Use of Carbohydrate-Based Fat Substitutes and Emulsifying Agents in Reduced-Fat Shortbread Cookies[1]

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ABSTRACT

Low-fat shortbread cookies were prepared using combinations of carbohydrate-based fat substitutes (Litesse, N-Flate, Rice*Trin, Stellar, or Trimchoice) and emulsifiers (diacetyl-tartaric esters of monoglycerides [DATEM], glycerol monostearate [GMS], or sodium stearoyl-2-lactylate [SSL]). The experimental design was an incomplete randomized design with two factors: fat substitute (at 35, 45, or 55% of shortening weight) and emulsifier (at 0.125, 0.25, or 0.5% of flour weight). Response surface methodology and analysis of variance were the statistical techniques used to analyze the experimental results. Processing modifications were necessary to make low-fat shortbread cookies. The principal effects of fat substitutes on shortbread cookie attributes were higher moisture content, greater toughness, and lower specific volume. Fat substitution of 35% had the least negative effects on the physical attributes. The combinations N-Flate/SSL and Litesse/DATEM showed minimal differences in cookie breaking strength in comparison with the traditional shortbread cookie at the three levels of fat substitution and 0.5% emulsifier.

The U.S. Public Health Service has recommended that dietary fat consumption be cut to 30% or less of total caloric intake by the year 2000 (McDowell 1994). Preliminary data from the Third National Health and Nutrition Examination Survey (NHANES III) conducted in 1988-91 indicate that Americans currently are consuming about 34% of their total calories as fat, down from 36% in 1976-80 (NHANES II), but still considerably higher than the goal. Modification of the food supply through the use of fat substitutes is one way to achieve this goal. Substitutes are grouped broadly into either lipid-, carbohydrate-, or protein-based materials. Carbohydrate-based substitutes incorporate water into a gel-type structure, resulting in lubricant or flow properties similar to those of fats in some food systems. It is likely that desirable textures can be achieved using those types of substitutes, and there are few regulatory obstacles regarding any toxicological potential (Hassell 1993).

The baking industry has responded to the demands of consumers by developing low- or reduced-fat products, defined as those foods that have at least one-third fewer calories than an equivalent serving of a normal counterpart. The reduced-calorie product also must not be nutritionally inferior to the standard similar product (Vetter 1991).

Low-fat products normally contain fat substitutes and are produced using formula or processing modifications. Until now, most cookie products with reduced fat levels have had chewy texture, intermediate final moisture content, and nontraditional snap characteristics (Vetter 1991).

Flavor, texture, and appearance of baked products are affected by types and amounts of fat used (Pyler 1988). The primary function of fat is to create more tender products and shorter doughs. Fat lubricates the structure by being dispersed in the dough or batter during mixing and helps prevent the starch and protein from forming a continuous network. The sensation of a fatty mouthfeel is formed by a combination of several poorly defined or quantitated parameters including viscosity, absorption, cohesiveness, adhesiveness, and waxiness (Glicksman 1991).

Replacement of the sensory properties of fat is difficult in low-moisture bakery foods like cookies, with a final moisture between 3-4% (Vetter 1991). Normally, increased levels of water are needed to replace high levels of fat, and a means of stabilizing the extra water is necessary (Jackel 1990). In addition to low moisture contents, cookies are characterized by high levels of sugar. Sugar competes with the starch and gluten for water, so little or no starch gelatinization occurs during baking.

Shortbread cookies traditionally contain about 24% fat (USDA/HNIS 1991). The dough has a very low moisture content, and cohesiveness is the result of fat coating the flour particles. The rotary mold method normally is used to form shortbread cookies. The dough should be well mixed and slightly crumbly but have enough cohesiveness to retain its shape on removal from the mold (Pyler 1988). One option available for reducing fat or calories in this commercial product is to replace part of the fat with carbohydrate-based fat substitutes like maltodextrins, modified food starches, or polydextrose compounds. In addition, the incorporation of emulsifiers has been proposed (Vetter 1991) to reduce interfacial tension and increase the effectiveness of the fat, allowing less to be used.

Sodium stearoyl-2-lactylate (SSL) at 0.5% of flour weight effectively improved quality, increased spread, and produced a finer more uniform pattern of surface cracks in sugar snap cookies (Tsen et al 1975). The optimum level for improving the eating quality and permitting shortening reduction was found to be 0.75% (Hutchinson et al 1977).

The natural emulsifier lecithin is a complex mixture of phospholipids that provide the majority of its surface-active properties. In some cases, lecithin acts synergistically to improve the functionality of SSL and monoglycerides (Central Soya 1990). In addition, lecithin provides drier doughs that machine better and release well from rotary die faces (Pyler 1988).

Mono- and diglycerides, including glycerol monostearate (GMS), are the emulsifiers perhaps used most commonly to replace fats in bakery foods. Diacetyl tartaric acid esters of mono- and diglycerides (DATEM) have a favorable balance between hydrophilic and lipophilic groups, have a high anionic affinity, and are capable of interacting with the flour protein (Pyler 1988). When shortening in the cookie dough is reduced, the incorporation of these emulsifiers at levels of 0.125 to 0.75% (flour weight) at the first step or creaming phase of mixing results in considerably softer cookies (Hutchinson et al 1977).

The objective of this study was to evaluate the effects of reduced fat content in shortbread cookies using combinations of carbohydrate-based fat substitutes and emulsifiers.

MATERIALS

The formula for the traditional (full-fat) shortbread cookie on a percent flour weight basis was: pastry flour, 100; nonemulsified shortening, 42.5; granulated sugar, 25; dry whole eggs, 5.28; water, 4.93; vanilla flavoring, 1.00; and salt, 1.25. Those are the ingredi-

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ents commonly used in commercial shortbread cookies (Smith 1972), and the resulting cookies were texturally similar to shortbread cookies now being marketed. Using a response surface design, carbohydrate-based fat replacers were substituted for 35, 45, or 55% of the fat in the formula in combination with different emulsifiers (Table I). A dozen cookies were prepared for each test.

Fat replacers tested included: 1) Trimchoice-OC (ConAgra, Inc., Omaha, NE), which is prepared from hydrolyzed oat and barley flours and contains β-glucan soluble fiber; 2) Rice*Trin 10 DE (Zumbro, Inc., Hayfield, MN), a rice maltodextrin; 3) Stellar (powder, Staley Manufacturing Co., Decatur, Il), produced from a controlled acid treatment of corn starch; 4) N-Flate (National Starch and Chemical Company, Bridgewater, NJ), a balanced blend of emulsifiers, modified food starch, guar gum, and nonfat dried milk; and 5) Litesse (Pfizer, New York, NY), a randomly bonded condensation polymer of dextrose that provides 1 calorie per gram. All of these fat substitutes are classified as GRAS (generally recognized as safe) by FDA.

Emulsifiers were used at levels of 0.125, 0.25, or 0.5% (flour weight basis) in combination with the fat replacers and included SSL, GMS, and DATEM, all of which are also GRAS substances and must be used in accordance with good manufacturing processes. Lecithin (1%) also was added to all experimental cookies.

METHODS

Shortbread Cookie Preparation

A Hobart N-50 mixer with paddle speeds of 145 (low), 257 (medium), and 457 (high) rpm was used for the multiple-stage mixing method. In Stage I, the shortening, sugar, salt, and dry whole eggs were mixed on low speed for 30 sec, then creamed at medium speed for 5 min, the bowl and paddle were scraped between speed adjustments and at 2.5 min after starting the creaming process. The fat substitute (when present) also was incorporated at the start of this stage as a dry powder with its corresponding amount of water at a ratio of 1:3 (fat substitute to water). Also, the appropriate percentage of emulsifier plus 1% lecithin was added to the low-fat cookie dough at this stage.

In Stage II, the liquid ingredients (water and liquid vanilla) were blended into the creamed mixture for 30 sec at low speed and for 2 min on medium speed; the bowl and paddle were scraped at the speed change. When the fat substitute was present, 12.5% (flour weight basis) of extra sugar was added before the last minute of mixing to improve the textural and flavor characteristics of the low-fat shortbread cookies. In Stage III, the flour was added and blended at low speed for 15 sec, the bowl and paddle were scraped, and the mixture was blended again for 15 sec at medium speed.

Samples of shortbread cookie dough (58 g) were rolled out with a wooden rolling pin to a standard thickness (6 mm) and cut according to AACC Method 10-50D (1983). The cookies were baked for 16 min at 350°F on Cushion Aire 12- × 14-in. insulated aluminum baking sheets (WearEver, Manitowac, WI) in a Despatch mini-bake reel test oven (Despatch Oven Co., Minneapolis, MN).

Cookie width (W) and thickness (T) were measured according to AACC Method 10-50D (1983). Specific volume was calculated for each sample. Moisture analyses were conducted by the Analytical Laboratory of the Department of Grain Science and Industry, KSU using AACC Method 44-15A (1983).

Color Evaluation

Color differences among the shortbread cookies were determined using the Minolta Chroma Meter II CR-210 (Minolta, Osaka, Japan). Values for L (lightness scale 100 = pure white, 0 = black), a (+) red and b (+) yellow were recorded for 12 cookies per batch.

Texture Evaluation

The TA.XT2 Texture Analyzer (Texture Technologies, Scarsdale, NY/Stable Micro Systems, Haslemere, Surrey, UK) with a capacity of 25 kg, a force sensitivity of 1 g, and a distance sensitivity of 0.0025 mm was used for textural evaluations. Twelve shortbread cookies were evaluated measuring the peak breaking force (kg) using the three-point break (triple-beam snap) technique and also by the change in penetration force gradient (kg/sec), which we have called toughness.

Experimental Design and Statistical Analyses

The experimental design applied in this study was a randomized incomplete design with two factors, fat replacement (at 35, 45, or 55%) and emulsifier (0.125, 0.250, or 0.5%) (Table I). At least seven combinations of each fat replacer and emulsifier were tested. A dozen cookies were prepared for each test.

Response surface methodology (RSM) was the statistical technique used to obtain the multiple correlation coefficient, standard error, and a general equation for the influence of two independent variables (fat replacement and emulsifier) on the dependent variables. The computer program provided predictions for untested values and printed response surface contour maps showing optimum conditions and predicted values (Walker and Parkhurst 1984).

Analysis of variance (ANOVA-one way) was performed, and the coefficients of variation and standard deviations were calculated. Means were compared by the least significant difference (LSD) test at the 0.05 level of probability.

TABLE I
Response Surface Experimental Design[a]

		Fat Substitute														
		Trimchoice			Rice*Trin			Stellar			N-Flate			Litesse		
Emulsifier Type[b]	%	35	45	55	35	45	55	35	45	55	35	45	55	35	45	55
SSL	0.5	A1	A2	A3	B1		B2	C1	C2	C3	D1		D2	E1	E2	E3
	0.25		A4		B3	B4	B5	C4	C5			D3	D4		E4	
	0.125	A5	A6	A7	B6		B7	C6		C7	D5	D6	D7	E5	E6	E7
GMS	0.5	F1	F2	F3	G1		G2	H1	H2	H3	I1		I2	J1	J2	J3
	0.25		F4		G3	G4	G5		H4	H5	I3	I4		J4	J5	
	0.125	F5	F6	F7	G6		G7	H6		H7	I5	I6	I7	J6		J7
DATEM	0.5	K1		K2	L1	L2	L3	M1	M2	M3	N1		N2	O1		O2
	0.25	K3	K4	K5		L4		M4	M5		N3	N4			O3	O4
	0.125	K6		K7	L5	L6	L7	M6		M7	N5	N6	N7	O5	O6	O7

[a]Fat substitutes replaced 35, 45, or 55% of the fat in the traditional shortbread cookie formula. Seven combinations of each fat substitute and emulsifier were tested as denoted by capital letter/number combinations. Levels of emulsifier used ranged from 0.125 to 0.5%. A dozen cookies were prepared for each fat substitute/emulsifier combination. A dozen traditional cookies were also prepared during each baking period. Lecithin (1%) was added to all cookies except the traditional cookies. Flour was provided by Mennell Milling, Fostoria, OH, and contained 8.80% protein (N × 5.7), 12.9% moisture, 0.47% ash, 0.42% fat, and 0.49% crude fiber.

[b]SSL = sodium stearoyl-2-lactylate; GMS = glycerol monostearate; DATEM = diacetyl tartaric acid esters of mono- and diglycerides.

RESULTS AND DISCUSSION

Shortbread and Standard Snap Cookies Comparison

Most scientific publications about cookies have referred to sugar snap cookies made according to AACC Method 10-50D (1983) as the standard product. That type of cookie has higher amounts of sugar and water but less shortening than shortbread cookies. In addition, the snap cookie formula includes chemical leavening agents that the shortbread style does not require, and the conditions of mixing and baking are different. All of these variations produce two totally different types of cookies, with regard to texture, flavor, and external attributes such as spread and surface characteristics.

In comparison with a standard snap cookie, a shortbread cookie does not have any surface cracking pattern, because of the absence of spreading during baking, and is more uniform in size. That is very important when considering packaging operations and governmental guidelines for food labeling.

The extra sugar (12.5%) added to the low-fat shortbread batter during the last 1 min of mixing improved the color characteristics and made the cookies less tough. In this low moisture system, not enough water was present to solubilize the sugar; it melted in the oven, enhancing cookie texture and color (as a result of caramelization).

RSM Predictions of Optimum Conditions for Use of Fat Replacers in Shortbread Cookies

RSM techniques determined the optimum conditions for each low-fat shortbread cookie as a function of different fat replacements and emulsifiers (Tables II–VI). In general, the use of fat replacers resulted in tougher (greater penetration force gradient) shortbread cookies with higher moisture content. Low-fat cookie widths and heights were generally not much different than for the traditional cookies (data not shown), but the experimental cookies tended to have lower specific volumes than the traditional cookie. Yellow color (*b*) was lighter than in the traditional cookie, with the exception of the Rice*Trin-GMS (Table III), Stellar-GMS (Table IV), and Litesse-SSL and DATEM (Table VI) combinations. Optimum replacement levels for all fat replacer products ranged from 30 to 35% (on a shortening basis).

TABLE II
Response Surface Methodology Predicted Optimum Conditions for Trimchoice Shortbread Cookies

Measurement	Emulsifier[a] SSL	GMS	DATEM	None
Emulsifier (%)	0.34	0.23	0.47	. . .
Trimchoice (%)	33.0	35.0	32.0	0.0
Moisture (%)	7.48	8.25	7.89	5.04
Specific volume (g/cm^3)	1.88	1.67	1.84	2.03
Color (b)	−3.01	6.19	3.17	10.93
Breaking force (kg)	3.77	3.24	2.42	2.13
Toughness (kg/s)	4.19	4.10	2.43	1.60

[a]SSL = sodium stearoyl-2-lactylate; GMS = glycerol monostearate; DATEM = diacetyl tartaric acid esters of mono- and diglycerides.

TABLE III
Response Surface Methodology Predicted Optimum Conditions for Rice*Trin Shortbread Cookies

Measurement	Emulsifier[a] SSL	GMS	DATEM	None
Emulsifier (%)	0.17	0.24	0.14	. . .
Rice*Trin (%)	33.0	34.0	34.0	. . .
Moisture (%)	7.70	9.00	8.88	5.04
Specific volume (g/cm^3)	1.85	1.78	1.72	2.03
Color (b)	−4.51	22.58	1.47	10.93
Breaking force (kg)	3.60	3.14	2.80	2.13
Toughness (kg/s)	4.92	4.04	4.09	1.60

[a]SSL = sodium stearoyl-2-lactylate; GMS = glycerol monostearate; DATEM = diacetyl tartaric acid esters of mono- and diglycerides.

Effects of Different Types and Levels of Fat Replacers and Emulsifiers

The finished-product results, showing the effects of fat substitution at 35, 45, and 55% (shortening basis) and emulsifier at 0.125, 0.25, and 0.5 (flour basis) for each fat replacer, are shown in Tables VII–IX. Moisture content in the cookies increased as fat substituion levels increased. That was a consequence of the higher water requirements with higher levels of substitution. Breaking force was higher for all the experimental cookies than for the control cookies, except those containing N-Flate (35, 45, and 55%)/0.5% SSL; Litesse (55%)/0.5% GMS; Rice*Trin (55%)/0.5% DATEM; and Litesse (35, 45, and 55%)/0.5% DATEM.

In general, addition of fat replacers had minimal effect on cookie height and width but did affect the specific volume of the low-fat cookies. SSL appeared to have less negative effect on cookie width than either GMS or DATEM. The effect on specific volume was also less when SSL was added (0.5% level) than when other emulsifiers were used (Table VII). For GMS (Table VIII) and DATEM (Table IX), the effect on specific volume was more pronounced, with generally reduced specific volumes.

Fat substitution at the three different replacement levels produced an important and significant change in color *b*. In general, as the level of fat substitution increased, the *b*-value

TABLE IV
Response Surface Methodology Predicted Optimum Conditions for Stellar Shortbread Cookies

Measurement	Emulsifier[a] SSL	GMS	DATEM	None
Emulsifier (%)	0.45	0.24	0.22	. . .
Stellar (%)	34.0	33.0	32.0	. . .
Moisture (%)	7.62	6.97	8.27	5.04
Specific volume (g/cm^3)	1.88	1.69	1.75	2.03
Color (b)	3.00	23.36	3.66	10.93
Breaking force (kg)	3.00	3.60	2.65	2.13
Toughness (kg/s)	4.06	3.20	3.29	1.60

[a]SSL = sodium stearoyl-2-lactylate; GMS = glycerol monostearate; DATEM = diacetyl tartaric acid esters of mono- and diglycerides.

TABLE V
Response Surface Methodology Predicted Optimum Conditions for N-Flate Shortbread Cookies

Measurement	Emulsifier[a] SSL	GMS	DATEM	None
Emulsifier (%)	0.44	0.12	0.35	. . .
N-Flate (%)	32.0	33.0	33.0	. . .
Moisture (%)	7.44	7.85	7.21	5.04
Specific volume (g/cm^3)	1.63	1.78	1.89	2.03
Color (b)	4.16	1.74	3.78	10.93
Breaking force (kg)	2.68	2.45	2.50	2.13
Toughness (kg/s)	2.88	3.16	2.95	1.60

[a]SSL = sodium stearoyl-2-lactylate; GMS = glycerol monostearate; DATEM = diacetyl tartaric acid esters of mono- and diglycerides.

TABLE VI
Response Surface Methodology Predicted Optimum Conditions for Litesse Shortbread Cookies

Measurement	Emulsifier[a] SSL	GMS	DATEM	None
Emulsifier (%)	0.38	0.10	0.47	. . .
Litesse (%)	32.0	31.0	32.0	. . .
Moisture (%)	7.52	7.87	7.29	5.04
Specific volume (g/cm^3)	1.79	1.58	1.86	2.03
Color (b)	25.42	−1.03	24.66	10.93
Breaking force (kg)	2.68	2.42	1.97	2.13
Toughness (kg/s)	5.06	3.28	3.35	1.6

[a]SSL = sodium stearoyl-2-lactylate; GMS = glycerol monostearate; DATEM = diacetyl tartaric acid esters of mono- and diglycerides.

decreased, which meant lower yellow color intensity. The fat replacer-emulsifier systems Litesse/SSL (Table VII) and Litesse/DATEM (Table IX), Stellar/GMS (Table VIII) and Rice*Trin/GMS (Table VIII) produced higher yellow color intensity than the control shortbread formula, possibly because of a higher degree of Maillard browning reactions as a consequence of the carbohydrate nature of these fat substitutes.

Matz (1962) described the texture of cookies as a combined function of the size and shape of the crumb structure, the moisture content and gradient, and the internal stresses produced during baking and cooling. The incorporation of fat replacers affected those characteristics, altering the texture of low-fat shortbread cookies. Since these carbohydrate-based fat replacers function by incorporating water into gel-type structures that emulate the properties bestowed by fats, it seems likely that products prepared from them will need to maintain a higher final moisture content (but not necessarily higher water activity) than the traditional products to maintain the desired texture. For instance, Nabisco's SnackWells Double Fudge fat-free cookies (without topping) contain over 17% water, and their reduced-fat Creme Sandwich cookies (without filling) have nearly 7% water.

In this study, the area under the force versus time curve (texture, kg·sec) at break was used to estimate product toughness, which, in general, tended to increase as the fat replacement level increased. Trimchoice at the 35% level of replacement with 0.5% DATEM (Table IX) produced cookies most like the traditional cookies (2.74 kg/sec vs. 1.60 kg/sec, respectively) in that regard.

CONCLUSIONS

Products low in moisture, such as cookies, remain difficult to prepare without fat, which is very important for tenderness and mechanical handling. In this experiment, formula and processing modifications were necessary to make low-fat shortbread cookies using carbohydrate-based fat substitutes and emulsifiers. The principal effects of fat substitutes on shortbread cookie

TABLE VII
Physical Characteristics of Low-Fat Shortbread Cookies at Different Levels of Fat Replacers and SSL at 0.125, 0.25, and 0.5%[a,b]

Fat Replacer	Moisture (%)			Specific Volume (g/cm^3)			Color (*b*)			Breaking Force (kg)			Toughness (kg/sec)			Width (cm)			Height (cm)		
(%)	0.125	0.25	0.5	0.125	0.25	0.5	0.125	0.25	0.5	0.125	0.25	0.5	0.125	0.25	0.5	0.125	0.25	0.5	0.125	0.25	0.5
Trimchoice																					
35	7.67	7.90	6.79	1.86	1.86	1.89*	−3.15	−3.19	−2.91	4.46	3.89	4.18	5.02	4.44	5.07	6.6*	6.6*	6.6*	1.13	1.15*	1.15*
45	9.36	9.58	8.42	1.84	1.82	1.83	−4.28	−4.06	−3.24	3.99	3.52	3.98	6.02	5.40	5.93	6.5*	6.5*	6.5*	1.15*	1.16*	1.15*
55	11.58	11.30	10.57	1.85	1.80	1.79	−5.23	−5.02	−3.48	2.89	3.09	3.15	6.87	6.03	6.64	6.5*	6.5*	6.4*	1.21*	1.21*	1.18*
Rice*Trin																					
35	7.92	7.90	7.13	1.81	1.87	1.94*	−4.65	−4.71	−4.29	3.29	3.95	4.15	4.89	5.37	5.57	6.5*	6.5*	6.5*	1.20*	1.21*	1.24*
45	9.35	9.40	8.79	1.80	1.82	1.81	−4.43	−5.23	−5.26	3.20	3.73	3.66	5.79	6.14	6.25	6.4	6.3	6.4*	1.22*	1.20*	1.22*
55	11.16	11.29	10.84	1.81	1.80	1.72	−4.43	−4.93	−5.40	3.08	3.47	3.14	6.76	6.98	6.82	6.3	6.3	6.3	1.26*	1.25*	1.22*
Stellar																					
35	7.96	7.82	7.76	1.92	1.88	1.90*	0.26	2.16	2.50	3.46	2.93	3.22	7.25	5.31	4.38	6.6*	6.6*	6.6*	1.21*	1.18*	1.18*
45	9.60	9.45	9.23	1.91	1.87	1.89*	−0.37	1.23	0.98	3.48	2.93	3.19	6.92	5.54	5.73	6.5*	6.5*	6.4*	1.22*	1.19*	1.18*
55	11.74	11.44	11.08	1.91	1.87	1.89*	0.21	1.51	0.67	3.18	2.62	2.85	5.09	4.27	5.57	6.4	6.4	6.4*	1.25*	1.24*	1.29*
N-Flate																					
35	7.91	7.55	8.27	1.84	1.85	1.57	1.74	2.71	3.74	2.91	2.90	2.55*	3.81	3.67	3.13	6.7*	6.6*	6.6*	1.14	1.13*	1.00
45	9.39	9.11	9.99	1.90	1.95	1.77	1.34	1.93	2.20	2.89	2.86	2.47*	4.75	4.78	4.58	6.5*	6.5*	6.4*	1.21*	1.19*	1.16
55	11.00	10.81	11.85	1.99	2.10	2.01*	1.67	1.88	1.37	2.80	2.76	2.33*	5.70	5.89	6.05	6.5*	6.5*	6.3	1.29*	1.43	1.38
Litesse																					
35	7.20	7.90	7.23	1.91	1.83	1.85	24.78	25.14	25.16	3.84	3.23	2.72	5.41	4.73	5.84	6.9	6.7*	6.8	1.13	1.04	1.08*
45	9.12	9.74	8.91	1.85	1.80	1.92*	24.55	24.84	24.69	3.20	2.93	3.10	4.89	4.10	4.99	6.6*	6.6*	6.6*	1.11	1.08	1.11*
55	11.80	12.34	11.35	2.05	1.74	1.93*	10.93	10.93	24.40	2.13	2.13	2.76	4.10	3.19	3.85	6.6*	6.5*	6.6*	1.18*	1.15*	1.26*
Traditional	5.04	5.04	5.04	2.03	2.03	2.03	10.93	10.93	10.93	2.13	2.13	2.13	1.60	1.60	1.60	6.6	6.6	6.6	1.22	1.22	1.22
LSD						0.15						0.45			0.68	0.18	0.15	0.16	0.03	0.13	0.16

[a] Test cookies also contained 1% lecithin.
[b] Mean values followed by * are not significantly different than traditional cookie value.

TABLE VIII
Physical Characteristics of Low-Fat Shortbread Cookies at Different Levels of Fat Replacers and GMS at 0.125, 0.25, and 0.5%[a,b]

Fat Replacer	Moisture (%)			Specific Volume (g/cm^3)			Color (*b*)			Breaking Force (kg)			Toughness (kg/sec)			Width (cm)			Height (cm)		
(%)	0.125	0.25	0.5	0.125	0.25	0.5	0.125	0.25	0.5	0.125	0.25	0.5	0.125	0.25	0.5	0.125	0.25	0.5	0.125	0.25	0.5
Trimchoice																					
35	7.75	8.32	8.33	1.81	1.65	1.53	0.49	6.82	2.21	3.33	3.24	3.72	4.22	4.10	4.69	6.6*	6.4	6.2	1.15*	1.08	1.07
45	9.57	9.95	9.60	1.79	1.70	1.71	2.59	4.20	0.51	3.31	3.18	3.58	5.56	5.39	5.87	6.5*	6.4	6.5*	1.14*	1.13*	1.15*
55	12.04	12.24	11.52	1.75	1.72	1.87	−5.62	1.63	−1.13	3.10	2.93	3.24	7.11	6.89	7.26	6.4	6.3	6.4	1.24*	1.21*	1.24*
Rice*Trin																					
35	7.86	9.16	7.93	1.75	1.77	1.84	22.75	22.51	22.46	3.28	3.13	3.19	4.06	4.15	4.72	6.5*	6.5*	6.5*	1.11*	1.20*	1.19*
45	8.34	10.20	10.08	1.72	1.72	1.75	22.21	21.91	21.73	3.21	3.12	3.28	5.34	5.23	5.42	6.4	6.3	6.4	1.15*	1.13*	1.16*
55	8.72	11.13	12.12	1.73	1.71	1.69	21.74	21.38	21.07	2.89	2.86	3.12	6.88	6.59	6.39	6.3	6.3	6.3	1.25*	1.22*	1.18*
Stellar																					
35	7.43	7.31	7.20	1.71	1.68	1.72	22.81	23.19	23.74	3.37	3.58	3.60	3.89	3.36	3.69	6.5*	6.5*	6.5*	1.10	1.08	1.09
45	9.40	9.31	9.25	1.71	1.67	1.68	22.17	22.31	22.42	3.23	3.38	3.26	4.86	4.28	4.51	6.4	6.4	6.3	1.14*	1.12*	1.14*
55	11.85	11.79	11.79	1.75	1.70	1.67	21.79	21.71	21.36	2.98	3.06	2.80	5.81	5.18	5.31	6.3	6.3	6.3	1.22*	1.19*	1.20*
N-Flate																					
35	8.09	7.87	8.96	1.78	1.80	1.81	1.65	2.60	3.19	2.50	2.86	2.74	3.38	4.05	3.80	6.6*	6.7*	6.7*	1.12*	1.13*	1.09
45	9.50	9.12	9.86	1.81	1.84	1.85	1.50	2.03	1.80	2.85	3.04	2.60	4.57	5.14	4.68	6.5*	6.5*	6.6*	1.17*	1.19*	1.17*
55	11.17	10.61	11.02	1.89	1.92	1.94*	2.20	2.32	1.26	3.47	3.51	2.74	6.27	6.73	6.07	6.4	6.4	6.5*	1.25*	1.28*	1.29*
Litesse																					
35	8.41	9.18	8.19	1.60	1.57	1.63	−0.87	−0.15	−0.70	2.43	2.74	2.64	3.59	4.29	4.09	6.6*	6.6*	6.6*	1.07	1.10	1.11*
45	9.24	10.24	9.90	1.76	1.68	1.64	−0.35	0.22	−0.64	2.24	2.54	2.45	3.90	4.56	4.30	6.6*	6.5*	6.5*	1.15*	1.10	1.12*
55	10.06	11.35	11.60	2.02	1.89	1.75	1.20	1.62	0.45	2.03	2.33	2.24*	4.28	4.90	4.58	6.5*	6.4	6.4	1.29*	1.25*	1.21*
Traditional	5.04	5.04	5.04	2.03	2.03	2.03	10.93	10.93	10.93	2.13	2.13	2.13	1.60	1.60	1.60	6.6	6.6	6.6	1.22	1.22	1.22
LSD						0.12						0.30			1.18	0.16	0.18	0.18	0.12	0.11	0.11

[a] Test cookies also contained 1% lecithin.
[b] Mean values followed by * are not significantly different than traditional cookie value.

TABLE IX
Physical Characteristics of Low-Fat Shortbread Cookies at Different Levels of Fat Replacers and DATEM at 0.125, 0.25, and 0.5%[a,b]

Fat Replacer (%)	Moisture (%)			Specific Volume (g/cm^3)			Color (*b*)			Breaking Force (kg)			Toughness (kg/sec)			Width (cm)			Height (cm)		
	0.125	0.25	0.5	0.125	0.25	0.5	0.125	0.25	0.5	0.125	0.25	0.5	0.125	0.25	0.5	0.125	0.25	0.5	0.125	0.25	0.5
Trimchoice																					
35	8.31	8.44	8.25	1.79	1.85	1.80	3.21	2.81	2.96	2.18	2.38	2.42	3.35	3.37	2.74	6.5*	6.6*	6.5*	1.14*	1.36	1.14*
45	9.81	9.97	9.84	1.70	1.78	1.75	2.71	2.21	2.21	2.26	2.46	2.49	4.17	4.41	4.24	6.4	6.4	6.5*	1.13*	1.13*	1.20*
55	11.64	11.83	11.76	1.62	1.71	1.72	2.49	1.87	1.59	2.39	2.58	2.61	5.02	5.49	5.78	6.4	6.4	6.4	1.27*	1.20*	1.27*
Rice*Trin																					
35	8.91	9.39	8.72	1.74	1.62	1.67	1.02	3.24	2.94	2.75	2.90	2.92	4.08	4.35	4.29	6.5*	6.4	6.4	1.15*	1.12*	1.15*
45	10.05	10.61	10.09	1.76	1.62	1.64	11.27	11.91	11.54	1.79	1.63	1.62	4.40	4.66	4.57	6.5*	6.4	6.4	1.13*	1.12*	1.15*
55	11.27	11.91	11.54	1.79	1.63	1.62	2.08	3.94	2.93	2.16	2.26	2.20*	4.59	4.84	4.73	6.5*	6.4	6.4	1.24*	1.15*	1.12
Stellar																					
35	8.36	8.70	8.69	1.80	1.73	1.70	2.41	3.40	3.62	2.41	2.71	2.60	3.83	3.47	3.47	6.4	6.4	6.4	1.25*	1.18*	1.20*
45	10.07	10.21	9.80	1.73	1.71	1.72	1.83	2.38	1.71	2.56	2.77	2.61	4.41	4.17	4.44	6.3	6.3	6.3	1.24*	1.16*	1.17*
55	12.28	12.22	11.42	1.68	1.66	1.73	2.09	2.19	0.64	2.70	2.89	2.66	4.76	4.65	5.16	6.2	6.2	6.3	1.23*	1.19*	1.30*
N-Flate																					
35	8.00	7.00	7.80	1.86	1.88	1.86	3.09	3.78	2.11	2.52	2.54	2.43	3.16	3.04	3.27	6.7*	6.7*	6.7*	1.19*	1.16*	1.14*
45	9.63	9.63	10.32	1.89	1.91	1.88	2.22	3.02	1.58	2.46	2.53	2.50	3.75	3.60	3.75	6.5*	6.5*	6.6*	1.18*	1.18*	1.18*
55	11.39	11.68	12.97	1.98	1.99	1.93	1.78	2.69	1.47	2.25	2.36	2.42	4.30	4.12	4.21	6.5*	6.4	6.4	1.28*	1.25*	1.25*
Litesse																					
35	7.76	7.08	8.06	1.75	1.78	1.87	24.54	24.37	24.71	2.83	2.49	2.01*	3.83	3.68	3.47	6.8	6.8	6.9	1.07	1.11*	1.09
45	9.74	9.01	9.90	1.81	1.83	1.90	24.84	24.57	24.67	2.54	2.34	2.13*	4.03	3.91	3.75	6.6*	6.6*	6.8	1.06	1.15*	1.13*
55	12.10	11.32	12.12	1.92	1.94	1.99*	25.34	24.95	24.83	1.91	1.85	1.91*	3.98	3.88	3.91	6.5*	6.6*	6.6	1.22*	1.26*	1.23*
Traditional	5.04	5.04	5.04	2.03	2.03	2.03	10.93	10.93	10.93	2.13	2.13	2.13	1.60	1.60	1.60	6.6	6.6	6.6	1.22	1.22	1.22
LSD						0.05						0.22			1.03	0.16	0.18	0.17	0.10	0.11	0.09

[a] Test cookies also contained 1% lecithin.
[b] Mean values followed by * are not significantly different than traditional cookie value.

attributes were higher moisture content and breaking force, increased toughness, and lower specific volume. Low-fat shortbread cookies prepared with with fat substitution of 35% had breaking force and toughness values most similar to the traditional full-fat shortbread cookie.

Recommendations for future research in this area include the use of protease enzymes or replacement of some of the soft wheat flour with starch; dextrose or high fructose corn syrup might be used to enhance texture and color.

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