried out using Design-Expert 8.0.1.0 (Stat-Ease Inc) statistical software. The goal

Table 2 : Regression model results for hardness scores of chocolate nuggets samples

Source		Hardness		Regression coefficient
		F-value	P-value	
Model		5.72**	0.0009	30.00**
Linear	X_1	3.52	0.0802	-1.40
	X_2	20.15	0.0004	3.35**
	X_3	5.48	0.0335	1.75*
	X_4	0.42	0.5283	-0.48
Quadratic	X_1^2	8.19	0.0119	-2.00*
	X_2^2	17.98	0.0007	-2.96**
	X_3^2	14.26	0.0018	-2.64
	X_4^2	6.99	0.0184	-1.85
Interaction	X_1X_2	7.81	0.0136	-2.56
	X_1X_3	4.22	0.0577	-1.88
	X_1X_4	0.78	0.3909	-0.81
	X_2X_3	3.00	0.1036	1.59
	X_2X_4	1.14	0.3030	0.98
	X_3X_4	0.34	0.5703	-0.53
Lack of fit		1.68	0.3184	
R^2	84.35%			
Adeq Precision	8.569			

Table 3 : Regression model results for L* scores of chocolate nuggets samples

Source		Hardness		Regression coefficient
		F-value	P-value	
Model		5.79**	0.0008	26.08**
Linear	X_1	3055	0.0790	0.93
	X_2	11.31**	0.0043	1.65**
	X_3	15.01**	0.0015	1.90**
	X_4	7.51	0.0152	1.35
Quadratic	X_1^2	0.16	0.6981	0.18
	X_2^2	10.17	0.0061	-1.47
	X_3^2	13.25	0.0024	-1.67
	X_4^2	0.11	0.7479	0.15
Interaction	X_1X_2	0.48	0.4991	0.42
	X_1X_3	0.13	0.7267	-0.21
	X_1X_4	1.01	0.3303	-0.61
	X_2X_3	0.16	0.6979	0.24
	X_2X_4	2.44	0.1389	-0.94
	X_3X_4	16.24**	0.0011	2.43**
Lack of fit		1.12	0.4458	
R^2	84.39%			
Adeq Precision	8.719			

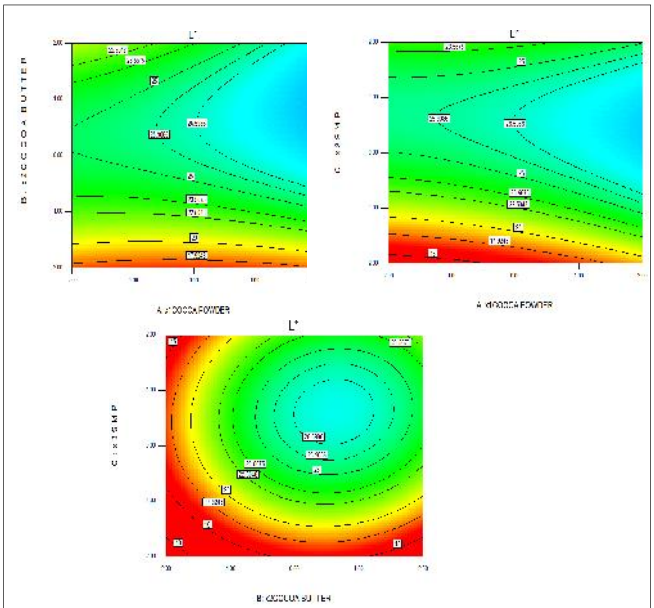

Fig. 2 : Effect of independent variable on L* score of nugget

was fixed to be in certain range for cocoa powder, cocoa butter, SMP and black pepper powder hardness and L* values. The range for independent variables was -2 to +2 and for hardness in the range 12.1978-38.2536N and L* values in 16.063-31.344. All the responses and independent variables were given similar (+++) importance.

The optimized levels of cocoa powder, SMP, cocoa butter, black pepper powder were 8.59%, 26.98%, 22.57% and 0.86%, respectively.

Hardness = 34.62N

L* = 26.45

Conculsion :

Therefore, planned experiments were conducted to develop powder jaggery based nugget using ingredients namely, cocoa powder, cocoa butter, skim milk powder (SMP) and black pepper powder. The ingredients were cocoa powder (15, 20, 25, 30 and 35g), cocoa butter (50, 55, 60, 65 and 70g) and black pepper powder (1, 1.5, 2, 2.5 and 3g) in per 100 g jaggery powder. The experimental design was based on Response Surface Methodology using Center Composite Rotatable Design in 4 variables. Physical characters were taken as dependent variables representing the product quality. The experimental data were analyzed to develop second order response surface model for these responses using multiple regression.

– Chocolate nugget prepared in this study had the sensory rating ranging from 12.1978-38.2536N for hardness and 16.063-31.344 for lightness (L*)

– The effect of cocoa powder was more on all responses followed by cocoa butter, skim milk powder and black pepper powder in that order.

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