Role of Ingredients in the Texture of a Flanlike Food

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ABSTRACT

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Custards are a popular food in many parts of the world. Similar foods called flans, made from milk and certain colloids, are being introduced in the U.S. market. These foods are considered to have a great potential for use as a snack, dessert, or meal replacement. This study reports the role of various food polysaccharides, lipids, emulsifiers, rice flour, and sugar in imparting custardlike (egglike) texture, as measured by a texturometer. The results showed that all of the textural characteristics of egg custard can be duplicated by using appropriate amounts of the above mentioned ingredients. The significance of a flanlike engineered food in providing a nutritious, desirable and convenient food product to our growing elderly population and as as a food for infants and children is discussed.

Continuous changes in the life style of affluent and working populations, particularly in developed countries, lead to novel food demands to meet increased awareness of health, fitness, and well-being. Most of the developed countries have also reached static population growth, but the proportion of middle aged and elderly will continue to increase. The fastest growing segment of the United States population is 65 and older. This group is prone to certain nutritional diseases such as obesity, osteoporosis, and hypertension. Nutritionists advocate increased consumption of calcium-rich foods to combat many of these diseases (Heaney 1986). Dairy products are the major source of calcium in the American diet. Nonfat dry milk (NFDM) can be used as a convenient and natural source not only of calcium but also of high-quality protein to engineer new foods for this group.

A custardlike dairy food has been recognized as having good potential in the United States food market (Anonymous 1984a). Similar foods, called flans, are already popular in Europe. An old fashioned custard/flan is a moldable, fresh dairy product made from a mixture of milk and sugar that utilizes eggs as a gelling agent. The product is consumed as a dessert or snack food. Advances in food technology have shown that a moldable flan can also be made by using special mixtures of carrageenans to form the gel (Anonymous 1984b). The carrageenan gel shrinks in a controlled manner as it sets up, allowing easy unmolding. Usually, small amounts of specially prepared and purified starches are used in the flans to avoid pastiness or mealy mouthfeel to the finished product. Several examples of such products have been described (Anonymous 1984b).

Carrageenans have been used as a gelling agent in milk for hundreds of years, initially by boiling Irish moss with milk and sugar to form gels. The extracted carrageenans have many forms, each having distinct gel characteristics. Usually various forms such as kappa, iota, and lambda are blended to provide the desired gel characteristics. Exploratory research in our laboratory showed that a desirable flanlike food could be formulated from mixtures of NFDM, sugar, rice flour, carrageenans, water, and other additives. Development work also showed that the texture of the final product was significantly affected by the amount and variety of carrageenan mixtures and other additives. Similarly the addition of fat, emulsifier, rice flour, and stabilizers imparted distinct texture and mouthfeel. This study was planned to identify the components that impart the egg-flan texture, as measured by a modified FMC Marine Colloids gel tester (model GT-2) and by an organoleptic panel.

MATERIALS AND METHODS

A fractional factorial experimental design was used to characterize the effect of the components on texture of the flanlike food. One hundred twenty-eight treatments, termed a "quarter rep" (a fourth of the possible 512 interactions of the 18 variables considered), were selected so that no main effects or two-way interactions between components were confounded (Cochran and Cox 1957, Box et al 1978).

One level from each group of components given in Table I was used to formulate the experimental flanlike food as required by the "quarter rep" design. All components except those containing fat and emulsifier were mixed in a 400-ml tall beaker for 2–3 min with a spatula to make a homogeneous slurry. Samples containing fat and/or emulsifier were suspended into a NFDM-water mixture, heated to about 60° C to melt, homogenized using a Gaulin single-piston, two-stage homogenizer using 800 psig on the second stage and 3,000 psig on the first stage, and then freeze-dried. The freeze-dried mixture was then combined with the other ingredients instead of NFDM. The slurry was heated in a boiling water bath and cooked while being stirred with a spatula until the contents reached 88–90° C. It was held at this temperature for another 2–3 min while the temperature was continuously checked using a metal-stemmed dial thermometer immersed in the test sample. Then the contents were transferred into a mold. The mold was immediately transferred to a 4° C refrigerator, then held overnight,

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unmolded, and evaluated using a modified gel tester (Anonymous 1982) and by an organoleptic panel. For comparison, an egg custard was prepared according to a published recipe (Anonymous 1968).

An FMC Marine Colloids gel tester (model GT-2) was modified to compare the gel strength of experimental foods with egg custard. This instrument was custom designed to measure the "break force" and to develop texturometer curves of food gels. The modification involved using a Mettler PE 2000 top-loading balance interfaced with a computer to record force (in grams) instead of a dietary (spring) scale as shown in Figure 1. The force exerted by the plunger on the experimental gel was then recorded as a function of time. A circular knife, with a cylindrical die approximately 2-cm in diameter, fitted with a 4.5-cm circular ring attached by four spokes (0.05 cm thick and 0.5 cm high) was used as a plunger. This plunger gave reproducible curves (force vs. time) during initial evaluation. The instrument was fitted with a synchronous motor that lowered the plunger into the gel at a constant rate of 10.9 sec/cm. The rate can be adjusted depending upon the sample characteristics. After the knife contacted the gel, the top-loading balance started transmitting weight signals every 0.125 sec, thus recording force (g) versus time (sec) data. From the rate of descent, knife penetration (distance) into the gel could also be determined.

The typical texturometer curve (i.e., force vs. time) from egg custard is shown in Figure 2. Eleven responses were measured or calculated in the following manner.

XA = Time (sec) at which a first reading of 5 g or greater was recorded.

YA = Actual force recorded at time XA.

XB = Time at which curve reached the maximum height.

YB = Force (g) recorded at time XB. This is the force required to break the gel.

XC = Time at which minimum force following XB was recorded. This is the second break in the curve.

YC = Force recorded at time XC.

YD = Force recorded at 14.08 sec (XD).

E = Organoleptic texture score (1–10, 10 being comparable to egg custard).

$$\text{Slope } 1 = (\text{YB} - \text{YA})/(\text{XB} - \text{XA})$$

$$\text{Slope } 2 = (\text{YC} - \text{YB})/(\text{XC} - \text{XB})$$

$$\text{Slope } 3 = (\text{YD} - \text{YC})/(\text{XD} - \text{XC})$$

TABLE I
Ingredient Composition of Experimental Flanlike Foods

Component Level	Amount (g)
Carrageenan[a]	
1. FL674 P	0.30
2. FL674 P	0.50
3. FL431 P	0.30
4. FL431 P	0.50
Sugar[b]	
1. Iso sweet 100	33.30
2. Iso sweet 5500	25.45
Fat[c]	
1. No added fat	
2. Milk fat	4.90
3. Crisco shortening	4.90
4. Crisco shortening	9.80
Gum[d]	
1. Locust bean gum (FL50-50)	0.15
2. Locust bean gum (FL50-50)	0.20
3. Pectin (Genulacta, type PL93)	0.10
4. Pectin (Genulacta, type PL93)	0.15
Rice flour[e]	
1. Long grain	2.00
2. Long grain	4.00
Emulsifier[f]	
1. Durlac 100	...
2. Durlac 100	0.25
Nonfat dry milk[g]	13.3
Tetrapotassium pyrophosphate[h]	0.36
Deionized water	140.00

[a] Carrageenan mixtures from FMC Corp., Marine Colloids Division, Philadelphia, PA.

[b] High-fructose syrup having 42% (level 1) and 55% (level 2) fructose, from A. E. Staley Manufacturing Co., Decatur, IL.

[c] Vegetable shortening from Procter & Gamble Co., Cincinnati, OH.

[d] From Hercules, Inc., PFW Division, Wilmington, DE.

[e] From Riviana Foods Inc., Houston, TX.

[f] From SCM, Durkee Industrial Foods, Louisville, KY.

[g] Low heat, extra grade, from Mid-America Farms, Springfield, MO.

[h] Food grade, from FMC Corp.

The data were analyzed using analysis of variance techniques. All 11 response variables were examined for normality and homogeneity of variance (across the main effects categories). It was unnecessary to transform XA, XB, XC, and E variables, but a square root transformation was needed for four other variables (YA to $\sqrt{\text{YA}}$, YB to $\sqrt{\text{YB}}$, YC to $\sqrt{\text{YC}}$, and YD to $\sqrt{\text{YD}}$), and a log transformation was needed for the remaining three variables (slope 1 to log slope 1, slope 2 to log (log slope 2x − 1 slope 2x − 1), and slope 3 to log (slope 3 + 1). Analyses were conducted on the transformed variables but were transformed back to report means and confidence intervals.

Two broad questions were addressed in the analysis: Which of the components affected responses? and Which combinations of components resulted in a product with textural properties most similar to the control (egg custard)?

RESULTS AND DISCUSSION

Foods like flans are not bitten and chewed but compressed between the tongue and palate and then moved around the mouth to mix with saliva. The amount of pressure exerted by the tongue is adjusted subconsciously by the person, depending upon the hardness of food. A texturometer cannot adjust to the food being tested. In the present study the texturometer plunger (knife) compressed the test sample uniformly and at a fixed rate. Figure 2 indicates the shear force deformation curve of a typical egg flan. The point YB is the maximum gel strength or the force required to rupture the gel. Similarly YC is the minimum gel strength of the test sample and is a distinct break in the compression curve.

The significant *F* values shown in Table II reject the hypothesis that the effect of a component was the same for all levels of that component (e.g., Ho: fat 1 = fat 2 = fat 3 = fat 4). Similarly, significant *F* values for two-way interactions reject the hypothesis that the response variable exhibits unchanged behavior across all possible combinations of levels for two interacting components.

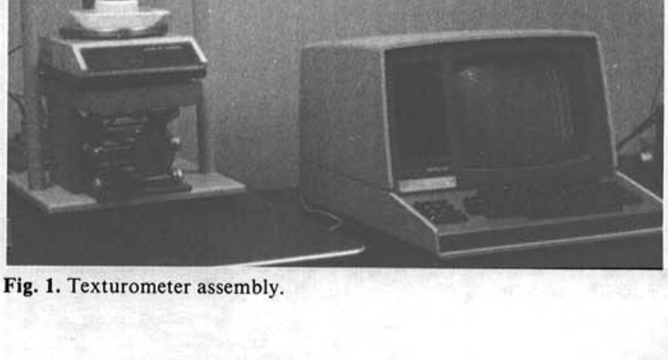

Fig. 1. Texturometer assembly.

For each response (e.g., XA), a model with all six main effects and all 15 two-way interactions was fit, and all higher order interactions were combined into the error term. The carrageenans affected XB, YB, XC, YC, YD, E, slope 1, slope 2, and slope 3. Sugars affected only slope 2. Fat affected YB, YC, YD, E, slope 2, and slope 3. The gums affected XB, YC, XC, YC, YD, E, slope 1, slope 2, and slope 3. Rice flour affected YA, XB, YD, and slope 3, and emulsifier affected only slope 3. There was significant interaction between carrageenans and sugar, affecting XB, YC, YD, E, and slope 3; between carrageenans and fat affecting XB, YC, YD, and slope 3; between carrageenans and gums affecting YD, slope 2, and slope 3; between carrageenans and rice affecting slope 3; and between carrageenans and emulsifier affecting E and slope 3. The significant interaction between sugars and fat affected XC, YC, and YD. There was no significant interaction between sugars and gums or between sugars and emulsifier, which indicated that these components acted independently of each other (not shown in Table II). Sugars and rice interacted significantly affecting slope 2 and slope 3. Significant interactions occurred between fat and gums, affecting XB, XC, slope 2, and slope 3; fat and rice, affecting XA and slope 3; and fat and emulsifier, which affected only slope 2. Gums and rice levels did not interact significantly, but the interaction between gums and emulsifier was significant, affecting YB, YC, YD, E, slope 2, and slope 3. Rice and emulsifier levels did not show significant interaction.

To see which components imparted responses similar to egg flan (control), the response of each treatment combination (i.e., combination of component levels) was compared with the 95% confidence interval (CI) of the control for the same response; those that fell within this range are presented in Table III. For example, only four treatment combinations out of 32 (128/4) fell within the 95% CI for YB and none for XC, when carrageenan 4 was used. The analysis further showed that most of the responses that did not fall within the 95% CI, fell below, whereas very few exceeded the 95% CI.

Duncan's multiple range test (Steele and Torrie 1980) was applied to mean values to determine if the overall *F* test for main effect was significant at the 5% level. The result showed that carrageenan 4 (FL43IP at 0.50 g) gave comparable texture to egg flan at all response levels. The other three carrageenan levels were inadequate to duplicate the egg flan texture. There was no significant difference in mean response between the levels of sugar. In the case of fat, level 1 (i.e., no added fat), duplicated all except E response parameters of egg flan. The next best texture was imparted by 4.9 g of milk fat followed by 9.8 g of Crisco. Larger amounts of locust bean gum and pectin (i.e., samples containing 0.20 and 0.15 g, respectively) gave a texture closer to egg flan than smaller amounts. The larger amount of rice flour was better than that observed using the smaller amount. The emulsifier apparently made no difference to the texture even though it would be needed if additional fat were used. Fat and emulsifier acted independently of each other.

Pearson product correlations (*r*) of organoleptic texture evaluation (E) with all other responses are given in Table IV. The data indicate that response variables XB, YB, XC, YC, YD, slope

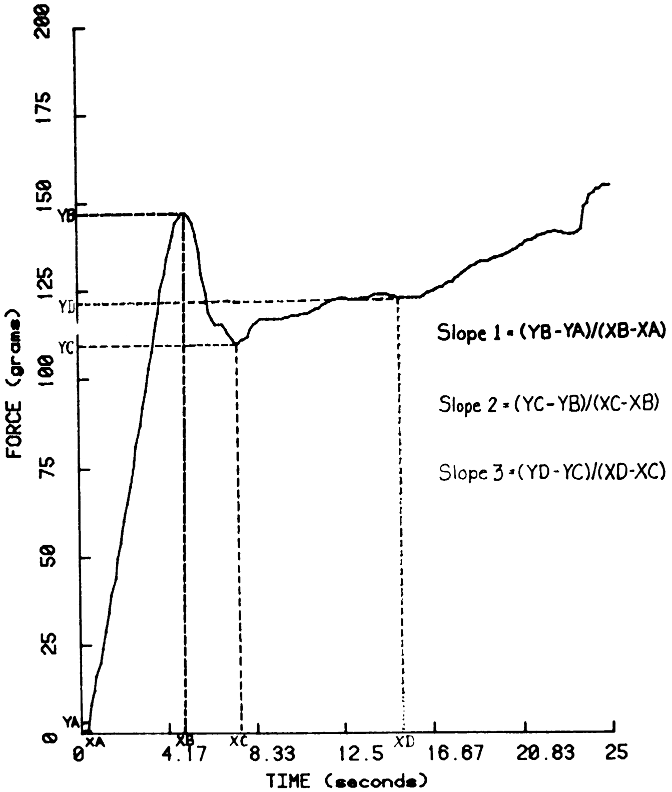

Fig. 2. A typical egg flan texturometer curve.

TABLE II

Significant *F* Values of All Main Effects and Two-Way Interactions for Each Response Variable[a]

									Slope		
Ingredient	**XA**	**YA**	**XB**	**YB**	**XC**	**YC**	**YD**	**E**	**1**	**2**	**3**
Carrageenan	...	...	**[b]	**	**	**	**	**	**	*	**
Sugar	...	...	...	...	...	...	...	...	...	*	...
Fat	...	...	...	*	...	**	**	**	...	*	**
Gum	...	...	**	**	**	**	**	**	**	**	**
Rice	...	...	**	...	...	...	**	...	...	...	**
Emulsifier	...	...	...	...	...	...	...	...	...	...	**
Carrageenan vs.											
Sugar	...	...	*	...	...	*	*	**	...	...	*
Fat	...	...	**	...	...	*	*	...	...	...	*
Gum	...	...	...	...	...	...	*	...	...	**	**
Rice	...	...	...	...	...	...	...	...	...	...	*
Emulsifier	...	...	...	...	...	...	...	*	...	...	**
Sugar vs.											
Fat	...	...	...	...	*	*	*	...	...	...	...
Rice	...	...	...	...	...	...	...	...	...	*	*
Fat vs.											
Gum	...	...	**	...	*	...	...	...	...	**	*
Rice	*	...	...	...	...	...	...	...	...	...	**
Emulsifier	...	...	...	...	...	...	...	...	...	*	...
Gum vs.											
Emulsifier	...	...	...	*	...	*	*	**	...	**	*

[a] Response variables as shown on Figure 2, except for E, the organoleptic panel response.

[b] Significant at $P < 0.01$ (**) or $P < 0.05$ (*).

TABLE III
Number of Treatment Combinations Yielding Responses Within 95% Confidence Intervals for the Control

Ingredient Level[b]	No. of Treatments	Responses[a]										
		XA	YA	XB	YB	XC	YC	YD	E	Slope 1	Slope 2	Slope 3
Carrageenan 1	32	27	22	0	0	0	0	0	3	5	16	32
Carrageenan 2	32	24	17	2	1	0	1	1	8	2	13	30
Carrageenan 3	32	26	14	1	1	0	1	0	7	9	18	32
Carrageenan 4	32	23	12	0	4	0	2	8	12	9	14	32
Fat 1	32	20	17	2	2	0	2	2	6	6	22	32
Fat 2	32	25	20	0	2	0	2	4	8	8	14	30
Fat 3	32	26	16	0	2	0	0	3	4	4	8	32
Fat 4	32	29	12	1	0	0	0	0	12	7	17	32
Gum 1	32	28	19	0	0	0	0	1	7	9	20	30
Gum 2	32	20	15	3	6	0	4	8	22	14	22	32
Gum 3	32	27	16	0	0	0	0	0	1	1	9	32
Gum 4	32	25	15	0	0	0	0	0	0	1	10	32
Rice flour 1	64	49	38	1	4	0	2	4	17	13	32	63
Rice flour 2	64	51	27	2	2	0	2	5	13	12	29	63
Emulsifier 1	64	51	36	2	1	0	2	3	12	11	31	62
Emulsifier 2	64	49	29	1	5	0	2	6	18	14	30	64
Sugar 1	64	49	32	2	3	0	2	6	16	15	34	63
Sugar 2	64	51	33	1	3	0	2	3	14	10	27	63

[a] Responses shown in Figure 2, except for E, the organoleptic panel response.
[b] Levels described in Table I.

TABLE IV
Pearson Product Correlations (r) of Organoleptic Texture Evaluation (E) with All Response Variables

Response Variables	Correlation[a] (r)	$P>F$[b]
XA	0.03	0.70
YA	0.12	0.16
XB	0.81	0.0001
YB	0.89	0.0001
XC	0.82	0.0001
YC	0.89	0.0001
YD	0.87	0.0001
Slope 1	0.72	0.0001
Slope 2	0.58	0.0001
Slope 3	0.37	0.0001

[a] Simple correlation.
[b] Probability of correlation by chance alone.

1, and slope 2 have a highly significant correlation with organoleptic evaluation of the processed flans.

Critical evaluation of the test results indicated that the best ingredient combination to obtain a texture most similar to egg flans was carrageenan 4 (0.50 g of FL43IP), fat 2 (4.9 g of milk fat), gum 2 (0.02 g of locust bean gum), and rice flour 2 (4.0 g), with or without emulsifier. Subsequent experiments also indicated that the addition of a pectin (Genulacto, 0.15 g of type PL93) substantially improved the texture. These combinations of ingredients duplicated all of the textural response characteristics of egg flan except XC, i.e., the time in seconds needed to obtain YC. This response essentially measures the resiliency or resistance of the gel to breaking. Further efforts to improve the XC response by varying the ingredient levels and/or processing conditions proved futile. However, adding 0.10 g of xanthan gum (Miles Laboratories, Biotech Product Div., Elkhart, IN) and 0.1 g of a whey protein concentrate (Meloskim WP-25, Dairyland Products, Savage, MN) to the mix described above exactly duplicated all the textural responses as measured by the texturometer. However, organoleptic evaluation could still differentiate between the two textures. The egg flan tended to be more "chewy" and "rubbery," whereas the gum mixture flan was smooth, homogenous, and tended to melt during mastication.

The texture of a multicomponent food such as flan is obviously due to interactions of its ingredients during processing and storage. Considerable progress has been reported in understanding the gelling characteristics of individual components under controlled conditions. Polysaccharides, whose native roles are as structural components of cell walls (e.g., carrageenan, alginate, and pectin), revert from disordered to a partially ordered product on gelation (Morris 1985). Descamps et al (1986) described interactions between starch and carrageenan in water and milk. Christianson et al (1981) reported that xanthan and other gums modified the gelatinization characteristics of wheat starch. However, the characteristics of a finished gel are the net result of complex interactions of all the components. A detailed nature of the interactions in the final product, therefore, is difficult to describe (Morris 1985, Oakenfull 1987). Apparently, in the gel the molecules are held together by a combination of weak intermolecular forces, such as hydrogen bonds, electrostatic forces, Van der Waals forces, and hydrophobic interactions (Oakenfull 1987). The temporary nature of cross-linkages would make this system free to break and reform. The results of this study also showed that the texture of the finished product was very sensitive to the source of added sugar (e.g., fructose vs. glucose or regular NFDM vs. lactase-treated NFDM), processing conditions of NFDM (high vs. low heat), and other processing conditions. Nevertheless, the product can be stored at refrigerated temperature for an extended period without developing objectionable syneresis or significant changes in texture.

Polysaccharides such as carrageenans, pectin, and xanthan gum, aside from imparting characteristics of gel strength to the food, can also contribute desirable nutritional attributes. For example, the glycosidic linkages of food gums are resistant to small intestinal digestion. Therefore, these additives can also be considered as sources of water-soluble fibers (Ink and Hurt 1987). The engineered foods containing NFDM, rice, and gums should be uniquely suited for an elderly population and for small infants and children. Such foods will have the advantages of convenience and quick cooking and are a valuable source of much needed calcium, high-quality protein (from NFDM), and caloric control. The caloric content of the flan can be decreased by substituting nonnutritive sweeteners for sugar or increased by adding vegetable oil/milk fat to the product. Similiarly other nutrients such as minerals and vitamins, can also be conveniently added to the dry mix, especially if these foods are to be used in food programs for infants and children.

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