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Formulation and evaluation of dry dessert mix containing sweetener combinations using mixture response methodology

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Abstract

Reduced calorie foods are an important area for product development. Foods formulated for diabetics and/or weight reduction tend to replace bulk caloric sweeteners with high intensity sweeteners. A mixture experimental design was used to model the acceptability of a low calorie dessert mix sweetened with single, binary and tertiary combinations of saccharin, cyclamate and stevioside. The design included constraints to permit sweetener addition according to the limits of food laws. The dessert mixture had a 37% caloric reduction when compared to the sucrose sweetened pudding, and texture equivalent to commercial products was reproduced with the addition of 0.01 g/100 ml carrageenan. The most acceptable combination of the sweeteners tested was saccharin: cyclamate (0.755:0.245), but other combinations could be used to obtain an acceptable product taking cost of the ingredients into consideration.

1. Introduction

Reduced calorie products, either having low fat concentration or low content of energy providing carbohydrates, continue to be an important area for product development and the consumer market. Consumers are now more aware of the relationship between diet and health, and consumption of this class of products has had a high rate of expansion in the last decade. Products that combine quality, safety, appropriate nutrient balance (less fat, cholesterol, sodium and sugar), that are easily prepared and of low cost, are ideal (IFT, 1989). Dry dessert mixes are low cost, easily prepared and can be formulated to fit a desirable nutritional content.

Reduced sugar consumption is recommended for diabetes (Kurihara & Nirasawa, 1994), weight control (Kreitzman, 1985), and prevention of dental cavities (Sillman & Coulston, 1991). Dietetic products for diabetics are formulated with intense sweeteners to combine absence of sugars with reduced calorie content, since weight control is also an important health consideration for diabetics. Verdi and Hood (1993) described the ideal sweetener as a substance that would duplicate the sensory properties of sucrose with no aftertaste or non-sweet side tastes, provide the functional proprieties of sucrose, be chemically stable, have low caloric density on a sweetness basis, and be nontoxic, non cariogenic, readily soluble, and economically feasible. None of the commercially available intense sweeteners combine all these characteristics, but limitations can be partially overcome by the use of sweetener blends (Hanger, Lotz, & Lepeniotis, 1996; Lim, Setser, & Kim, 1989; Matysiak & Noble, 1991).

Hanger et al. (1996) reported that blends of high intensity sweeteners provided flavour profiles that more closely matched sucrose, and that off-flavour, bitter, or sweet after-taste attributes of single sweeteners were minimized in a blend of two or more sweeteners. Other advantages are cost-reduction due to synergistic enhancement of sweetening power, an increased stability in aqueous systems and reduced exposure to a single chemical substance (Verdi & Hood, 1993; Lindey, 1993). The first sweetener blend used successfully was saccharin/cyclamate (Gelardi, 1987). When sugar is removed from starch-based dessert, the principal negative effect is an increase in syneresis. Carrageenan is a hydrocolloid with affinity for calcium-rich casein, that can be used to prevent syneresis in starch-based desserts formulated without sugar (Glicksman, 1983).

Optimization is the choice of a best alternative from a specified set of alternatives (Arteaga, Li-Chan, Vasquez-Arteaga, & Nakai, 1994). Optimization of product formulations can be achieved through the use of statistical

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techniques and various experimental designs are available to minimize the number of experiments in product optimization. Mixture experiments are suitable for food products that require more than one ingredient, since proportions of the ingredients in the mixture and their levels are dependent on each other, and the sum of all components is always one or 100% (Hare, 1974). Our objective was to test single sweeteners and combinations of sweeteners to be used in a dry dessert mix, using a mixture design that included constraints to permit sweetener addition according to the limits regulated by food laws in Brazil.

2. Material and methods

2.1. Dry mix for dessert

The following ingredients were used: corn starch (Maizena, Brazil Corn Refineries Ltd.); powdered non-fat milk (Molico, Nestlé Industry and Commerce Ltd.); partially defatted chocolate powder (Chocolates Garoto Inc.); carrageenan (FMC Brazil); sodium cyclamate and sodium saccharin (Brasfanta Inc.); stevioside (Stevia Farma). Dry dessert mixes were prepared using 23.9 g of corn starch, 8 g of partially defatted chocolate powder, 0.05 g of carrageenan and sweetener or sweetener combinations according to the experimental design. The dry mix was dissolved in 500 ml of reconstituted non-fat milk, cooked with constant stirring until done and then distributed in disposable plastic cups, 50 ml capacity, cooled to room temperature, refrigerated to 5°C and stored for 24 h until sensory analysis.

2.2. Texture measurement

Gels were formed in plastic cups, 40 mm in diameter and 50 mm height and removed from the mould before texture measurement. The prepared desserts were tested with a Stevens LFRA texture analyzer (Stevens Advanced Weighing System Ltd., England), with a cylindrical probe of 12.74 mm diameter, 10mm penetration in the central region of the gel and at 10 mm/min constant punching speed. Maximum resistance to penetration, to a fixed depth, was determined in Newtons as an index of gel firmness of the prepared desserts.

2.3. Experimental design

An experimental design for mixtures, the ADMIX procedure, with the XVERT algorithm to select the vertices of a sub-area of the simplex, of the SAS/QC program was used (SAS, 1989). The variables in the sweetener mixture were: saccharin (X_1), cyclamate (X_2) and stevioside (X_3). Proportions of the variables in the mixture were calculated in % and the sum was equivalent to 100 % or:

$$X_1 + X_2 + X_3 = 1.$$

Single sweeteners or sweetener combinations were selected to be equivalent to a 10% sucrose solution. Proportions of cyclamate and stevioside were limited to 0.00–0.49 and 0.00–0.70, the maximum limit for addition of these sweeteners calculated in g/100 ml of the prepared product.

2.4. Sensory analysis

Twenty-four panellists, 20–40 years of age, 3 males and 21 females, consumers of this type of dessert, were selected for their familiarity with the product being tested. Sensory analysis occurred in three sections (4, 4 and 3 samples), in the morning, between 9 and 11 am. Samples were presented in disposable plastic cups, 50 ml, coded with 3 digit numbers, after the 24 h storage at 5°C. Each panellist tasted the 11 samples from the experimental design, randomized before each test period and in individual booths. Samples were evaluated for acceptability using a randomized balanced block design, with a structured hedonic line scale with anchor points, 1 (dislike very much) and 9 (like very much) (Stone & Sidel, 1993).

2.5. Data analysis

Data from the sensory analysis was used to calculate Scheffé's canonical special cubic equation for three components:

$$Y = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_{12} X_1 X_2 + \beta_{13} X_1 X_3 + \beta_{23} X_2 X_3 + \beta_{123} X_1 X_2 X_3,$$

where Y, the dependent variable, is the value given for acceptance of each sample, β's are the parameter estimates for each linear and crossproduct term for the prediction model and X_1 = saccharin, X_2 = cyclamate and X_3 = stevioside in sweetness equivalent to sucrose solutions in %. Analysis of variance to examine significance of the canonical model followed recommendations of Cornell (1981), using the software MIXREG (Barros Neto, Scarminio, & Bruns, 1995). Triangular contour plots were constructed based on the regression equations generated with the sensory data of acceptability of the dessert sweetened with a single or a mixture of sweeteners, using the MIXPLOT program (Barros Neto et al., 1995).

3. Results and discussion

3.1. Caloric value

The prepared dessert, approximately 32 g of the mix in 500 ml of reconstituted non-fat milk, serves four portions of 130 g, with 288.7 J, while the caloric value of the same product sweetened with sucrose is 167.4 J higher. There was a 37% reduction in caloric content for the product formulated with sweetener or sweetener combinations.

3.2. Sweetness equivalent

Data from the literature for relative sweetness of the sweeteners in 100 ml of water, compared to sucrose solutions of different concentrations, was used to determine equi-sweet equations for the three sweeteners (Furia, 1972; Mori, 1992). The adjusted equations were: (mg of saccharin)$^{1/2} = 0.343 + 0.943X - 0.063X^2 + 0.002X^3$, $R^2 = 0.99$; (mg of cyclamate) $= 7.90 + 9.62X + 1.09X^2$, $R^2 = 0.99$; (mg of stevioside) $= -0.66 + 4.9X + 0.53X^2$, $R^2 = 0.99$, where X = % sucrose in solution. The maximum amount of each sweetener that could be used according to current food laws in Brazil was observed and incorporated in the design as the constraints, to limit the sub area of the simplex: saccharin 30 mg/ 100 g of the prepared product, cyclamate 130 mg/100 g and stevioside 60 mg/100 g. The maximum value allowed for saccharin was equi-sweet to a 10% sucrose solution, cyclamate to 4.9% and stevioside to 7%.

3.3. Texture

Texture is an important sensory attribute when evaluating acceptability of a product. It is basically a physical property and its perception can be affected by chemical, psychological and cultural factors (Peleg, 1983). When sugar is eliminated from a food gel there is an increase in syneresis, which occurred as soon as the dessert cooled. The textures of 16 commercial desserts of 4 different brands, prepared according to package instructions, were determined and found to be 0.157 ± 0.009 N. The test puddings could reproduce the same texture (0.158 N) with 0.01 g/100 ml carrageenan added to the dessert mix and, at the same time, the hydrocolloid controlled the syneresis of the starch gel prepared without sucrose.

3.4. Sensory analysis

Average values for acceptability from the sensory analysis for the 11 test samples, varied from 3.88 to 6.13 (Table 1). The lowest acceptability, for a single sweetener, was for saccharin, among the binary combinations saccharin (0.3):stevioside (0.7) and among the three component combinations saccharin (0.15): cyclamate (0.15): stevioside (0.7). For sweetener blends the highest level of stevioside, 60 mg, equivalent to a 7% sucrose solution, seems to be a factor for reduced acceptability, except when combined with cyclamate in a 0.3:0.7 mixture in experiment 8.

The most acceptable of the binary combinations and the most acceptable among the tested desserts was the one sweetened with the mixture saccharin (0.755): cyclamate (0.245). Among the tertiary blends, saccharin (0.362): cyclamate (0.256): stevioside (0.382) was the one with the highest acceptability. Probably, various combinations, with very similar average acceptability could be used to sweeten the product and the determining factor for selecting the combination would be the cost of the sweeteners.

Table 1
Acceptability of formulations in the three-component constrained mixture design

Formula	Component proportion			Acceptability
n°	X_1[a]	X_2[b]	X_3[c]	
1	0.150	0.150	0.700	5.38
2	0.000	0.395	0.605	5.88
3	0.300	0.000	0.700	4.46
4	0.000	0.490	0.510	5.92
5	0.510	0.490	0.000	6.13
6	0.255	0.490	0.255	5.92
7	0.362	0.256	0.382	6.04
8	0.000	0.300	0.700	6.04
9	0.755	0.245	0.000	6.21
10	1.000	0.000	0.000	3.88
11	0.650	0.000	0.350	5.96

[a] X_1 = saccharin.
[b] X_2 = cyclamate.
[c] X_3 = steveoside.

The values for sweetness were calculated from equi-sweet data, but when the blends were used in the product, deviations in sweetness perception were likely to occur. The products with the highest acceptability were, probably, the samples that contained blends that combined a sweetness profile more similar to sucrose and had the least off-flavour, bitterness or aftertastes, characteristics associated with the individual ingredients, which could be reduced when blends are used (Hanger et al., 1996; Verdi & Hood, 1993).

The canonical Scheffé's equation for acceptability was:

$$Y = 3.92X_1 - 2.22X_2 + 1.69X_3 + 20.78X_1X_2 + 11.28X_1X_3 + 24.97X_2X_3 - 32.53X_1X_2X_3$$

Binary combinations of sweeteners contributed to the model more than the other factors, and the negative sign for the parameter estimate of the tertiary combination seems to indicate that, in these experiments tertiary combinations are less acceptable. The model was significant at $p \leq 0.05$ with 93% of the variation being explained by the model and variation coefficient of 5.6%. A comparison between observed measurements and predicted values for acceptance had an average relative error of 3%.

The model was used to generate the constrained contour plots for the acceptability of the pudding (Fig. 1). Binary combinations of saccharin: cyclamate, right side

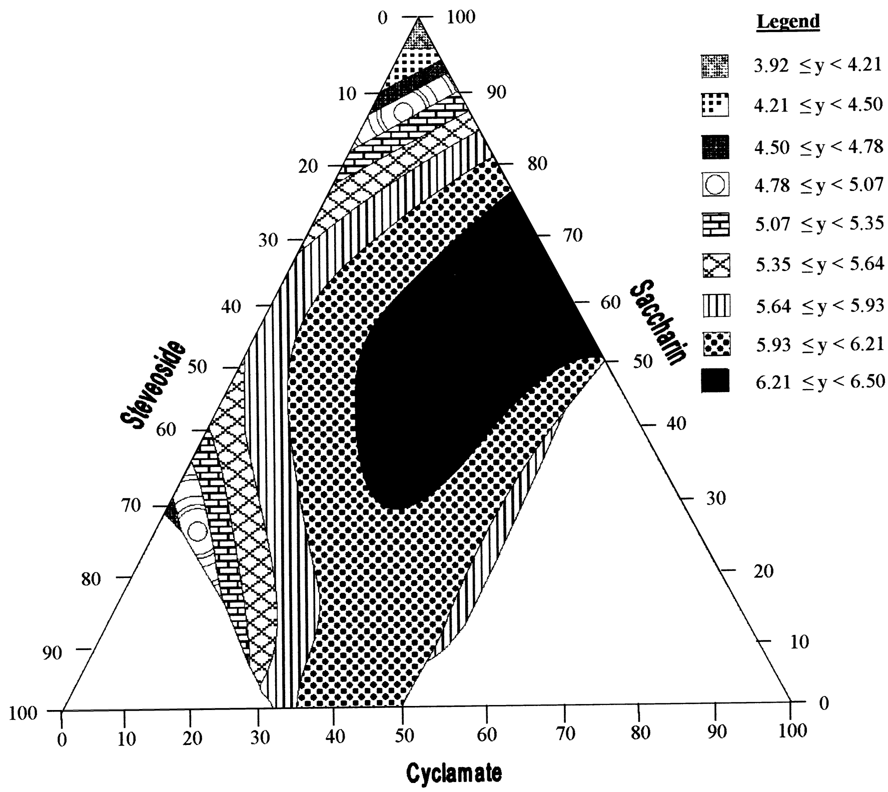

Fig. 1. Contour plot for pudding acceptability (Y) for blends containing saccharin (X_1), cyclamate (X_2) and steveoside (X_3).

of the figure, had higher average acceptabilities (experiments 5 and 9) and the proportions varied from 0.49:0.51, practically equal sweetness from each ingredient, to a 0.755:0.245 proportion. Cost of the ingredients can be used as a deciding factor when selecting combinations for product application. Acceptability declined towards the single sweetener saccharin and towards the left side of the experimental area, where saccharin: stevioside combinations were tested (Fig. 1).

4. Conclusion

The sweetener-sweetened dessert had a 37% reduction in calories compared to a sucrose-sweetened mix. Addition of carrageenan, 0.01 g/100 ml, controlled the tendency of liquid leakage from the starch gel and the prepared product had the same firmness as commercial products. The highest acceptability was for a product formulated with a binary combination of saccharin:cyclamate (0.755:0.245), but other combinations could be used to obtain an acceptable product.

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