Sensory and Physical Properties of Chocolate Chip Cookies Made with Vegetable Shortening or Fat Replacers at 50 and 75% Levels[1]

W. L. ARMBRISTER and C. S. SETSER[2]

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ABSTRACT

Selected sensory and physical properties of chocolate chip cookies made with vegetable shortening or protein-based, lipid-based, and carbohydrate-based fat replacers at 50 and 75% levels (shortening weight basis) were studied. Compared to the control cookie, all shortening-reduced cookies had significantly ($P \leq 0.05$) less surface cracking, fewer surface protrusions, and more uniform but larger cells. The cookies with fat replaced by the acid-treated cornstarch had the most rounded contours of all cookies studied. All fat replacers resulted in cookies with more mouthcoating than the control, and mouthcoating was significantly higher ($P \leq 0.05$) for the carbohydrate fat replacers than it was for the other types. Chew count and cohesiveness of mass differed slightly among the various cookies. The control cookie was significantly more fracturable than all cookies with fat replacers, except for that with 50% polydextrose. Sensory firmness was highest for control cookies, which agreed with instrumental compression measurements. Surface roughness and loose particles were significantly less for shortening-reduced cookies than for control cookies. Bitterness and saltiness were unaffected by fat replacement. Vanilla-like, sweet aromatics, and caramelized flavors were higher ($P \leq 0.05$) in the control cookies than in any cookies made with fat replacers.

Almost 150 million persons, or three out of four adults, in the United States have used low-calorie and reduced-fat products at one time or another (Helm 1991). The explosion of reduced-calorie food products on the market has allowed individuals to budget their calories to include some caloric indulgences. However, some reduced-calorie bakery products have had limited acceptability (Barndt and Jackson 1990). According to a consulting firm, even the manufacturers admit that fat-free products can be too dry, moist, or gummy (Shapiro 1992). To produce high-quality, acceptable, reduced-calorie products, more consideration must be given to the effects of the substitutes on the sensory properties of the finished products (Setser and Racette 1992).

The cookie system presents one of the more challenging systems for shortening reduction because of the relatively high levels of fat and sugar and their particular functions in the system. Typically, chocolate chip cookies contain 75% sugar, 60% shortening, 7% egg solids, and 17% water on a flour weight basis (Pyler 1988). Reducing the fat component in food products alters appearance, flavor, aroma, and texture. The textural attributes, in particular, that are provided by fat are difficult to achieve with replacers. Types and uses of various macromolecule replacers for shortening and sweetening in bakery products were reviewed recently by Setser and Racette (1992). Carbohydrate, lipid, and protein derivatives all have been used in bakery products. However no studies comparing the sensory properties of cookies prepared with varied types of fat replacers were found.

Some researchers reported limited success using polydextrose in bakery products such as cookies, yellow cake, angel food cakes, and reduced-calorie cakes (Ernest 1982, Freeman 1982, Neville and Setser 1986, Frye and Setser 1992). Potato maltodextrin-emulsifier combinations replaced 50, 75, or 100% of the shortening in chocolate layer cakes, and some combinations had sensory characteristics similar to those of the control cake (Sobczynska and Setser 1991). Mono- and diglycerides replaced up to 50% of the fat in cookies, cakes, and cake mixes using a 50:50 ratio of emulsifier to water (Friedman 1978). The goal of this experiment was to ascertain the similarities and differences in sensory properties of control chocolate chip cookies and cookies made with two levels of selected protein-based, lipid-based, and carbohydrate-based fat replacers.

[1]Contribution 94-141-J from the Kansas Agricultural Experiment Station.

[2]Department of Foods and Nutrition, Kansas State University, Manhattan.

MATERIALS AND METHODS

Materials

The formulations for the reduced-fat chocolate chip cookies used in this study are given in Table I. Ingredients that remained constant were all-purpose flour (Gold Medal, General Mills, Minneapolis MN [10.5% protein, 0.5% ash, 14% mb]); brown sugar and granulated sugar (C&H Inc., Concord, CA); baking soda (Arm & Hammer, Princeton, NJ); salt (Morton International, Chicago, IL); fresh eggs; vanilla extract (McCormick & Co Inc., Hunt Valley, MD); and semisweet chocolate chips (Nestle Foods, El Paso, TX). Variable ingredients included water, hydrogenated vegetable shortening (Crisco, Maple Plain, NJ), and six fat replacers. The fat replacers included: polydextrose (Litesse, Pfizer Inc., Groton, CT); acid-treated cornstarch (Stellar, A. E. Staley, Decatur, IL); citrus peel pectin (Slendid, Hercules Inc., Wilmington, DE); mono- and diglycerides (MDG) (Durlo, Durkee Industrial Foods, Cleveland, OH); microparticulated milk protein (Simplesse Dry 100, Simplesse Co., Deerfield, IL); and potato maltodextrin (Paselli SA-2, Avebe America, Princeton, NJ). Each of the ingredients, except eggs, was from a single lot or was purchased in separate lots at the start of the study and mixed together so that aliquots could be taken from the composite batch. Fresh eggs were purchased weekly from a local supermarket.

Preparation Methods

Ingredients, except for eggs, were weighed 2–3 hr before mixing and baking. Eggs were beaten slightly and weighed immediately before mixing. All cookies were mixed (model K5SS, Kitchen Aid, St. Joseph, MI) and baked ~15–20 hr before evaluation. Mixing and baking procedures are shown in Figure 1. Cookies were stored overnight at 21 ± 1°C in 1-gal Glad (First Brands Corp., Danbury, CT; 6.5 × 5.5 × 1 in.) freezer storage bags before evaluations.

Physical Measurements

Duplicate measures were made for: specific gravity (Campbell et al 1979); compression (universal testing machine, Instron, model 1122, Canton, MA), using the 0.5 cm diameter probe to 5 cm depth; and color attributes (Ultrascan Sphere Spectrocolorimeter, Hunterlab, VA) for each cookie variation. Hue angle ($\tan^{-1} b/a$) and chromaticity ($\sqrt{a^2 + b^2}$ were calculated from the L, a, and b values (Little 1976). Chocolate chips were avoided during all physical measurements. Standard procedures (method 10-50D, AACC 1983) were used to determine the width-thickness ratio (cookie spread) using six cookies.

TABLE I

Formula Weight and Flour Weight Percentages of Control and Reduced-Shortening Chocolate Chip Cookies

Constant Ingredients	Formula Weight	Flour Weight	Variable Ingredients	% of Shortening Replaced: Formula Weight 0	50	75	Flour Weight 0	50	75
All-purpose flour	24.6	100.0	Water, distilled	0.0	6.1	9.3	...	24.8	37.8
Brown sugar	12.3	50.0	Shortening	16.5	8.3	4.1	67.0	33.7	16.7
Granulated sugar	12.3	50.0	Acid-treated cornstarch	...	2.1	3.1	...	8.5	12.6
Salt	0.5	2.0	Pectin	...	2.1	3.1	...	8.5	12.6
Baking soda	0.5	2.0	Potato maltodextrin	...	2.1	3.1	...	8.5	12.6
Vanilla	0.5	2.0	Polydextrose	...	2.1	3.1	...	8.5	12.6
Egg	8.2	33.3	Microparticulated protein	...	2.1	3.1	...	8.5	12.6
Chocolate chips	24.6	100.0	Mono- and diglycerides	...	2.1	3.1	...	8.5	12.6

Sensory Evaluation

A panel consisting of five professional panelists from the Kansas State University Sensory Analysis Center performed the sensory evaluations. Each had 120 hr of training in all aspects of sensory analysis and at least 300 hr of testing experience. Panelists were oriented for chocolate chip cookie evaluation during five, 1–2 hr training sessions. A structured 15-point numerical scale was selected for generic descriptive scaling (Setser 1992). The intensity of several attributes was evaluated: surface roughness, loose particles, firmness, fracturability, cohesiveness of chewed sample mass, chew count, molar packing, residual or mouthcoating, caramelized, sweet aromatics, sweet, salty, vanilla-like, sour, and bitter. Panelists clarified terminology and established references as anchor points for the terms during orientation. The definitions of each attribute and the product references are given in Table II. Chocolate chip cookies, prepared using a control formulation and procedure (Table I and Fig. 1), were evaluated at each session. Samples for sensory evaluation were selected randomly from the same batch as the samples used for physical measurements. Apple slices and taste-free water were provided for palate cleansing.

Experimental Design and Statistical Analysis

An incomplete block design with a control treatment in each block was used. Each block ($n = 3$) contained the chocolate chip control cookie and cookies with two levels of one of the six types of fat replacers. Samples were coded with random, three-digit numbers; presented in random order for each of the panelists; and evaluated in a session. The design allowed for accurate comparisons among the fat replacers, as well as accurate comparisons between levels of a fat replacer. Furthermore, accurate comparisons could be made between each of the treatments and the control. Three replicates were completed for the six blocks (one block for each replacer). Results of both sensory and physical measurements were analyzed for variance using the Statistical Analysis System (SAS 1985). When the analysis of variance showed significant treatment effect ($\alpha = 0.05$), least significant differences were used for comparisons of means of the cookies with the fat replacers, levels of fat replacers, and each of the fat replacers with the control. When panelist $\times$ treatment, panelist $\times$ level, or panelist $\times$ treatment $\times$ level interactions were found, the results were graphed and checked to determine the type and extent of interaction.

RESULTS

No cookies with fat replacers simulated all of the appearance, flavor, and textural attributes of the control cookies. All cookies with fat replacers were more similar to each other than they were to the control in texture and appearance attributes. However, flavor attributes of the cookies with the fat replacers were generally more similar to those of the control cookies.

Sensory Appearance Measurements

Control chocolate chip cookies exhibited a high degree of surface cracking (13.7 mean score on the 15-point scale) and few open holes (mean score = 2.1) as indicated in Table III. Use

Control with Shortening

1. Combine sugar, brown sugar, and shortening. Mix on speed 4 for 2 min. Scrape.
2. Add eggs and vanilla. Mix on speed 4 for 1 min. Scrape. Mix on speed 4 for 1 min. Scrape.
3. Add flour, baking soda, and salt. Mix on speed 4 for 2 min.
4. Add chocolate chips. Mix on speed 2 for 10 sec.
5. Measure specific gravity of dough.
6. Spray 9½ x 14" or 12 x 15" aluminum cookie sheet (Cushionnaire, Salina, KS) with Pam® cooking spray. Spray to cover for approximately 3 sec.
7. Portion using # 70 scoop. Place on cookie sheet approximately 2" apart.
8. Bake at 375° F for 10 min. Remove cookies from pan and place on paper towels on cookie rack to cool for 30 min. Place in plastic bags (Glad) until served.

Mono-diglyceride (MDG) Variation

1. Combine shortening, MDG, water, vanilla, and eggs on speed 4 for 1 min. Scrape.
2. Add dry ingredients. Mix for 30 sec. on speed 2. Scrape.
3. Mix 1 min. on speed 4. Scrape.
4. Add chocolate chips. Mix on speed 2 for 10 sec.
5. Spray 9½ x 14" or 12 x 15" aluminum cookie sheet (Cushionnaire, Salina, KS) with Pam® cooking spray. Spray to cover for approximately 3 sec.
6. Use cookie scoop # 70. Place dough on cookie sheet 2" apart.
7. Bake for 10 min. at 375° F. Remvoe from pan. Cool 30 min on paper towels on cookie rack. Place in plastic bags (Glad) until served.

Variations with Fat Replacers Other than MDG[a]

1. Combine shortening, eggs, water, and vanilla. Mix on speed 4 for 1 min. Scrape.
2. Add remaining dry ingredients. Mix on speed 2 for 30 sec. Scrape.
3. Mix on speed 4 for 1 min. Scrape.
4. Add chocolate chips. Mix on speed 2 for 10 sec.
5. Spray 9½ x 14" or 12 x 15" aluminum cooking sheet (Cushionnaire, Salina, KS) with Pam® cooking spray to cover for approximately 3 sec.
6. Use cookie scoop #70 to portion dough. Place on cookie sheet 2" apart.
7. Bake at 375° F for 10 min.[b] Remove from pan and place on paper towels on cookie rack to cool for 30 min. Place in plastic bags (Glad) until served.

[a] Fat replacements = pectin, corn maltodextrin, potato maltodextrin, polydextrose, and microparticulated protein.

[b] Cookies with polydextrose and microparticulated protein were removed after 9 min.

Fig. 1. Preparation procedures for chocolate chip cookies with 100% shortening or 50 or 75% shortening replacement.

of a shortening replacer significantly reversed these patterns. Mean scores of the variations with shortening replacers were significantly lower than those of the control cookie for surface cracking, ranging from 0.1 to 3.7 (Table III); scores were significantly higher (6.3–10.5) than those of the control for open holes. Surface cracking significantly decreased from the 50 to 75% levels for all variations, except cookies with polydextrose. No significant differences in quantity of holes on the cookie surface were found among any of the cookies with 50% shortening replacer. The number of open holes was significantly lower for cookies with mono- and diglycerides and acid-treated cornstarch when the replacement level was increased to the 75% level. All other cookies did not differ significantly between levels.

All cookie variations, and each of the levels within each variation, also had significantly fewer ($P \leq 0.05$) protrusions than did the control cookie, with the exception of cookies containing 50% potato maltodextrin or 75% acid-treated cornstarch as shortening replacers. The cookie with 50% acid-treated cornstarch had significantly ($P \leq 0.05$) more protrusions (mean value of 4.0) than did all other variations or the control cookie. Cookies with the 75% substitution level of microparticulated protein and MDG cookies had the lowest mean values (0.6) and significantly fewer protrusions than did cookies with acid-treated cornstarch as the shortening substitute. As the fat replacement increased, the water level increased. More water resulted in a less stiff dough and a smoother cookie with fewer surface protrusions. Thus, the general trend found in this study was a decrease in surface protrusions on the cookie as more fat was replaced.

Cookies made with the MDG, potato maltodextrin, and pectin at 50, 50, and 75% replacement levels, respectively, did not differ significantly in contour from that of the control cookies, but all other variations differed significantly ($P \leq 0.05$). At the 50% replacement level, cookies made with acid-treated cornstarch and pectin were more rounded and had the largest mean values of all cookies (7.1 and 6.0, respectively). Cookies made with polydextrose, microparticulated protein, and MDG at 50% replacement levels had significantly less rounded contours ($P \leq 0.05$) than did those made with corn maltodextrin at the 50% replacement level. At the 75% replacement level, the cookies made with acid-treated cornstarch and potato maltodextrin were the most rounded

TABLE II
Definitions of Terms with Reference Products Used for Sensory Evaluation

Attribute	Definition	Reference Product[a]
Appearance		
Optical surface cracking	Distinct appearance of islands as a result of deep cracking patterns	
Open holes	Holes on the top of cookie in the absence of cracking pattern	
Protrusions	Degree to which raised surfaces or meringue-like peaks either large or small are present, with the exception of chocolate chips	
Contour	The amount of curve present when the cookie is placed on a flat surface and cross-section is viewed from the side	
Cell size	Size of the majority of the cells on the area of cut surface. A high value indicates large cells.	Graham cracker (Nabisco) = 10.0
Cell uniformity	Number of large air cells in otherwise small cells that give the impression of uneven cell size. A high value indicates an uneven cell structure	
Texture		
Surface roughness	Degree to which top surface contains bumps or particles (geometrical) when lips are passed over surface	Bordeaux cookie (Pepperidge Farms) = 12.5 Graham cracker (Nabisco) = 6.0
Loose particles	Number of loose particles on surface of lips	Pecan Supremes (Nabisco) = 10.0
Firmness	Force required to completely bite through sample that is placed between molars	Olive (with pimiento removed, Vlasic) = 6.5 American cheese (Kraft) = 4.5
Fracturability	Force with which the cookie shatters	Pecan Supremes (Nabisco) = 5.0 Graham cracker (Nabisco) = 7.0
Cohesiveness of chewed sample mass	After 7–8 chews, the degree to which the sample holds together in a mass after chewing (loose to firm)	
Chew count	Number of chews required to hydrate sample and bring to a state ready to swallow	
Molar packing	Amount of material left in and around the molar teeth	
Residual mouthcoating	Degree of material left in mouth (geometrical)	American cheese (Kraft) = 9.0
Flavor		
Carmelized	A round full-bodied medium brown aromatic	Bordeaux cookies (Pepperidge Farm) = 9.0
Sweet aromatics	Aroma of Pepperidge Farm Bordeaux cookie	Bordeaux cookies (Pepperidge Farm) = 2.5
Sweet	Fundamental taste factor	5% sucrose = 5.0 7% sucrose = 7.0 10% sucrose = 10.0
Salty	Fundamental taste factor	0.3% sodium chloride = 4.5 0.5% sodium chloride = 10.0
Vanilla-like	Perception of a round, smooth, full sensation that may or may not be accompanied by the following flavor notes: beany, brown, creamy, perfumy, sweet, woody, vanilla	1/16 tsp of vanilla extract (McCormick) in 1/4 c. of whole milk = 4.0
Sour	Fundamental taste factor	0.03% citric acid = 1.5
Bitter	Fundamental taste factor	0.03% caffeine = 1.5

[a] Scale range was from 0 (none) to 15 (high) for all attributes.

and differed significantly ($P \leq 0.05$) from the cookies made with MDG, polydextrose, pectin, and microparticulated protein. Cookies containing MDG, microparticulated protein, and polydextrose at the 75% replacement level were not significantly different from each other. The cookies made with microparticulated protein and acid-treated cornstarch did not differ significantly between the 50 and 75% replacement levels. All other variations differed significantly ($P \leq 0.05$) between levels.

The results comparing cell size determinations of the reduced shortening cookies and of the control cookie are presented in

TABLE III
Mean Values Comparing Sensory Appearance and Texture Attributes[a] of Control Chocolate Chip Cookies and Cookies Containing Selected Fat Replacers at 50 and 75% Levels

		Fat Replacer[b]					
Attribute	Control	Microparticulated Protein	Mono- and Diglycerides	Polydextrose	Potato Maltodextrin	Acid-Treated Cornstarch	Pectin
Surface cracking	13.7	x2.1a	x2.2a	x0.8a	x3.7a	x1.9a	x2.1a
		*	*		*	*	*
		x(0.1)a	x(0.3)a	x(1.5)a	x(0.6)a	x(0.2)a	x(0.6)a
Open holes	2.1	x9.2a	x9.3a	x10.1a	x10.5a	x9.2a	x10.5a
			*			*	
		x(6.8)b	x(8.3)ab	x(9.3)a	x(9.2)a	x(6.3)c	x(10.0)a
Protrusions	3.0	x1.4b	x1.8b	x1.3b	2.3b	x4.0a	x1.8b
			*		*	*	
		x(0.6)b	x(0.6)b	x(1.2)ab	x(0.9)ab	(2.1)a	x(1.0)ab
Contour	4.9	x3.7c	4.8c	x3.8c	5.2b	x7.1a	x6.0ab
			*	*	*		*
		x(3.0)c	x(3.2)c	x(2.7)c	x(6.4)a	x(7.2)a	(5.7)b
Cell Size	5.2	6.3b	x8.2ab	x8.3ab	x7.7ab	x7.3ab	x8.9a
		*	*			*	
		x(8.4)a	x(8.0)a	x(7.3)a	x(9.0)a	x(9.4)a	x(8.3)a
Cell uniformity	12.6	11.1a	x9.6a	10.5a	x9.8a	10.8a	x9.8s
						*	
		x(9.8)ab	x(7.7)b	(11.3)a	x(8.4)ab	x(8.9)ab	x(9.4)ab
Surface roughness	12.3	x3.3a	x3.4a	x3.3a	x3.5a	x3.7a	x4.1a
			*		*	*	*
		(2.9)a	x(2.6)a	x(3.1)a	x(2.6)a	x(2.2)a	x(2.7)a
Loose particles	10.7	x0.37a	x0.24a	x0.17a	x0.44a	x0.17a	x0.17a
			*				
		x(0.27)a	x(0.0)a	x(0.21)a	x(0.31)a	x(0.14)a	x(0.14)a
Firmness	7.2	x4.8b	x5.7a	x6.0a	x5.8a	x5.3ab	x5.9a
			*	*			*
		x(4.7)ab	x(4.5)b	x(4.8)ab	x(5.8)a	x(5.1)ab	x(5.1)ab
Fracturability	1.7	x0.0b	x0.6ab	1.2a	x0.2ab	x0.3ab	x0.2ab
				*			
		x(0.0)a	x(0.4)a	x(0.0)a	x(0.2)a	x(0.2)a	x(0.1)a
Cohesiveness of mass	7.1	x8.0a	x7.9a	7.7a	x8.3a	x8.3a	x7.9a
		x(8.5)a	x(7.8)a	x(8.3)a	x(8.2)a	x(8.7)a	x(8.0)a
Chew count	12.3	12.2a	12.3a	12.3a	12.8a	x13.0a	12.8a
		(12.7)ab	(12.0)b	(12.7)ab	x(13.0)a	x(13.5)a	(12.9)ab
Molar packing	6.1	6.0a	5.8a	6.0a	5.7a	6.3a	6.2a
		(5.7)a	(5.6)a	(6.1)a	(6.1)a	(6.2)a	(5.9)a
Residual mouth coating	1.3	1.5b	x1.9ab	x1.9ab	x2.3a	x2.0ab	x2.1a
						*	
		(1.6)b	x(1.9)ab	x(2.0)ab	x(2.1)ab	x(2.4)a	x(1.9)ab

[a] Based on structured numerical intensity scale from 0 (none) to 15 (most intense).

[b] The letter x preceding the mean indicates a significant difference from the control. Means in the same row with the same letter are not significantly different from each other ($P \leq 0.05$). Each value represents the mean of three replicates. The value in the first row represents replacement of 50% of the shortening in the control formulation; the value in the second row (in parentheses) represents the mean for cookies with 75% of the shortening replaced. An asterisk in the column between the values of the two levels indicates a significant difference at $P = 0.05$.

Table III. For this one attribute, significant crossover panelist × treatment interactions among panelists were found. Apparently, the panelists were not interpreting the definition similarly for this attribute. Thus, these results should be interpreted with that caveat in mind. Nevertheless, all cookies with fat replacers had significantly greater cell size ($P \leq 0.05$) than that of the control, except for the cookie with microparticulated protein replacing 50% of the shortening.

All variations with fat replacers had more uniform cell structure (low values indicating fewer large cells) than did the control cookies ($P \leq 0.05$), except for those containing polydextrose at either level of shortening replacement and microparticulated protein and acid-treated cornstarch at the 50% level. The MDG at the 75% level of shortening replacement produced the most uniform cell structure (presumably it produced a more stable bubble film) with the lowest mean value (7.7), but its uniformity was not significantly different from that of any of the other variations, except for the cookies with 75% replacement by polydextrose. No differences were observed in cell uniformity between the levels of any of the fat replacers.

Sensory Texture Measurements

All of the variations had fewer loose particles on the cookie surface than the control cookie had (Table III). The control had a mean value of 10.7 compared to values of <1 for each of the substitutes. The control cookie also had the highest mean value (12.5) for surface roughness. All of the variations with shortening replacers again were rated much lower (2.2–4.1) than the control. Although surface roughness and loose particles are geometrical textural attributes, they are related to optical surface cracking and open holes, which are both appearance characteristics. Normally, a rough cookie surface corresponds to a large amount of surface cracking and loose particles. Replacement of shortening with any of these fat replacers resulted in a smoother cookie surface, fewer cracks, and more open holes.

Cookies made with fat replacers were significantly less fracturable than the control cookie, except for those containing polydextrose at the 50% replacement level (Table III). At the 50% level, the cookie with microparticulated protein had the lowest fracturability, which was significantly less ($P \leq 0.05$) than that of the cookie with polydextrose. No significant differences were found in the force needed to shatter the cookies at the 75% levels for each of the replacers. Cookies made with polydextrose at the 50% replacement level were significantly more fracturable (1.2) than those containing 75% (0) ($P \leq 0.05$). All other variations did not differ significantly between levels. It is possible that differences in fracturability resulted, in part, from differences in the water held in the system. Entrapment of water created a softer cookie that was less fracturable than the control chocolate chip cookie, which itself was low in fracturability.

The control cookie had the highest sensory firmness (Table III). It also required the highest force for instrumental compression (Table IV), indicating that it was the hardest cookie. Cookies with 50 or 75% of the shortening replaced with any of the replacers generally were not different from each other. The sensory panel rated the cookies with microparticulated protein at the 50% level the same as those with acid-treated cornstarch; they rated them less firm than all other replacers. All of the cookies with replacers at the 75% level were rated the same or less firm ($P \leq 0.05$) than were the control or potato maltodextrin cookies. Instrumental compression results (Table IV) were not always in agreement with the sensory results, but differences in compression force among the cookies with fat replacers were small on an absolute basis.

Both the 50 and 75% variations with acid-treated cornstarch and 75% potato maltodextrin resulted in cookies with significantly higher ($P \leq 0.05$) chew counts than that of the control cookies (Table III). However, the actual numbers of chews were similar; the differences probably had no practical importance. Cookies made with replacers at both levels also had slightly, but significantly, higher values for cohesiveness of chewed sample mass than did the control cookie, except for the cookie in which poly-

TABLE IV
Mean Values Comparing Physical Measurements of Control Chocolate Chip Cookies and Cookies Containing 50 and 75% Selected Fat Replacers

		Fat Replacer[a]					
Attribute	**Control**	**Microparticulated Protein**	**Mono- and Diglycerides**	**Polydextrose**	**Potato Maltodextrin**	**Acid-Treated Corn Starch**	**Pectin**
Specific gravity		1.0a	x1.1a	x1.1a	x1.1a	x1.1a	x1.1a
		*	*	*	*	*	*
		(1.1)a	x(0.9)b	x(1.2)a	x(1.2)a	x(1.2)a	x(1.2)a
Compression[b]	11.8	7.1a	x4.3a	x3.4a	x5.7a	x4.6a	x1.1a
		(7.2)a	x(3.4)ab	x(0.0)b	x(3.9)ab	x(2.0)ab	x(0.3)b
Spread ratio[c]	6.4	x9.4a	x7.6b	x10.0a	x7.3b	x5.4c	7.0b
			*	*			*
		x(9.2)b	x(8.7)bc	x(11.0)a	(6.7)d	x(5.3)e	x(8.0)c
L Value	44.7	45.5ab	x49.4a	43.3b	45.5ab	45.5ab	46.1ab
							*
		(46.9)ab	x(48.8)ab	(45.0)b	(46.4)ab	(45.7)ab	x(49.8)a
Hue angle[d]	24.7	22.3a	22.3a	23.7a	24.7a	25.2a	24.5a
				*			*
		(21.3)a	(21.3)a	x(17.7)a	(23.3)a	(23.7)a	x(18.3)a
Saturation index[d]	14.0	14.9ab	x15.9a	14.5ab	15.3ab	14.9ab	13.7b
		x(15.7)a	x(16.4)a	(13.6)b	x(16.5)a	x(16.0)a	(14.7)ab

[a] The letter x preceding the mean indicates a significant difference from the control. Means in the same row with the same letter are not significantly different from each other ($P \leq 0.05$). Each value represents the mean of three replicates. The value in the first row represents replacement of 50% of the shortening in the control formulation; the value in the second row, in parentheses, represents the mean for cookies with 75% of the shortening replaced. An asterisk indicates the difference between the two levels was significant.

[b] Measured using a universal testing machine at 50% compression.

[c] Method 10-50D (AACC 1983).

[d] Calculated from *L*, *a*, and *b* (UltraScan, Hunterlab, Reston, VA) values using: $\tan^{-1} b/a$ for hue angle and $\sqrt{(a^2 + b^2)}$ for saturation index.

dextrose replaced 50% of the shortening. Molar packing did not differ significantly among any of the shortening-replaced cookies at either the 50% or 75% level, nor did any of the variations differ significantly from the control for this attribute. No significant differences in chew count, molar packing, or cohesiveness of mass were found between the 50 and 75% levels of any replacer.

All cookies with replacers at both levels had significantly more residual mouthcoating ($P \leq 0.05$) than did the control cookie, except for those with microparticulated protein (Table III). Microparticulated protein cookies had the least mouthcoating; it was significantly lower than that for cookies with acid-treated cornstarch at the 75% replacement level. Of the variations, only cookies containing acid-treated cornstarch differed significantly ($P \leq 0.05$) between the two levels of replacement (2.0 vs. 2.4 for 50 and 75% replacement, respectively). As the shortening level increased, mouthcoating could be expected to increase as well. However, the full shortening cookie had the lowest mouthcoating, which indicated that panelists did not identify the mouthcoating as an oily type. The cookies with carbohydrate-based replacers had higher levels of mouthcoating than did the cookies with the lipid- or protein-based replacers. Thus, this attribute could have been related to a chemical feeling factor coating the oral mucosa that Civille (1990) found for some carbohydrate bulking agents used in semifluid foods.

Sensory Flavor Measurements

Panelist measurements of bitterness, saltiness, sweetness, and sourness are given in Table V. The results indicated that replacement of up to 75% of the shortening did not affect ($P \leq 0.05$) the bitterness or saltiness of chocolate chip cookies. All variations were significantly less sweet than was the control, except for cookies with MDG or the microparticulated protein at 50% shortening replacement.

Cookies with MDG, polydextrose, or acid-treated cornstarch at the 75% level had significantly higher ($P \leq 0.05$) sourness than did the control cookies. No significant differences were found for sourness at either the 50 or 75% levels among the replacers and between the levels for each replacer. The control cookie had similar vanilla-like flavor as cookies using polydextrose at 50 and 75%, pectin at 50 and 75%, or the acid-treated cornstarch at 50% replacement levels. However, the control cookie had significantly more vanilla-like flavor than the other variations and significantly more sweet aromatics than any of the cookies using fat replacers. The reduced shortening cookies had less fat. The vanilla-like and related sweet aromatics probably were more volatile with less shortening in the system. Plug and Haring (1993) pointed out that lipophilic flavorings can be poorly bound to the food matrix in the absence of fat, and vanilla is dispersed in an alcohol, which volatilizes if not bound to macromolecules. No significant differences were found among the replacers at the 50 and 75% levels or between the 50 and 75% levels of each replacer for sweet aromatics.

All variations of the shortening-reduced cookies also had significantly less caramelized flavor than did the control (Table V), and cookies with pectin as the shortening replacer had significantly less (5.6 vs. 5.0 for 50 and 75% replacement, respectively) caramelized flavor as more shortening was replaced. Other cookies did not differ significantly in caramelized flavor between the 50 and 75% levels of fat replacers.

Physical Measurements

The mean values for physical measurements of the cookies with the two levels of the different fat replacers and for the control cookie are given in Table IV. These measurements supplemented the findings from the sensory studies. As stated earlier, the control cookie required more force for compression than any of the cookies with 50 to 75% fat replacers, with the exception of the cookies made with the microparticulated protein. All cookies with 50% replacer had the same ($P = 0.05$) hardness and the same specific gravity values. At the 75% level of shortening replacement, the cookies with MDG, potato maltodextrin, and acid-treated cornstarch required similar compressive force. A 75% shortening replacement allowed significantly more air incorporation by the MDG than was achieved using any other replacer, and it, and the variation using 50% microparticulated protein for shortening replacement, had the same specific gravity as the control cookie. Cookies with pectin at the 75% replacement level required less compression ($P \leq 0.05$) than the cookies with microparticulated protein for the fat replacer.

The cookie with 75% potato maltodextrin and the cookie with

TABLE V
Mean Values Comparing Sensory Flavor Attributes[a] of Control Chocolate Chip Cookies and Cookies Containing 50 and 75% Selected Fat Replacers

		Fat Replacer[b]					
Attribute	Control	Microparticulated Protein	Mono- and Diglycerides	Polydextrose	Potato Maltodextrin	Acid-Treated Corn Starch	Pectin
Sour	0.53	0.67a	0.63a	0.70a	0.57a	0.60a	0.67a
		(0.60)a	x(0.80)a	x(0.73)a	(0.60)a	x(0.75)a	(0.67)a
Bitter	1.9	1.9a	1.7a	1.9a	1.9a	1.7a	1.9a
		(1.6)a	(2.0)a	(2.0)a	(1.8)a	(1.6)a	(2.1)a
Salty	3.6	3.3a	3.4a	3.4a	3.3a	3.7a	3.5a
		(3.2)a	(3.4)a	(3.4)a	(3.5)a	(3.4)a	(3.4)a
Sweet	8.2	7.9a	8.0a	x7.7a	x7.8a	x7.8a	x7.8a
		x(7.6)a	x(7.8)a	x(7.6)a	x(7.7)a	x(7.4)a	x(7.6)a
Sweet aromatics	10.5	x10.0a	x10.0a	x9.9a	x9.9a	x9.7a	x9.9a
		x(9.8)a	x(9.9)aa	x(9.8)a	x(9.5)a	x(9.5)a	x(9.6)a
Vanillalike	2.0	x1.7a	x1.7a	1.8a	x1.7a	x1.6a	1.9a
		x(1.6)a	x(1.7)a	(1.9)a	x(1.6)a	x(1.6)a	(1.8)a
Caramelized	6.5	x5.2a	x10.0a	x5.6a	x5.3a	x5.5a	x5.6a
							*
		x(5.5)a	x(9.9)a	x(5.5)a	x(5.1)a	x(5.0)a	x(5.0)a

[a] Based on structured numerical intensity scale from 0 (none) to 15 (most intense).

[b] The letter x preceding the mean indicates a significant difference from the control. Means in the same row with the same letter are not significantly different from each other ($P \leq 0.05$). Each value represents the mean of three replicates. The value in the first row represents replacement of 50% of the shortening in the control formulation; the value in the second row (in parentheses) represents the mean for cookies with 75% of the shortening replaced. An asterisk in the column between the values of the two levels indicates a significant difference at $P = 0.05$.

50% pectin did not differ significantly from the control for spread. All other variations had greater spread than the control ($P \leq 0.05$), except for the cookies with either level of acid-treated cornstarch, which spread less ($P \leq 0.05$) than the control. Fat replacement with acid-treated cornstarch at the 50 and 75% levels produced thick, "cakelike" cookies, which could be attributed to the ability of cornstarch to trap large amounts of water within its system. In contrast, fat replacement with polydextrose produced a thin batter and a flat, thin cookie. Even though each of the replacers is considered hygroscopic, how the water was held and its mobility undoubtedly influenced the spread and other textural properties. The spread of chocolate chip cookies with 75% replacers was in the order: polydextrose > microparticulated protein > MDG > pectin > potato maltodextrin > acid-treated cornstarch.

Mean values of instrumental color measurements of the cookies are given in Table IV. Polydextrose at the 50% replacement level produced the darkest cookie (43.3) among all replacers, but it was significantly different only from the lightest cookie (49.4) that used MDG for shortening replacement. At the 75% replacement level, use of polydextrose also resulted in the darkest cookie (mean value = 45.0), and it was significantly different from the cookie using the pectin fat substitute (49.8). Cookies using MDG at both the 50 and 75% replacement levels and pectin at the 75% level were significantly lighter (48.8–49.8) than the control cookie (44.7).

The control cookie was significantly more yellow (hue angle of 24.7 in the red–yellow quadrant) than cookies containing pectin (18.3) or polydextrose (17.7) to replace 75% of the shortening. Cookies with all other replacers were not significantly different from the control. No differences in hue angle were found among the 50 and 75% levels of replacers for any of the cookies. The cookies with MDG at 50 and 75% replacement levels or the microparticulated protein, potato maltodextrin, and acid-treated cornstarch at the 75% level had mean hue saturation indices between 15.7 and 16.4, indicating that they were significantly brighter than the control (14.0). Cookies with all other replacers did not differ significantly in hue saturation from the control. At the 50% shortening replacement level, the cookies containing MDG had the highest mean value (15.9) and were significantly brighter than cookies containing the pectin replacer. A 75% replacement of shortening with pectin resulted in cookies that were duller than any of the others, except for cookies with 75% polydextrose as the replacer. No differences in saturation were found between levels of each replacer.

DISCUSSION

In general, the levels of fat replacement (50 vs. 75%) in this study did not have much effect on any sensory attributes in differentiating the shortening-replaced cookie from the control. Carbohydrate-based replacers produced cookies with greater textural differences from the control than from the protein or lipid-based replacers. The carbohydrate-based fat replacements, and, in particular, the acid-treated cornstarch and pectin, produced cookies that were soft, thick, and cakelike, with little spread. Each type of replacer, however, produced cookies with some texture, flavor, and appearance attributes that were similar to those of the control.

The cookies containing pectin at both levels were similar to the control for sour, salty, bitter, and vanilla-like flavors; they were similar for chew count, molar packing, and contour at the 75% replacement level. Potato maltodextrin and acid-treated cornstarch as fat replacers resulted in cookies similar to the control for salty and bitter tastes and for the degree of molar packing. Cookies containing polydextrose at the 50% level had notable similarities to the control in cohesiveness of chewed sample mass and fracturability. Many texture and appearance attributes of cookies using MDG as the shortening replacer were similar to those of cookies with carbohydrate replacers. Sweetness, sourness, lightness of color, contour, and specific gravity of cookies with MDG tended to be similar to those of the control. Cookies containing the protein-based fat replacer had several textural attributes that were similar to control cookies including compression (firmness), specific gravity, and mouthcoating.

The textural and appearance attributes of the control chocolate chip cookie were difficult to achieve with any one of the shortening replacers in cookies. This was probably related to two factors: 1) modification of sucrose crystallization, and 2) altered water mobility and its holding-release behavior. How and when the water is released in the oral cavity is influenced by the specific fat replacer and its interactions with the other ingredients. This factor determined, at least partially, the texture and appearance attributes of the shortening-replaced chocolate chip cookies. Water associated with fat replacers generally created smoother, softer cookies.

How the water was held by the particular fat replacer could influence how much was free to dissolve the sugars present. Furthermore, some fat replacers might have had sugars present from the processing, such as fructose, that inhibited sucrose crystallization or depressed dough expansion temperature. According to Doescher et al (1987), granular sucrose in cookies resulted in higher glass transition temperatures for gluten than did sugar syrups, which decreased in the following order: sucrose > glucose > fructose. The higher glass transition temperature, which occurred just before dough expansion, resulted in cookies with greater spread. Furthermore, they found that glass transition and dough expansion temperatures were lower as moisture content increased (Doescher et al 1987). Thus, both the addition of some glucose and fructose as sugars associated with the fat replacers and the increased moisture in the system would be expected to produce cookies with less spread and greater softness than that of cookies produced using only shortening and sucrose, as in the control cookie. Not all findings in this study corroborated the obvious expectations based upon these theories. Cookies containing polydextrose with a relatively high glucose content (Allingham 1982) had the greatest spread of any of the cookies made with fat replacers in this study. Further studies on the relationships among the type of fat replacer, sugar, shelf life and storage properties, water binding, glass transitions of the gluten, and perceived sensory moisture of the cookies are needed to understand these systems more completely.

Additional work is recommended to explore consumer acceptability of the shortening-reduced cookies with fat replacers. Differences from the control do not automatically imply that the cookies would be unacceptable by consumers. Results from this study can provide the basis for optimization of levels of a combination of fat replacers to achieve the levels of the attributes in a chocolate chip cookie that are determined to be acceptable to the consumer in a chocolate chip cookie.

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