Reduction of Fat in Fried Batter Coatings with Powdered Cellulose[1]

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The fat contents of fried batter coatings were reduced significantly (7–28%) when 1% powdered cellulose (fiber length in excess of 100 microns) was incorporated into the batter. In addition, moisture and dry material contents were increased significantly in these coatings. Although fat reductions were observed in both shortening and oil, cellulose had a greater effect in shortening. The decrease in fat and increase in moisture could be due to hydrogen bonds forming between water molecules and cellulose fibers. Results from water and oil retention capacities indicate that powdered cellulose is more hydrophilic than lipophilic. This could also restrict the displacement of water by fat during frying.

KEY WORDS: **Batter, cellulose, coatings, fat pick-up, fat reduction, fiber, fried foods, frying, powder.**

The United States and other developed nations are greatly concerned with the development of low-caloric food products that also have reduced fat and cholesterol levels. This concern stems from medical findings that high intake of fat and cholesterol may lead to arterial and heart diseases (1). However, an obstacle to achieving a healthier diet is the general enjoyment of fried foods. The health-conscious consumer is, therefore, torn between reducing fat intake and enjoying fried foods. In recent years, a number of companies have conducted intensive research on the development of noncaloric fat substitutes that can withstand high processing temperatures. Some of these include polyol fatty acid polyesters, esterified propoxylated glycerols, dialkyl dihexadecymalonate and trialkoxytricarballate.

However, there are alternative methods to the manufacturing of fried products with reduced fat and/or cholesterol. Instead of frying in fat substitutes, reformulation of products can result in less fat pick-up during the frying process. Such uses of ingredient technology have been reported previously in the literature (2–5). However, most of these studies were based primarily on hydrocolloids and/or modified starches.

Powdered cellulose, a natural polymer of β-1,4-glucan, has been used as a food ingredient for many years. Because it is an insoluble dietary fiber with an average total dietary fiber content of not less than 99% dry weight basis, powdered cellulose is noncaloric (6). Depending on its physical structure, this ingredient can retain approximately 3–10 times its weight in water or about 2–8 times in oil (7). Due to its preference for hydrophilic groups, the effect of powdered cellulose on fat uptake during frying was investigated.

EXPERIMENTAL PROCEDURES

Materials. Samples of powdered cellulose (Solka-Floc® 900 FCC, 1000 FCC, 40 FCC and 200 FCC) with average fiber lengths of approximately 110, 290, 65 and 35 microns, respectively, were obtained from the Fiber Sales & Development Corp. (Urbana, OH). Guar gum (Uniguar 80) was obtained from Celanese (Clifton, NJ); carboxymethylcellulose (CMC 9M31XF) from Hercules (Wilmington, DE); and xanthan gum (E415) from Jungbunzlauer (Germany). Two types of frying medium were examined: (i) nonhydrogenated soybean oil (liquid at room temperature, 57% polyunsaturated, 29% monounsaturated and 14% saturated) and (ii) partially hydrogenated soybean shortening (solid at room temperature, 25% polyunsaturated, 50% monounsaturated and 25% saturated). All other ingredients and chemicals were of food or analytical grade.

Sample preparation. Batters were prepared with the ingredients listed in Table 1. Powdered cellulose was preblended with the dry ingredients prior to mixing. Cellulose additions were based on weight of the total formulation. The batter was allowed to hydrate for 5 min prior to coating. Medium-sized mushroom, chicken breast strip and codfish fillet were used as matrices. These were coated with batter (single pass) and then fried at 180°C for 3 min. After cooling, the batter coating was removed from the matrix and analyzed.

Fat content. Batter coatings were first ground in a Waring blender. An accurately weighed sample (*ca.* 20 g) was then placed into a tared pure cellulose extraction thimble. This was extracted with 175 mL methylene chloride in a Soxhlet extraction apparatus for 4 h. Methylene chloride was evaporated using a hot plate underneath a fume hood. The tared flask containing fat extracted from the sample was dried overnight in a 105°C oven. After cooling in a desiccator, the content of the flask was weighed and fat content calculated.

Moisture content. Batter coatings were first ground in a Waring blender. An accurately weighed sample (*ca.* 20 g) was then placed into a tared crucible. This was dried for 24 h in a 105°C gravity convection oven. The crucible containing the dried sample was then cooled in a desiccator and weighed. Moisture content was expressed as a percentage of the batter coating.

Dry material content. After fat removal, cellulose thimbles containing the samples were removed from the Soxhlet extraction apparatus and dried overnight in a 105°C oven. They were then cooled in a dessiccator and weighed. The weight of this residue (after fat and mois-

TABLE 1

Batter Formulation

	Percent
Dry ingredients	
General purpose flour	28.4
Corn starch	3.6
Salt	1.0
Sugar	0.8
Baking powder	0.3
Black ground pepper	0.2
Paprika powder	0.2
Wet ingredients	
Milk	53.0
Whole eggs	12.5

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ture removal) was reported as dry material content and expressed as a percentage of the original sample.

Water and oil retention capacity. Samples of powdered cellulose were mixed with distilled, deionized water and centrifuged at 2000 × *g* for 15 min in an International Centrifuge (Model SBV) (International Equipment Corp., Needham Heights, MA) per Ang (7).

Apparent viscosity. Apparent viscosities of batters were measured with a Brookfield digital viscometer (Model DV-1) (Brookfield, Canton, MA) as outlined by Ang (7).

Statistical analysis. Analysis of variance on the data was made by the Multiple Comparison Test. Significant differences ($P < 0.05$) among sample means were determined by the Tukey's Test.

RESULTS

Fat, moisture and dry material contents. The effect of powdered cellulose on fat, moisture and dry material content is shown in Figure 1. Sections I–III represent data obtained from batters prepared with the formulation outlined in Table 1, and sections IV–VI demonstrate data obtained from commercial batter formulations (obtained from grocery stores). In addition, section II, III and VI depict data obtained from frying in nonhydrogenated soybean oil, and the data from section I, IV and V were from partially hydrogenated shortening. Various combinations of batter formulation, matrix type and frying medium were investigated. However, for the sake of brevity, only six combinations are presented. In addition, to monitor the accuracy of the fat, dry material and moisture determinations, the sum of these three percentages were also calculated. These were determined to be 100 ± 1%.

In all cases, the fat contents of batter coatings containing powdered cellulose (PC) in excess of 100 microns (PC > 100) were decreased significantly ($P < 0.05$). At the same time, their corresponding moisture contents were increased. The data indicate that 1% cellulose addition could reduce fat by about 7–42%, whereas moisture could be increased by about 2–38%. Based on the data presented in Figure 1, PC > 100 was more effective in reducing the fat contents of coatings fried in shortening. On the average, the fat content of batters fried in shortening was reduced 27%, compared to 24% for batters fried in oil. The average in moisture content of coatings fried in shortening (25%) was also higher than those processed in oil (14%).

Powdered cellulose with fiber lengths of less than 100 microns did not significantly affect the fat and moisture contents of batter coatings. Although the 65-micron cellulose fiber consistently showed marginally lower fat readings, these reductions were not statistically significant ($P < 0.05$).

Use of powdered cellulose can increase the recovery of dry material from some batter coatings. These data suggest the possibility that fiber-fat complexes may be formed during frying, as suggested by Ang and co-workers (8). At elevated processing temperatures, fat molecules may form complexes with cellulose fibers that are not extractable by methylene chloride.

Effect of viscosity on fat content. Addition of both forms of PC > 100 increased the batter viscosity significantly ($P < 0.05$), as shown in Table 2. One percent PC > 100 addition increased apparent batter viscosity about fivefold. While the 65-micron fiber enhanced apparent viscosity by approximately 58%, addition of the 35-micron fiber did not significantly affect batter viscosity. This was expected because PC > 100 has been associated with viscosity enhancements (7). Therefore, the effect of this increased viscosity on fat pick-up during frying was investigated.

Food-grade stabilizers were used to increase the viscosity of batters, simulating the thickening effect of cellulose additions. The batters were then coated, fried and analyzed in the same manner. Table 2 depicts the results of this study. Although all three stabilizers studied, *i.e.*, guar gum, xanthan gum and carboxymethylcellulose, increased batter viscosity, no significant reduction in fat content was observed (Table 2). On the contrary, samples containing 0.26% guar and 0.05% xanthan had significantly ($P < 0.05$) higher fat contents than the control. Therefore, it was concluded that the reduction of fat in batter coatings containing powdered cellulose was not due to increased batter viscosity.

Water retention properties of powdered cellulose. To understand the observed fat reduction in fried batter coatings, powdered celluloses were analyzed for differences in water and oil retention capacities. As shown in Table 3, powdered cellulose had significantly higher water than oil retention capacity. These data indicate that powdered cellulose is more hydrophilic than lipophilic. In addition, both the longer celluloses could retain about 9.5–10.0 times their weight in water compared to 4.0–5.5 times (w/w) for the shorter celluloses. This demonstrates that longer cellulose fibers are more effective in binding water molecules. Therefore, reduction in fat content could be due to increased amounts of hydrogen bonding between water molecules and the longer cellulose fibers. Another contribution to this reduced-fat phenomenon may be related to decreased surface roughness by cellulose addition, as suggested by Blumenthal (9). As a result, displacement of water by fat during the frying process is restricted.

The three stabilizers used in this study have significantly higher water retention capacities than PC > 100. However, the levels of stabilizer used in the batter formulation were only a fraction of the PC > 100. This may account for the differences in results between the two types of ingredient. Due to the smaller amount of stabilizer present, insufficient hydrogen bonding may be formed to effectively reduce fat pick-up during frying.

Organoleptic evaluation. Organoleptic examinations indicated that there were some visual differences in the appearance of fried coatings with and without cellulose (all fiber lengths). The color of fried foods containing cellulose was lighter. In addition, these samples had a more uniform golden yellow color when compared to the controls. This was probably due to the color dilution effect caused by cellulose addition. Unlike other carbohydrates, cellulose (which is a complex carbohydrate) will not normally undergo nonenzymic browning (10).

DISCUSSION

In keeping with the current health trend in the United States and in other Western nations toward lower fat and increased fiber intakes in the diet (11), the findings of this study have some beneficial implications when applied along with other dietary strategies. Although this low-level usage of powdered cellulose in fried foods will only

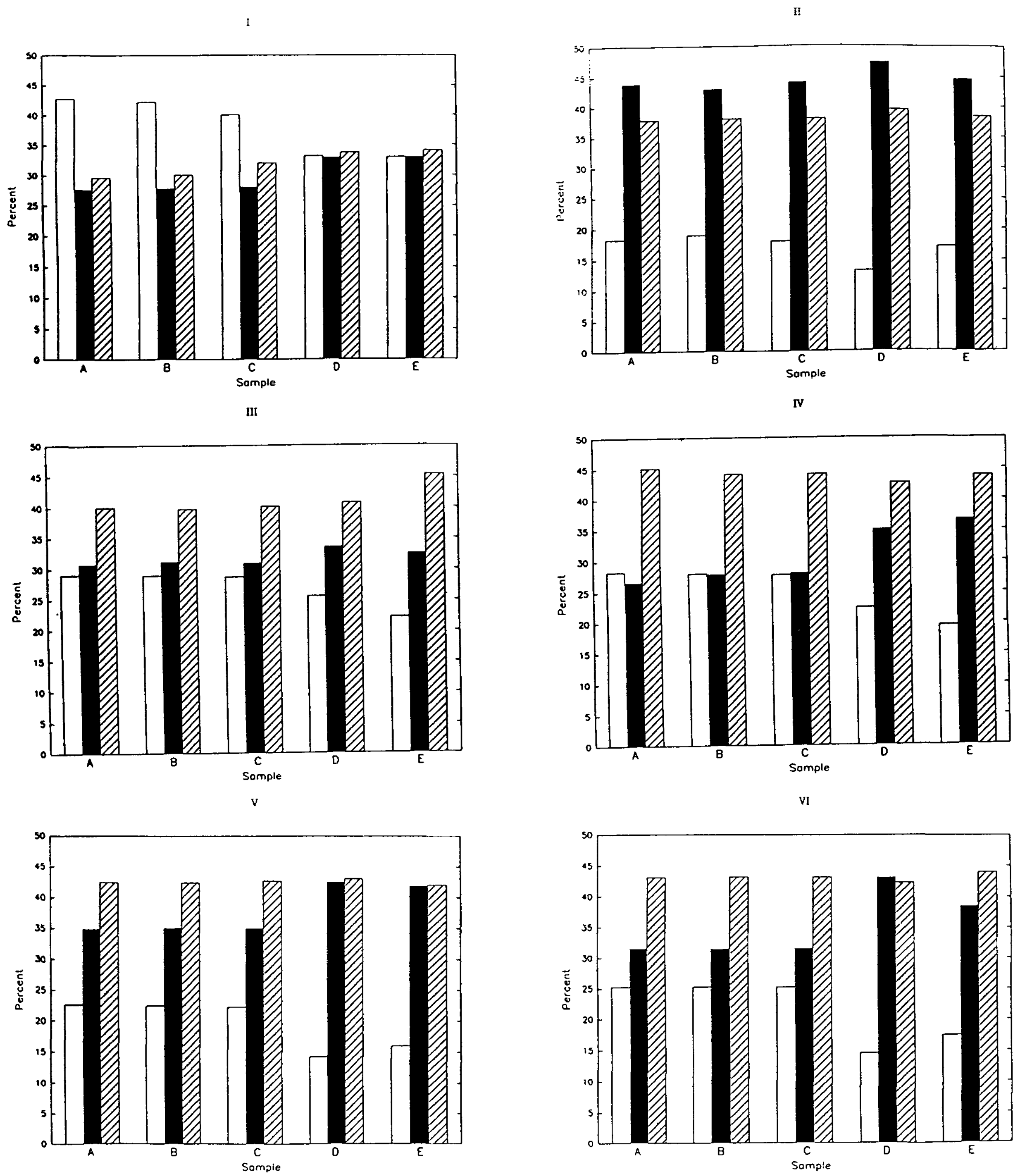

FIG. 1. The effect of powdered cellulose on fat, moisture and dry material contents of batter coatings fried in shortening. Section I, batter per Table 1, mushroom matrix, fried in shortening; II, batter per Table 1, chicken matrix, fried in oil; III, batter per Table 1, fish matrix, fried in oil; IV, commercial batter, mushroom matrix, fried in shorteing; V, commercial batter, fish matrix, fried in shortening; and VI, commercial batter, chicken matrix, fried in oil. A, Control; B, 1% powdered cellulose (PC) 35-micron; C, 1% PC 65-micron; D, 1% PC 110-micron; E, 1% PC 290-micron. White bars, % fat; black bars, % moisture; hatched bars, % dry material.

TABLE 2

The Effect of Viscosity on Fat Reduction in Fried Batter Coatings

Batter coating sample[a]	Percent reduction in fat content	Viscosity (cps)
Control	0.0[c]	1275[c]
1% PC[b], 110-micron	33.2[d]	7580[f,g]
1% PC, 290-micron	33.0[d]	6160[f]
1% PC, 65-micron	6.5[c]	2020[d]
1% PC, 35-micron	1.4[c]	1550[c]
0.17% Guar gum	2.9[c]	5440[e]
0.26% Guar gum	−6.0[e]	8130[g]
0.05% Xanthan gum	−10.0[e]	7510[f,g]
0.25% Carboxymethylcellulose	5.1[c]	4400[e]

[a]Batter formulation per Table 1, coated on mushroom and fried in solid shortening.
[b]Powdered cellulose.
[c–g]Means with different superscripts in the same column differ significantly ($P < 0.05$).

TABLE 3

The Water and Oil Retention Properties of Powdered Cellulose (PC)[a]

Cellulose sample	Water retention (g water/100 g sample)	Oil retention[b] (g oil/100 g sample)
PC, 110-micron	950	850
PC, 290-micron	1000	800
PC, 65-micron	550	350
PC, 35-micron	400	250

[a]All measurements were at room temperature and pH was between 5.0 and 7.5.
[b]Nonhydrogenated corn oil.

increase the total dietary fiber content marginally, fat content can be reduced significantly.

Moreover, the nonenzymic browning properties of powdered cellulose could also be advantageous in foods which brown too fast or too easily. By incorporating low levels of this ingredient, the color of fried foods can be controlled to a certain degree. Hence, cooking time can be increased without the usual problems of excessive browning.

The use of powdered cellulose in reducing fat pick-up in fried batter coatings should not be regarded as a general panacea to healthier diets. However, the inclusion of this ingredient in fried food formulations could be a step in the right direction. More importantly, it would allow consumers continued enjoyment of fried foods with a healthier profile than similar products prepared with conventional compositions.

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