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An alternative formula for the sweetening of reduced-calorie cakes

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A calorie-reduced sponge cake was formulated by using aspartame and/or acesulfame-K as sweeteners, fructose as a sugar substitute, and polydextrose as a bulking agent. On the basis of chemical, physical, and sensory analyses of the experimental combinations, it was demonstrated that adding any sweeteners as replacement for sucrose resulted in a decrease in the quality and acceptability of the resultant cake. A formulation involving fructose and polydextrose gave a product acceptability similar to that of the control sample. At the same time, the cake samples achieved 40% reduction in calories.

INTRODUCTION

Most low-calorie foods are better designated as 'reduced-calorie' since technically the food cannot be formulated or processed without some ingredients that yield calories. Such diets are used for maintenance of the ideal weight and for weight reduction. A significant number of people are overweight, and obesity is frequently cited as a serious health problem.

Dietetic foods suitable for diabetics may have the same 'calorie-value' but are used as a sugar substitute, which is intended to replace sucrose. Fructose and sugar alcohols sorbitol, mannitol, lactitol, and xylitol are often allowed for diabetics, since their metabolism does not require insulin (Askar & Treptow, 1985). Non-nutritive sweeteners can also be used in such diets. These are sweetening substances, which are not metabolised, such as saccharin and acesulfame-K, or which are contributing only a negligible amount of energy as normally consumed, such as aspartame and thaumatin (Askar, 1991).

Aspartame and acesulfame-K are 150–180 times as sweet as sucrose. Aspartame has a clean, sweet taste, but prolonged or intense heat can induce breakdown of the product, making it difficult to use in bakery products (Claninger *et al.*, 1974; Beck, 1978). On the other hand, acesulfame-K is stable for nearly all applications as a sweetener in foods. Its sweet taste remains unchanged under heat exposure (Von Rymon Lipinski *et al.*, 1981; Askar *et al.*, 1985).

Hess *et al.* (1983) studied the effects of using aspartame and fructose and combinations of the two substances on the properties of some cake brands. They found that the prepared cake with added fructose (at a level of 25%) was judged more tender than similarly baked cake with only aspartame. The same trend was also observed for textural and taste characteristics.

Askar *et al.* (1987) studied the effect of using a mixture of sucrose (at levels of zero, 25, 50, and 100%) with sugar substitutes (fructose, xylitol, and sorbitol) or sweeteners (acesulfame-K, aspartame, and saccharin) on the properties of the resultant dietetic cake. The findings obtained showed that the replacement of sucrose with sweeteners or sugar substitutes, at levels of above 25% resulted in a decrease in the quality and acceptability of cake.

Polydextrose is a bulking agent that supplies only 1 kcal per gram. It is reported to contribute no sweetness or flavour to products in which it is an ingredient and to give the appropriate texture and mouth feel, qualities normally provided by sugar (Torres *et al.*, 1981; Freeman, 1982).

This study was undertaken to determine whether polydextrose and sweeteners (aspartame and acesulfame-K) and/or fructose could be used to replace the sweetness and functional properties of sucrose in sponge cake, so that a significant reduction would be obtained in the caloric content and sucrose content of the product.

MATERIALS AND METHODS

Materials

The materials used in the investigation were:

wheat flour (72% extraction), sucrose (commercial grade), fat (pure butter oil), fresh whole eggs, baking powder (sodium bicarbonate and cream of tartar), and vanilla (pure vanillin) were purchased from the local market; fructose, crystalline and food grade from Xyrofin Ltd, Switzerland; acesulfame-K (Sunnet) from Hoechst AG, Germany; aspartame (Nutrasweet) from G. D. Searle & Co. Ltd, USA; polydextrose, from Pfizer Co., USA.

Processing of sponge cake

Cake samples were prepared according to the method of Bennion & Bamford (1973) and described by Askar *et al.* (1987) and by using the following recipe:

Flour	29·51%
Sucrose	23·19%
Fat	16·86%
Eggs	29·51%
Baking powder	0·85%
Vanilla	0·08%

The dietetic cake samples were prepared by substituting sucrose with fructose, aspartame, and acesulfame-K. The calculated relative-sweetness values of fructose, aspartame, and acesulfame-K were, respectively, 1·5, 150, and 150 times that of sucrose. The polydextrose used in cake-making was included in such a way that the mixture of sweeteners and polydextrose was equal to the substituted sucrose.

Methods of analysis

Moisture, protein, fat, reducing, non-reducing, and total sugars of the cake samples were determined according to AOAC methods (1980). The colour was determined as follows: 1 g of a sample from crumb only, crust only, and the whole cake, was extracted with 5 ml acetone (80%) for 24 h at room temperature. The extract absorbance was measured at 420 nm.

The volume of the cake was determined by the rapeseed-displacement method described by Bennion & Bamford (1973). The cake was weighed after removal from the pan, and the specific volume was measured.

Organoleptic analysis was carried out according to Gould (1977), and the results were statistically analyzed by using the method of Snedecor & Cochran (1967).

RESULTS AND DISCUSSION

Table 1 indicates that the moisture content of cake-batter samples ranged from 18 to 20%. The moisture content of the cake samples produced was slightly lower when aspartame or acesulfame-K was used. Insignificant differences were found with respect to fat and protein content. The content of reducing sugar and total sugars changed according to the substitute.

The energy value of the cake samples (Table 1) was 271 kcal in the control, 176 kcal when fructose was used (in a proportion of 25%) and only 126 kcal when acesulfame-K or aspartame was used (in a proportion of 100%). On the other hand, using polydextrose in the sweetener mixtures led to a slight increase in the calorie value of the cake samples produced.

The physical properties of the prepared samples were also studied (Table 2). The results indicated that the

Table 1. Chemical analysis and energy value of the cake produced

Treatment[a]	Moisture (%)	Protein (%)	Fat (%)	Reducing sugar (%)	Non-reducing sugar (%)	Total sugar (%)	Energy value (kcal)	Energy value (kJ)
Suc. (100%)	18·1	7·8	6·9	1·8	42·6	44·4	270·9	1151
Ace. (100%)	18·3	9·5	8·9	1·8	0·95	2·73	129·1	549
Ace. (100%) + P.D.	19·7	7·8	6·8	3·58	1·07	4·65	111·0	472
Ace. (75%) + Fruc. (25%)	20·9	8·5	8·7	15·7	0·18	15·88	175·8	747
Ace. (75%) + Fruc. (25%) + P.D.	19·2	7·83	6·72	17·73	0·37	18·1	161·2	685
Asp. (100%)	18·8	9·6	8·7	1·93	1·0	2·93	128·0	544
Asp. (100%) + P.D.	19·8	7·6	6·9	3·5	1·1	4·6	110·8	471
Asp. (75%) + Fruc. (25%)	20·2	8·6	8·5	15·3	0·17	15·47	172·8	734
Asp. (75%) + Fruc. (25%) + P.D.	19·4	7·75	6·81	17·9	0·40	18·3	165·4	703
Ace. (50%) + Asp. (50%)	18·6	9·6	8·9	1·75	0·98	2·73	129·40	550
Ace. (50%) + Asp. (50%) + P.D.	19·7	7·7	8·6	3·82	0·95	4·77	127·30	541
Ace. (37·5%) + Asp. (37·5%) + Fruc. (25%)	20·2	8·6	8·7	15·5	0·19	15·69	175·40	746
Ace. (37·5%) + Asp. (37·5%) + Fruc. (25%) + P.D.	19·3	7·79	6·70	17·70	0·39	18·09	163·8	696

[a] Percentages refer to replacement of sucrose sweetness.
Suc. = Sucrose Fruc. = Fructose Ace. = Acesulfame-K Asp. = Aspartame P.D. = Polydextrose.

Table 2. Cake characteristics in relation to the sweeteners used and polydextrose

Treatment[a]	Weight (*W*)	Volume (*V*)	Specific volume (*V*/*W*)	Crust colour	Crumb colour	Whole-cake colour
Suc. (100%)	125·7	446·2	3·55	0·31	0·21	0·24
Ace. (100%)	87·2	245·9	2·82	0·16	0·11	0·15
Ace. (100%) + P.D.	119·0	392·7	3·40	0·20	0·14	0·19
Ace. (75%) + Fruc. (25%)	95·4	295·7	3·10	0·27	0·18	0·23
Ace. (75%) + Fruc. (25%) + P.D.	119·0	407·0	3·30	0·23	0·17	0·21
Asp. (100%)	87·2	241·0	2·77	0·17	0·11	0·15
Asp. (100%) + P.D.	118·0	383·5	3·25	0·19	0·13	0·16
Asp. (75%) + Fruc. (25%)	94·8	298·6	3·15	0·26	0·17	0·22
Asp. (75%) + Fruc. (25%) + P.D.	119·0	416·5	3·5	0·22	0·15	0·20
Ace. (50%) + Asp. (50%)	88·0	246·5	2·80	0·17	0·12	0·14
Ace. (50%) + Asp. (50%) + P.D.	117·0	392·0	3·35	0·21	0·15	0·20
Ace. (37·5%) + Asp. (37·5%) + Fruc. (25%)	96·0	307·0	3·2	0·25	0·18	0·21
Ace. (37·5%) + Asp. (37·5%) + Fruc. (25%) + P.D.	120·0	410·5	3·42	0·23	0·16	0·22

[a] See footnote to Table 1.

reduction in specific volume was distinct when acesulfame-K or aspartame was used in cake preparation without adding polydextrose. In contrast, using polydextrose in the cake formula yielded cake samples having almost the same specific volume as that of the control samples.

Using fructose (at a level of 25%), with aspartame or acesulfame-K, yielded a reduction in specific volume.

Regarding the colour of cake batter, results indicated that the presence of fructose in the cake formula caused the development of a greenish colour. On the other hand, a decrement in cake colour was observed by using acesulfame-K, aspartame, or polydextrose in the cake formula in comparison with the control sample. These findings are in agreement with the results obtained by Velpe & Mekes (1976), Koespel & Hoseney (1980), Thompson *et al.* (1980), and Askar *et al.* (1987). The excessive exterior brown colour can be attributed to the reaction of fructose with non-reducing sugars.

The cake samples were evaluated for height, grain uniformity, softness, and over-all eating quality. The means of the scores and their significance are presented in Table 3. In all instances, the sucrose cake (control) scored higher than the cake that was prepared using sweeteners. The results indicated that replacement of sucrose with only acesulfame-K or aspartame caused a significant deterioration in cake properties. In contrast, when fructose (25%) was incorporated with the sweeteners, the eating quality of the prepared cakes was generally higher than that of those samples prepared with sweeteners. The results were in agreement with the findings of Hess & Setser (1983), who showed that the presence of fructose enhanced the taste character of layer cake.

Table 3. Mean values for sensory evaluation of sponge-cake properties

Treatment[b]	Height (10)	Grain uniformity (10)	Softness (10)	Eating quality (15)
Suc. (100%)	9·3 *a*	9·2 *a*	9·0 *a*	14·0 *a*
Ace. (100%)	7·3 *b*	7·2 *b*	7·0 *c*	11·2 *c*
Ace. (100%) + P.D.	8·6 *a*	8·4 *a*	8·2 *a,b*	11·4 *b,c*
Ace. (75%) + Fruc. (25%)	7·7 *b*	8·0 *b*	7·9 *a,b,c*	12·5 *b*
Ace. (75%) + Fruc. (25%) + P.D.	8·8 *a*	8·8 *a,b*	8·6 *a,b*	13·3 *a*
L.S.D.[a]$_{0·05}$	1·07	0·49	0·92	1·22
Suc. (100%)	9·3 *a*	9·2 *a*	9·0 *a*	14·0 *a*
Asp. (100%)	7·2 *c*	7·0 *c*	6·9 *c*	10·6 *b*
Asp. (100%) + P.D.	8·5 *a,b*	8·1 *b*	8·4 *b*	10·3 *b*
Asp. (75%) + Fruc. (25%)	8·0 *b*	7·8 *b*	8·0 *b*	12·8 *a*
Asp. (75%) + Fruc. (25%) + P.D.	9·0 *a,b*	8·8 *a*	8·6 *a,b*	13·4 *a*
L.S.D.[a]$_{0·05}$	1·07	0·46	0·90	1·30
Suc. (100%)	9·3 *a*	9·2 *a*	9·0 *a*	14·0 *a*
Ace. (50%) + Asp. (50%)	7·7 *b*	7·2 *c*	7·1 *c*	12·0 *b*
Ace. 50% + Asp. (50%) + P.D.	8·4 *a,b*	8·4 *b*	8·2 *a,b*	12·3 *b*
Ace. (37·5%) + Asp. (37·5%) + Fruc. (25%)	8·0 *b*	8·2 *b*	8·0 *b*	13·0 *a,b*
Ace. (37·5%) + Asp. (37·5%) + Fruc. (25%) + P.D.	8·9 *a,b*	8·7 *a*	8·5 *a,b*	13·6 *a*
L.S.D.[a]$_{0·05}$	0·95	0·45	0·85	0·11

[a] L.S.D.: Least significant difference at $P \leq 0·05$.
[b] See footnote to Table 1.

With regard to the effect of polydextrose on cake properties, Table 3 shows an increase in the height of cake samples containing polydextrose compared with the others. Polydextrose caused an improvement in textural properties of the prepared samples.

With respect to eating quality, there was a significant difference between cakes containing polydextrose and polydextrose-free cake samples.

Finally, it can be seen that the replacement of sucrose with the sweeteners in the presence of fructose and polydextrose gave a product acceptability similar to that of the control sample. At the same time, the reduction in calorie intake was about 40%.

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