High Fiber Sugar-Snap Cookies Containing Cellulose and Coated Cellulose Products[1]

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ABSTRACT

Sugar-snap cookies were prepared with 0–30% of the flour substituted with cellulose of different particle size and carboxymethyl cellulose or pectin-coated cellulose. High levels of cellulose substitution reduced cookie spread, crispness, browning, and sensory qualities. Cookies with 10% cellulose substitution, however, were of good quality. Comparison of the data obtained from using the various cellulose types at the 10% level of substitution showed some differences in physical parameters but no difference in sensory evaluations. These cookies had 1.4 g dietary fiber per 24 g cookie.

Low dietary fiber intake has been related to the incidence of a variety of noninfectious "diseases of civilization" (Spiller and Amen 1975). The fiber content of cookies has been increased through the substitution of part of the flour with bran (Vratanina and Zabik 1978) and brewers' spent grain (Prentice et al 1978). Cellulose products have been successfully incorporated in bread (Pomeranz et al 1977) and cakes (Zabik et al 1977). The purpose of our study was to determine the optimum level of cellulose and the type of cellulose that could best be incorporated into the cookie system. Levels of 0, 10, 20, and 30% substitution of cellulose or coated-cellulose products were substituted for flour in a basic sugar-snap cookie; a second experiment evaluated the effect of type of cellulose product used at the 10% level of flour substitution.

EXPERIMENTAL

The cellulose types have been described by Zabik et al (1977) and scanning electron microscopy pictures of the celluloses used have been published by Pomeranz et al (1977). The types used in this study were: Type A = Solka Floc, BW-200 Pharmaceutical (average particle size 30-35); type B = Avicel pH-101 (average particle size 50); type C = Prototype sample 174-2 (average particle size 150-225); type D = Prototype sample 174-1 (same as 174-2 except 2% carboxymethyl cellulose [CMC] was added during processing); type E = 85% sample 174-2 coated with 15% nonfood grade citrus pectin, medium viscosity.

Type A was a mechanically ground cellulose produced by the Berlin-Gorham Division of Brown Company, Berlin, NH 03570. The other cellulose types were hydrolyzed celluloses produced by the Avicel Department of FMC Corporation, Marcus Hook, PA 19061.

In the first series of experiments, cookies with 0, 10, 20, and 30% of the flour substituted with cellulose were prepared using a modification of the Micro III method as described by Zabik et al (1979). In addition, pure vanilla extract (4.5 ml) was substituted for an equal volume of water and 2% soy lecithin based on the total weight of flour and cellulose was added to the creamed mass (Kissell and Yamazaki 1975). Enriched soft red wheat cookie flour, which was donated by Mennel Milling Company, had the following characteristics on an as-is basis: pH 5.9, 13.80% moisture, 8.55% protein, and 0.41% ash. Four replications of cookies containing one type of cellulose were completed before another series of cookies were started to minimize climatic changes during the spring of the year. For the second series of experiments, four replications of cookies with 10% flour substitution with types A, B, C, D, and E cellulose were compared.

Top grain, spread, percentage moisture, lightness, breaking strength, tenderness, and sensory characteristics of the baked cookies were determined as outlined by Vratanina and Zabik (1978).

In the first series of experiments, data from each type of cellulose were analyzed and compared with that of the control. Two-way analyses of variance were determined and the means were compared according to Duncan's multiple range test (1957). For the second series of experiments, cookies containing each type of cellulose were compared with cookies containing the other four types of cellulose by the same statistical methods.

RESULTS AND DISCUSSION

Tables I and II present the objective data and sensory evaluations of the sugar-snap cookies prepared with 0, 10, 20, and 30% cellulose products. Top grain decreased progressively with each increasing level of cellulose substitution, although the decrease was small for cookies that had 10% of the flour substituted with type A (Solka Floc), type B (pH 101), or type D (CMC-coated prototype). Sensory evaluations of surface characteristics (Table II) indicated no significant difference among the control and cookies with 10% of the flour substituted with cellulose for all three of these cellulose types.

Spread decreased with each level of cellulose incorporation (Table I), whereas cookie shape was scored significantly lower for cookies with most cellulose types substituted at the 20 or 30% level. Moisture content increased while breaking strength and shear values decreased as the level of cellulose substitution increased. Thus because of the hydrophilic properties of these cellulose products, as their level of substitution increased, the cookies became thicker and softer, losing the characteristic appearance and texture of the sugar-snap cookie.

Increasing the level of cellulose substitution resulted in lighter cookies (Table I), which scored progressively lower for surface color (Table II). Pomeranz et al (1977) reported that substituting 15% of the flour with cellulose-prototype 174-1 lightened bread crust. Internal color scores also decreased as the level of cellulose substitution increased (Table II) although, except for cookies with 30% of the flour substituted with the various cellulose types, most all of the scores were above 5, which would be a description of a good characteristic evaluation on a 7-point scale. Scores of 4 identified fair evaluations and lower scores tended toward poor and unacceptable scores. We believed, however, that a cookie with characteristic good ratings would be more acceptable in the consumer market.

Other parameters of interior appearance were also adversely affected by increasing levels of cellulose substitution (Table II). As the level of cellulose substitution increased, cookie texture was scored as soft, requiring little force to bite through the cookie. Mouth-feel characteristics decreased with taste panelists commenting the cookies with 30% of the flour substituted with cellulose products felt gritty or powdery. Sensory scores decreased progressively as the level of cellulose substitution increased, and

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panelists commented that the cookies with 30 and sometimes 20% of the flour substituted with cellulose products had a chalky aftertaste.

Nevertheless, cookies with 10% of the flour substituted with cellulose products generally scored close to the control cookie. Previous research, in which 30% of the flour in a high-ratio white layer cake was substituted with cellulose products, showed few quality differences among these cakes for all cellulose types evaluated except pectin-coated cellulose (Zabik et al 1977), but Lee et al (1969) reported that substitution of high levels of cellulose resulted in decreased appearance, texture, and flavor scores in muffins, cookies, and mashed potatoes.

To compare the effect of the different cellulose types, a second series of cookies were prepared with the 10% level of substitution. This level had appeared to be the most acceptable for all types of cellulose in the initial study. Means and standard deviations of the objective and sensory evaluations from the second study are in Tables III and IV, respectively. Cookies with type B (pH 101) cellulose and the large particle size prototype coated with CMC (type D) had the largest spread; cookies with cellulose coated with pectin (type E) had the smallest spread. The characteristic high water-binding capacity of the pectin was also noted previously with cakes (Zabik et al 1977).

The surface appearance of these cookies and a control cookie from the first experiment is shown in Fig. 1. Cookies prepared with the pectin-coated cellulose variable (15%-P) had the poorest top grain. Surface cracks were both wider and deeper. Nevertheless, taste panelists scored the surface characteristic of these cookies as good.

There were no significant differences among the percentage moisture or lightness values of the cookies prepared with 10% of the flour substituted with the five types of cellulose. The cookies with type A cellulose (BW-200) were crisper and had higher breaking force values than the cookies with 10% of the flour substituted with types B (pH 101), C (large particle prototype), or D (CMC-coated large particle prototype). All sensory scores were good (Table IV) and no significant differences were found among cookies prepared with the various types of cellulose for the numerous sensory parameters evaluated.

Substitution of 10% of the flour with cellulose provided approximately 1.2 g of dietary fiber per 24 g of cookie, in addition

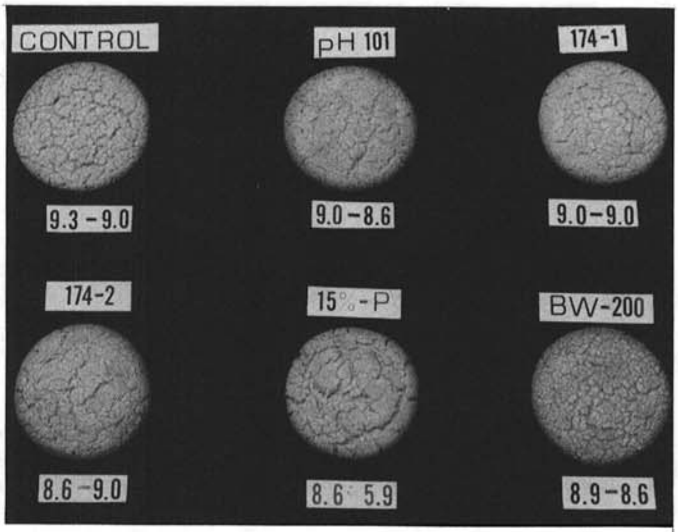

Fig. 1. Visual appearance of cookies with 10% cellulose substitutions with type A = BW 200, type B = pH 101, type C = 174-2, type D = 174-1, and type E = 15%-P, as well as a control cookie from the first series of experiments (cookie diameter and top grain score shown under each cookie).

TABLE I
Objective Tests[a] of Sugar-Snap Cookies Substituted with 0, 10, 20, and 30% Cellulose Products

Characteristic	Substitution (%)	Cellulose				
		Type A	Type B	Type C	Type D	Type E
Top grain[b]	0	9.0	9.0	9.0	9.0	9.0
	10	8.8	8.4	7.3	8.8	6.3
	20	5.5	6.3	6.5	5.3	3.8
	30	1.3	2.3	3.3	2.5	2.0
Spread Factor (W/T)	0	13.7 ± 0.4	13.7 ± 0.4 a	13.7 ± 0.4	13.7 ± 0.4	13.7 ± 0.7
	10	11.1 ± 0.1	12.1 ± 0.1 ab	9.1 ± 0.3	12.3 ± 0.2	10.2 ± 0.2
	20	8.5 ± 0.1	9.4 ± 0.5 bc	9.6 ± 0.2	9.9 ± 0.1	8.0 ± 0.3
	30	5.7 ± 0.1	6.7 ± 0.4 c	6.8 ± 0.2	7.4 ± 0.2	5.5 ± 0.2
Breaking Strength (lb force/cm^2)	0	5.2 ± 0.2 a	5.2 ± 0.2 a	5.2 ± 0.2	5.2 ± 0.2	5.2 ± 0.2
	10	4.2 ± 0.6 a	3.9 ± 0.5 b	4.4 ± 0.5 a	3.1 ± 0.3 a	3.0 ± 0.2
	20	5.6 ± 1.3 a	4.3 ± 0.9 ab	3.9 ± 0.5 a	3.0 ± 0.3 a	3.4 ± 0.2
	30	2.0 ± 0.8	2.3 ± 0.9	2.1 ± 0.4	2.4 ± 0.8 a	1.3 ± 0.1
Tenderness (lb force/g)	0	29.5 ± 0.6 a	29.5 ± 0.6 a	29.5 ± 0.6	29.5 ± 0.6 a	29.5 ± 0.6 a
	10	32.2 ± 2.2 a	32.7 ± 4.8 a	19.6 ± 1.0 a	32.6 ± 2.3 b	24.2 ± 6.3 a
	20	32.6 ± 3.7 a	32.4 ± 3.3 a	19.6 ± 2.7 a	31.2 ± 1.4 ab	29.1 ± 9.6 a
	30	16.1 ± 1.5	17.7 ± 1.2	14.6 ± 0.5	16.7 ± 1.7	13.6 ± 2.4
% Moisture	0	2.90 ± 0.45 a	2.90 ± 0.45	2.90 ± 0.45 a	2.90 ± 0.45 a	2.90 ± 0.45 a
	10	2.49 ± 0.80 a	3.79 ± 0.25	3.03 ± 0.23 a	3.29 ± 0.13 ab	3.28 ± 0.78 ab
	20	4.09 ± 0.54	5.06 ± 0.45	3.11 ± 0.34 a	3.78 ± 0.14 b	4.15 ± 0.08 b
	30	6.76 ± 0.71	7.49 ± 0.84	5.47 ± 0.59	6.12 ± 0.71	8.00 ± 0.48
Lightness	0	65.1 ± 2.2	65.1 ± 2.2	65.1 ± 2.2	65.1 ± 2.2 a	65.1 ± 2.2
	10	69.8 ± 1.9	69.1 ± 0.2	74.7 ± 0.3 ab	68.3 ± 0.6 b	69.2 ± 1.5
	20	74.4 ± 0.7 a	74.2 ± 1.6	73.1 ± 0.7 a	71.6 ± 0.6 c	71.5 ± 1.6 a
	30	76.4 ± 1.1 a	78.0 ± 1.6	76.0 ± 0.9 b	74.8 ± 0.9 d	75.9 ± 0.3

[a]Means are based on four replications. Any mean with the same letter within each objective test for that cellulose product is not significantly different at $P < 0.05$ (Duncan 1957).
[b]Data were not analyzed for variance.

to the 0.2 g of dietary fiber in the control sugar-snap cookie (Vratanina and Zabik 1978). The level of dietary fiber in the cellulose substituted cookies was calculated from the proportion of cellulose or cellulose products in the cookie formula, corrected for moisture loss during baking.

Forsythe and co-workers (1976) studied the effect of these and other dietary fibers on laxation and serum cholesterol levels. Rats were fed a basal diet intended to approximate the "typical" American diet of 40% calories from fat, 40% from carbohydrate, and 20% from protein that was supplemented with 8 g of fiber per

TABLE II
Sensory Evaluation Scores[a] for Sugar-Snap Cookies Substituted with 0, 10, 20, and 30% Cellulose Products[b]

Characteristic	Substitution (%)	Cellulose				
		Type A	Type B	Type C	Type D	Type E
Surface Appearance						
Shape	0	6.3 ± 0.3 a	6.2 ± 0.2 a	6.4 ± 0.1 a	6.3 ± 0.2 a	6.2 ± 0.3 a
	10	6.1 ± 0.2 a	6.2 ± 0.3 a	5.8 ± 0.3 ab	6.2 ± 0.2 a	6.2 ± 0.3 a
	20	5.4 ± 0.2 b	6.1 ± 0.3 ab	5.6 ± 0.6 bc	5.2 ± 0.4 b	5.2 ± 0.5
	30	5.5 ± 0.2 b	5.8 ± 0.5 b	4.9 ± 0.3 c	5.2 ± 0.2 b	4.5 ± 0.3
Color	0	6.1 ± 0.3 a	5.6 ± 0.6 ab	5.1 ± 0.6 a	6.1 ± 0.2 a	5.7 ± 0.5 ab
	10	6.0 ± 0.2 a	5.2 ± 0.2 a	4.8 ± 0.2 a	6.1 ± 0.2 a	6.0 ± 0.2 a
	20	4.2 ± 0.2	5.2 ± 0.5 b	4.8 ± 0.6 a	5.3 ± 0.4	5.2 ± 0.3 b
	30	2.7 ± 0.2	3.6 ± 0.6	3.2 ± 0.4	3.5 ± 0.3	3.2 ± 0.2
Characteristic	0	6.5 ± 0.2 a	6.2 ± 0.2 a	6.3 ± 0.3	6.5 ± 0.1 a	6.3 ± 0.3
	10	6.1 ± 0.3 a	6.1 ± 0.1 a	4.2 ± 0.3 a	6.4 ± 0.2 a	5.2 ± 0.3
	20	4.2 ± 0.5	4.6 ± 0.3	4.8 ± 0.5 a	4.5 ± 0.6	3.6 ± 0.5
	30	1.9 ± 0.1	2.6 ± 0.9	2.6 ± 0.4	2.3 ± 0.2	1.8 ± 0.1
Interior Appearance						
Distribution of cells	0	5.8 ± 0.2 a	5.3 ± 0.3 ab	5.4 ± 0.3	5.5 ± 0.4 a	5.5 ± 0.2 a
	10	5.7 ± 0.4 a	5.7 ± 0.3 a	4.3 ± 0.3 a	5.5 ± 0.3 a	5.4 ± 0.3 a
	20	4.5 ± 0.4	4.9 ± 0.3 b	4.5 ± 0.5 a	4.4 ± 0.1 a	4.2 ± 0.4
	30	2.5 ± 0.5	3.2 ± 0.3	2.6 ± 0.5	2.8 ± 0.2	1.9 ± 0.1
Shape and size	0	5.1 ± 0.2 a	5.0 ± 0.5 a	4.6 ± 0.3 a	4.7 ± 0.3 a	4.6 ± 0.3 a
	10	5.7 ± 0.5	5.9 ± 0.9	4.6 ± 0.3 a	5.4 ± 0.5	5.5 ± 0.4
	20	4.5 ± 0.5	5.0 ± 0.2 a	4.9 ± 0.2	4.4 ± 0.4 a	4.4 ± 0.4 a
	30	3.5 ± 0.6	3.6 ± 0.2	3.5 ± 0.2	3.4 ± 0.3	3.1 ± 0.2
Color	0	6.1 ± 0.4 a	5.5 ± 0.5 ab	5.2 ± 0.5 a	5.8 ± 0.2 ab	5.4 ± 0.4 ab
	10	6.0 ± 0.2 a	6.2 ± 0.3 a	5.3 ± 0.3 a	6.3 ± 0.2 a	5.9 ± 0.1 a
	20	4.8 ± 0.3	5.2 ± 0.2 b	5.2 ± 0.2 a	5.3 ± 0.3 b	5.0 ± 0.3 b
	30	3.6 ± 0.4	4.2 ± 0.3	4.4 ± 0.2	4.6 ± 0.4	4.0 ± 0.6
Eating Characteristic						
Texture	0	6.8 ± 0.1	6.5 ± 0.2 a	6.8 ± 0.1	6.7 ± 0.1	6.8 ± 0.1
	10	6.2 ± 0.2	6.2 ± 0.4 a	5.5 ± 0.3 a	6.5 ± 0.2 a	6.3 ± 0.2
	20	3.9 ± 0.5	4.8 ± 0.5	5.0 ± 0.5 a	4.8 ± 0.1	5.3 ± 0.5
	30	1.7 ± 0.1	1.8 ± 0.2	1.9 ± 0.4	1.8 ± 0.2	1.5 ± 0.1
Mouth-feel	0	6.3 ± 0.3 a	6.1 ± 0.3 a	5.6 ± 0.3 a	6.0 ± 0.2	5.9 ± 0.4 a
	10	6.0 ± 0.3 a	5.9 ± 0.6 a	5.3 ± 0.4 ab	6.6 ± 0.2	6.0 ± 0.3 a
	20	3.8 ± 0.6	5.0 ± 0.7	5.0 ± 0.4 b	4.6 ± 0.3	4.9 ± 0.4
	30	2.4 ± 0.1	3.1 ± 0.4	2.3 ± 0.3	2.8 ± 0.2	1.9 ± 0.1
Flavor	0	6.1 ± 0.4 a	5.7 ± 0.4 a	5.1 ± 0.5 a	5.8 ± 0.1	5.5 ± 0.2 ab
	10	5.9 ± 0.4 a	5.8 ± 0.3 a	5.2 ± 0.5 a	6.3 ± 0.1	5.7 ± 0.7 a
	20	5.1 ± 0.4	5.2 ± 0.1	5.2 ± 0.3 a	5.2 ± 0.2	5.1 ± 0.2 b
	30	4.0 ± 0.3	4.6 ± 0.1	4.1 ± 0.1	4.4 ± 0.4	3.8 ± 0.3

[a]Scores 1–7, 7 as optimum.
[b]Means are based on four replications; any mean with the same letter within each characteristic is not significantly different at $P < 0.05$ (Duncan 1957).

TABLE III
Objective Measures[a] of Sugar-Snap Cookies Substituted with 10% Cellulose Products

Objective Measure	Cellulose				
	Type A	Type B	Type C	Type D	Type E
Spread Factor	11.2 ± 1.2 a	12.1 ± 0.3 b	11.4 ± 0.6 a	12.1 ± 0.6 b	9.9 ± 0.3
Breaking Strength (lb force/cm^2)	4.9 ± 0.6 a	3.7 ± 1.0 b	3.6 ± 0.6 b	3.8 ± 0.8 b	4.3 ± 0.4 ab
Tenderness (lb force/g)	26.1 ± 1.7 a	23.5 ± 1.9 a	40.0 ± 10.8	23.0 ± 2.6 a	13.7 ± 6.4
Moisture (%)	3.67 ± 0.23 a	2.81 ± 0.45 a	3.12 ± 0.54 a	2.98 ± 0.44 a	3.35 ± 0.45 a
Lightness	69.2 ± 0.6 a	70.3 ± 1.8 a	69.8 ± 0.9 a	69.3 ± 2.0 a	69.6 ± 0.5 a

[a]Means are based on four replications. Any mean with the same letter within an objective measure is not significantly different at $P < 0.05$ (Duncan 1957).

TABLE IV
Sensory Evaluation Scores[a] for Sugar-Snap Cookies Substituted with 10% Cellulose Products

Characteristic	Cellulose Type A	Cellulose Type B	Cellulose Type C	Cellulose Type D	Cellulose Type E
Surface Appearance					
Shape	6.4 ± 0.3	6.0 ± 0.2	6.5 ± 0.2	6.4 ± 0.1	6.3 ± 0.4
Color	6.1 ± 0.2	5.8 ± 0.5	6.2 ± 0.2	6.1 ± 0.3	6.5 ± 0.1
Characteristic	6.0 ± 0.4	5.1 ± 1.7	5.9 ± 0.2	6.2 ± 0.2	5.1 ± 0.5
Interior Appearance					
Distribution of cells	5.2 ± 0.4	5.4 ± 0.3	5.5 ± 0.3	5.6 ± 0.6	5.0 ± 0.6
Shape and size of cells	5.9 ± 0.4	6.1 ± 0.3	6.0 ± 0.3	5.8 ± 0.7	5.9 ± 0.4
Color	5.4 ± 0.4	5.2 ± 0.4	5.6 ± 0.2	5.5 ± 0.4	5.1 ± 0.6
Eating Characteristics					
Texture	5.9 ± 1.0	6.7 ± 0.9	6.0 ± 0.6	5.5 ± 0.1	6.3 ± 0.5
Mouth-feel	5.8 ± 0.7	6.2 ± 0.8	6.0 ± 0.5	5.2 ± 0.3	6.1 ± 0.5
Flavor	5.5 ± 0.5	5.9 ± 0.6	5.8 ± 0.2	5.4 ± 0.5	5.9 ± 0.4

[a]Scores 1–7, 7 best. Means are based on four replications.

100 g of diet. Feeding these levels of cellulose types A (BW-200), B (pH 101), and C (CMC-coated cellulose) reduced transit time by about one-third and increased fecal wet mass by 2.5 times. Pectin-coated cellulose had the greatest hypocholesterolemic effect.

Spiller et al (1977) advocated the establishment of a recommended daily dietary allowance for dietary fiber, suggesting this level should be that quantity that produces a 36-hr intestinal transit time. Although what this specific amount should be has yet to be agreed upon, Painter et al (1972) reported that from 3 to 45 g of bran, fed to patients to cure constipation or symptoms of diverticular disease, was successful in preventing straining. The average value of approximately 15 g of bran (equivalent to 6 g of dietary fiber) rendered stools soft and easy to pass. A serving of two cookies would contribute about 3 g of dietary fiber. Because all the cookies with 10% of the flour substituted with these five cellulose products were of good quality, these cookies and other fiber-supplemented baked products could contribute to increasing dietary fiber consumption of the American population.

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