Extraction and Application of Dietary Fiber and Cellulose from Pineapple Cores

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Pineapple core dietary fiber (PDF) was obtained by alcoholic extraction; pineapple core cellulose (PC) was a product of alkali extraction with a bleaching process. Total dietary fiber content of PDF and PC was 99.8% and 95.2% (dry basis), respectively, and their water activity was 0.25. PC contained 91.2% cellulose with a pH value of 4.0, while that of PDF was 6.2. The fiber product with large particle size gave higher values than the product with smaller particles for pH, water and oil retention capacity, settling volume and emulsifying activity. Both had rough, pitted surfaces and ~~presented~~ showed good functions in cake-type doughnuts, golden layer cake and beef burgers.

Keywords: dietary fiber, cellulose, pineapple core, extraction, functional properties

Introduction

DIETARY FIBER IS A GROUP OF FOOD COMPONENTS WHICH IS resistant to hydrolysis by human digestive enzymes and necessary for promoting good health. It is classified into 2 groups by means of its solubility in water as soluble and insoluble dietary fiber. Cellulose is a kind of insoluble dietary fiber, consisting of units of glucose with b -1,4 linkage. It is one of the most common functional ingredient in food products and has been used as fat replacer, fat reducing agent during frying, volume enhancer, binder, bulking agent and stabilizer. (Ang and Miller 1991). It is frequently used in bakery products, deep-fat fried foods and meat patties. The source of fiber is also important because various arrays of plant cells can affect fiber properties. Pineapple cores, a high-fiber part of pineapple fruit, could be considered as a potential fiber source (Stuab and others 1983; Saksiri 1992; Thumthanarak 1996). The disadvantages are high sugar content and low pH (Teerapapthamkul 1991) which may cause adverse effects in food applications. Thus, extraction and purification of pineapple cores are needed to obtain better quality dietary fiber and cellulose. The objectives of this study were to extract dietary fiber and cellulose from pineapple cores, to study their physical and chemical properties and to test their application in foods.

Materials and Methods

Materials

Pineapple cores (*Ananas comosus L. Merr.*) were supplied by a local pineapple-canning factory (Malee Sampran Co. Ltd., Nakornpathom, Thailand). All chemicals used in the extraction process, including 95% ethanol, sodium hydroxide, hydrogen peroxide and phosphoric acid, were reagent grade.

Fiber extraction

Fresh pineapple cores were washed, sliced to less than 0.6-cm-thick with a cutter (AEG type KM21 fineness plus, AEG Hausgerate AG, Nurnberg, Germany), blended, washed several times with warm water (about 40 °C) and pressed with a hydraulic press to remove excess water.

Pineapple core dietary fiber (PDF) was obtained by alcoholic extraction using a modified method described by Thumthanarak (1996). The prepared material was boiled for 3 h (water decanted every hour and replaced with fresh water). The pulp was pressed and then extracted with 95% ethanol (1:5 w/v). The mixture was occasionally agitated overnight and then filtered through a nylon bag using a hydraulic press. The extraction was repeated twice and the remaining dry fraction was collected and air-dried for 6 h on stainless steel trays lined with plastic sheets.

Pineapple core cellulose (PC) was extracted using alkali extraction (Vail 1991). The slurry of prepared material in water was formed at the ratio of 1:25 (w/w) and adjusted to pH 12 by adding 25% sodium hydroxide. The slurry was agitated, left at room temperature overnight and heated up to between 87 to 98 °C in a double boiler kettle. This temperature was maintained for 2 h and 45 min. Then the slurry was filtered through a cheese-cloth and re-dispersed in water at the ratio of 1:2.32 (w/v). The pH of the slurry was adjusted to be in a range of 6.5 to 7.5 by adding 85% phosphoric acid. Then 35% hydrogen peroxide was added into the neutralized suspension at the ratio of 0.0115:1 (parts by weight of aqueous hydrogen peroxide: parts by weight of total suspension) for bleaching. The resulting admixture was heated at 87 to 98 °C for 3 h and filtered through cheese-cloth. The residue was dried at 70 °C in a hot-air oven overnight.

The yield of extraction was calculated as:

$$Y = (\text{weight of fiber after extraction} / \text{weight of fresh pineapple cores}) \times 100$$

Chemical properties

Total dietary fiber content of PDF and PC was determined based on AOAC method 985.29 (AOAC 1990) which is an enzymatic-gravimetric method. Cellulose content of PC was determined following the FCC assay method (CODEX 1981) and corrected with percent loss on drying. The pH of 2 g sample in 18 mL preboiled deionized water was measured after standing at room temperature for 60 min.

Physical properties

Particle size and size distribution

Fifty grams of sample was shaken on a Retsch test sieve (Vibro GmbH & Co., Retsch, Haan, West-Germany) sizes 35, 60, 80, 100, 120 and 140 mesh stacked in order of decreasing opening size. The weight of particles retained on each sieve was deter-

mined and calculated as percentage of total weight. Triplicate analyses of PDF and PC samples were carried out.

The logarithmic values of the mean particle size were plotted against the probability of cumulative weight percent retained. The geometric mean diameter by weight (d_g), which is the particle size at the 50% probability level, was estimated from the plot.

Bulk density

Fifty mL of a preweighed graduate cylinder was filled with sample and shaken slightly. The volume of the sample was recorded, the content of the cylinder was weighed and the bulk density was expressed as weight per volume.

Packed density

A calibrated 10-mL graduated syringe was filled with a known weight of sample. Pressure was applied manually until additional pressure would not further reduce the volume. The packed density was calculated as weight of sample per least volume of sample.

Hydrated density

A calibrated 10-mL graduate cylinder was filled with a known amount of distilled deionized water, and a known weight of sample was added carefully to avoid adhesion to cylinder walls. The difference between the volume of the water before and after adding sample was recorded as mL of water displaced. Results were expressed as grams of sample per mL of water displaced.

Water and oil retention capacity

The water retention capacity of the dietary fiber and cellulose was determined following the method described by Ang (1991). By using a glass rod, 2 g of sample was mixed with 30 mL of distilled water in a 50-mL centrifuge tube. The slurry was allowed to stand for 10 min, then centrifuged at 2,000 x *g* for 15 min. After centrifugation, the supernatant was drained and the wet sample precipitate was weighed. The result was expressed as gram of water per gram of sample. For oil retention capacity, the procedure was similar to the one described for water retention capacity except palm oil was used instead of water.

Emulsifying activity

Emulsifying activity (EA) of PDF and PC was determined following the simple system of emulsifying activity measurement (Katsuharu and others 1972). Seven grams of sample was suspended in 100 mL water and then 100 mL soybean oil was added. The mixture was emulsified using a homomixer (JKA Ultra Turax-T25) with designation of dispersing tool (S25N 25F) at 1,000 rpm for 1 min. The emulsion obtained was divided evenly into four 50-mL centrifuge tubes and centrifuged at 1,300 x *g* for 5 min. The emulsifying activity was calculated using the following equation:

$$EA = [\text{height of emulsified layer (cm)} / \text{height of whole layer (cm)}] \times 100$$

The amount of sample was reduced to 1.75 g when there was no excess water and oil retained before centrifugation.

Settling volume

Settling volume (SV) of dietary fiber and cellulose samples was measured by a modified procedure described by Kiriyama and Luangpituksa (Kiriyama 1979; Luangpituksa 1992). This experiment was performed by mixing 1 g of sample with 70 mL distilled water in a 100-mL screw-cap bottle. These bottles were subjected to ultrasonic treatment for 30 min in order to allow water to saturate the samples and also to remove some of the excess gas in the mixture. The mixtures were then degassed by vacuum suction for 30 min and placed in a cold storage room for 24 h to facilitate the penetration of water into the interstices of samples. The individual mixture in the bottle was quantitatively transferred to a 100-mL volumetric cylinder. The content of each cylinder was adjusted to 100 mL by adding distilled water. Settling volume is the volume, in mL, formed by the sample residue layer, read by naked eyes after 24 h at room temperature.

Scanning electron microscopy

Each of the dry powdered samples of dietary fiber and cellulose was sprinkled onto a carbon-conductive adhesive tape that was attached to the stub. Then it was coated with gold by the SPI-sputter coater. The photos of the prepared samples were taken by using a JEOL scanning electron microscope (model JSM-5410LV), at an accelerating voltage of 15 or 20 kv, and an attached JEOL 35031 camera.

Water activity

The water activity was determined using a Novasina (Zurich, Switzerland) water activity analyzer (model MB-MIK 3000) at 25 °C.

Viscosity

The apparent viscosity of PDF and PC suspensions (2 to 4% w/v) was measured after standing for 15 min at room temperature with a Brookfield digital viscometer, model RVT DV-II, with an attached UL-adapter, at speed 100.

Color

The color of the PDF and PC powder was determined in the Munsell system (using Munsell book) under daylight.

Incorporation of PDF and PC into food products

Cake-type doughnut. PDF and PC with large particle size (100 to 170 mesh) were incorporated into cake-type doughnuts. The control formula was: 47.3% all-purpose flour, 18% granulated sugar, 2% shortening, 2% nonfat dry milk, 0.65% baking powder, 0.6% salt, 0.45% baking soda, 10% whole egg and 14% water. In the experimental products, all-purpose flour was partially replaced with PDF or PC (3% by weight of total ingredients). All dry ingredients were mixed in a KitchenAid mixer (model KSM5). Eggs and water were then added and the mixture was beaten about 1 min at speed 2. The dough was rolled out on a floured surface to about 1.25 cm thickness, cut and fried for 1 min on each side in a kettle containing soybean oil preheated to 190 °C, then allowed to cool on a paper towel. Each formula was prepared in duplicate (12 pieces) and pooled together for the analysis.

The moisture (drying method at 100°C) and fat contents (acid hydrolysis prior to solvent extraction by Soxhlet apparatus) of cake-type doughnuts before and after frying were determined and the oil uptake ratio (U_R) was calculated to evaluate the effectiveness of fibers in reducing oil absorption during frying. The firmness of doughnuts was measured as the maximum force of resistance to compression by a Chatillon texturometer (model DFIS 50, Greensboro, North Carolina, USA), using a compression head. The color of half-sliced doughnuts was evaluated under daylight using Munsell color book.

Golden layer cake. PDF and PC with large particle size were

Table 1—Chemical and physical properties of fibers from pineapple cores

	PDF			PC		
Properties	pooled	100 to 170 mesh	>170 mesh	pooled	100 to 170 mesh	>170 mesh
%TDF (dry basis)	99.7	—	—	95.6	—	—
%Cellulose (dry basis)	—	—	—	91.2	—	—
PH	—	6.35	6.14	—	4.11	3.97
Bulk density (g/mL)[1]	—	**0.171 ± 0.003**	**0.148 ± 0.003**	—	**0.313 ± 0.005**	**0.254 ± 0.005**
Packed density (g/mL)[1]	—	0.385 ± 0.013	0.337 ± 0.006	—	0.481 ± 0.005	0.514 ± 0.187
Hydrated density (g/mL)[1]	—	1.47 ± 0.36	0.84 ± 0.03	—	1.37 ± 0.32	1.12 ± 0.10
Water retention capacity[1] (g of water retained/g fiber)	—	12.16 ± 1.04	10.31 ± 0.07	—	9.92 ± 0.1	6.00 ± 0.12
Oil retention capacity[1] (g of oil retained/g of fiber)	—	3.91 ± 0.01	3.77 ± 0.02	—	2.15 ± 0.09	2.44 ± 0.10
Emulsifying activity (2)[2]	11.33 ± 1.36(1)[2]	23.02 ± 1.82(2)[2]	11.63 ± 1.01(2)[2]	—	4.27 ± 4.07	
Settling volume (mL/g) [3]	—	37.75	33.25	—	14.00	16.25
Color[4]	—	5Y8.5/4	5Y8.5/2	—	5Y9/2	5Y9/1

Results are mean ± SD of triplicate analyses
[2](1) = result from 7 g sample
(2) = result from 1.75 g sample
[3]Results are mean of duplicate analyses
[4]Color code; 5Y represents yellow color (hue)
8.5 and 9 indicates value (10 = absolutely white, 0 = absolutely black)
4, 2 and 1 indicates chroma (16 = totally dark neutral, 0 = neutral gray)

Table 2—Particle size distribution of fibers[1]

	% Retained on sieve	
Sieve size (mesh)	PDF	PC
35	1.1 ± 0.4	2.1 ± 0.4
60	19.1 ± 2.4	6.7 ± 0.6
80	28.4 ± 6.6	22.1 ± 2.2
100	9.3 ± 0.5	14.8 ± 0.4
120	6.0 ± 0.7	12.2 ± 1.7
140	3.4 ± 0.4	10.6 ± 5.8
>140	33.0 ± 1.1	31.9 ± 11.2

[1]Results are means ± SD of triplicate analyses

incorporated to golden layer cake. The control formula was prepared by measuring and mixing 24.06% cake flour, 24.06% sugar, 1.35% baking powder, 0.2% salt, 11.28% shortening, 27.09% milk, 0.68% vanilla flavor and 11.28% eggs together for 0.5 min at low speed in a mixing bowl (KitchenAid model K45ss). The speed was increased to high and mixing continued for 3 min. The batter was poured into a pan and baked about 45 to 50 min. In experimental formulas, the cake flour was partly replaced with 4% of PDF or PC based on total weight of dry ingredients.

The cake volume was determined by the displacement method (Penfield and Campbell 1990) using sesame seeds. A texturometer (Chatillon model DFIS-2) with attached compression head was used to measure firmness. The color of sliced cake was also recorded in Munsell system.

Beef burger. PDF and PC with small particle size (>170 mesh) were added into lean minced beef at 2% w/w using a KitchenAid Mixer model K45ss equipped with a cake paddle. Only minced beef was mixed for 1 min, then the fiber was added and mixing continued for 1.5 min. Burgers weighing about 40 g each (1 cm thickness, 6.5 cm diameter) were formed and cooked on a greased Teflon-coated pan until inside temperature reached 60 °C (6 min). The nonfiber-added formula was used as control.

Texture and size of each burger was measured in triplicate. The yield after burger cooking was calculated as follows:

$$Y = [\text{weight after cooking (g)} / \text{weight before cooking (g)}] \times 100$$

Statistical analysis

The SPSS program version 8.0 was used for analysis of the difference between experimental formula and control formula, using Mann-Whitney U Test with significance defined at $p < 0.05$.

Results and Discussion

Yield of extraction

PDF was derived from 3 alcoholic extractions, while PC was pooled from 4 cellulose extraction. Average yield of PDF was 1.81% and that of PC 1.58% (w/w of fresh pineapple cores). The conditions of cellulose extraction were modified from the legume hull-extraction process that produced purified short fiber cellulose (Vail 1991). The conditions used might not be the most suitable for pineapple core. Nevertheless, the extraction process showed acceptable yield and purity results.

Chemical properties

The pooled samples of PDF and PC were analyzed for their %TDF. Both of them were high in purity and PDF contained more dietary fiber than PC (Table 1). The cellulose content of the PC was 91.2% after correcting for 5.4% loss on drying.

The suspension of each pooled fiber sample in preboiled deionized water was tested for its pH (Table1). Acid pH was found in PC, while that of PDF was close to neutral. The pH value of PC was lower than the requirement of powdered cellulose according to Food Chemical Codex (CODEX 1981). This might be the result of excess phosphoric acid addition during pH adjustment in the extraction process. Large-size particles (100 to 170 mesh) of both fibers gave slightly higher pH values than the smaller particles (>170 mesh).

Physical properties

The pooled samples of PDF and PC were sieved through Retsch test sieves stacked in order of decreasing opening size (35, 60, 80, 100, 120 and 140 mesh). The largest amount of both fibers was retained on the 80 mesh screen (Table 2). The process of grinding was the major factor affecting particle size of fibers.

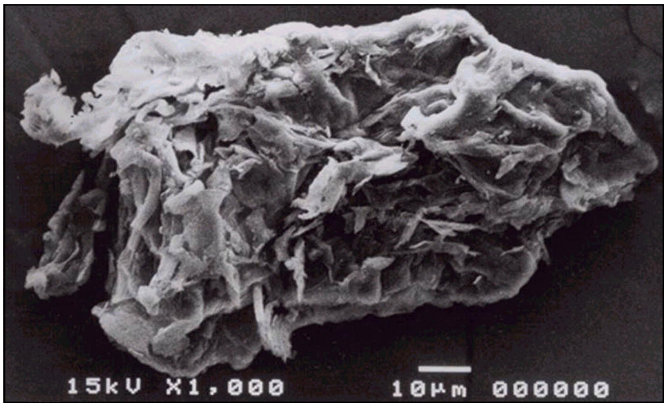

Figure 1—Scanning electron micrograph of PC, size smaller than 170 mesh; Bar = 10 microns

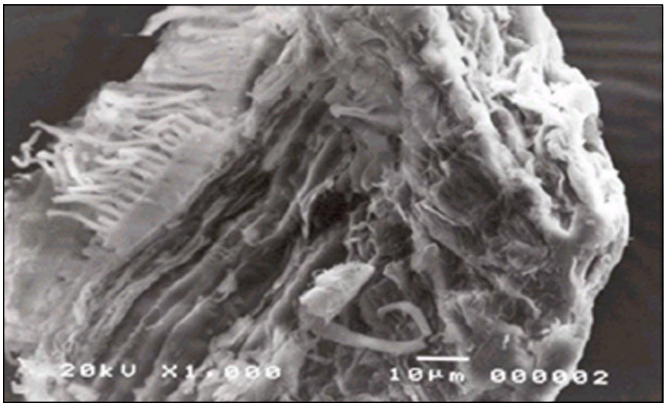

Figure 2—Scanning electron micrograph of PC, size 100 to 170 mesh; Bar = 10 microns

The average geometric mean diameter of PDF and PC from 3 determinations was 171.3 and 151.7 microns, respectively (Table 2). Hence, PC was smaller in particle size and showed narrower size distribution than PDF.

Bulk, packed and hydrated densities of various sizes of PDF and PC are shown in Table 1. Normally, the bulk density of the fibers depends on their shape and size. All large-size particles showed higher density than the small-size ones except the packed density of PC, where the small-size particles gave a higher value than the large-size particles.

Water and oil retention capacity of PDF and PC was determined and their results are shown in Table 1 as g of water or oil retained per g of dry sample. Overall, it was found that PDF could retain more water and oil than PC. PDF sized 100 to 170 mesh could hold the highest amount of water and oil. The characteristics of fibers in imbibing and swelling in water are important not only in food application, but also in human gastrointestinal function. Results of oil retention capacity analysis indicated the same pattern. All fibers are hydrophilic, so they could retain a larger amount of water than oil. As particle size of fiber was reduced from mechanical milling, the water retention capacity was also reduced (Altomare and others 1984; Chen and others 1984; Ang 1991). The difference in microstructure of cellulose fibers, obtained from different methods of extraction, could affect their water retention capacity (Stephen 1995). From the scanning electron micrographs (Figure 1 to 4), the PDF particles appeared more porous than the PC, thus causing the difference in their water imbibing properties. Moreover, the presence of other hydrogen bonding ingredients, such as acids and sodium chloride, tends to interfere with bond sites available between fibers and water (Todd and others 1989). Hence, the ability in water binding of fiber could be altered when used in different foods.

The means and SD of emulsifying activities of fiber are given in Table 1. Only small-size particles of PC formed an emulsion layer when 7 g of sample was suspended. Other samples, large-size PC particles and both sizes of PDF, were not able to achieve that emulsion layer height because of their greater water and oil absorption, so the amounts of fiber samples were reduced to 1.75 g. The results indicated that both particle sizes of PDF and large-size PC could exhibit emulsifying properties while being used at lower concentrations than the small-size PC. The emulsifying property of fibers from pineapple might be the results of their ability to stabilize an emulsion, like in most cases of polysaccharides, rather than acting as an emulsifier (Sanderson 1981).

Large-size PDF particles gave the highest SV value, 37.75 mL/g, similar to the value reported by Thumthanaruk (1996), whereas large-size PC particles gave the lowest value, about 14 mL/g.

From the scanning electron micrograph, both kinds of fiber from pineapple cores have scale, rough and pitted surface. They were various in sizes with irregular shapes of plant cells binding together as shown in Figure 1 to 4.

The water activity values (a_w) of PDF and PC were 0.24 and

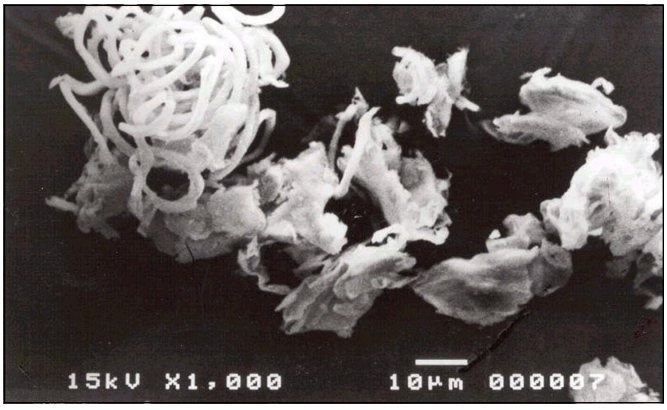

Figure 3—Scanning electron micrograph of PDF, size smaller than 170 mesh; Bar = 10 microns

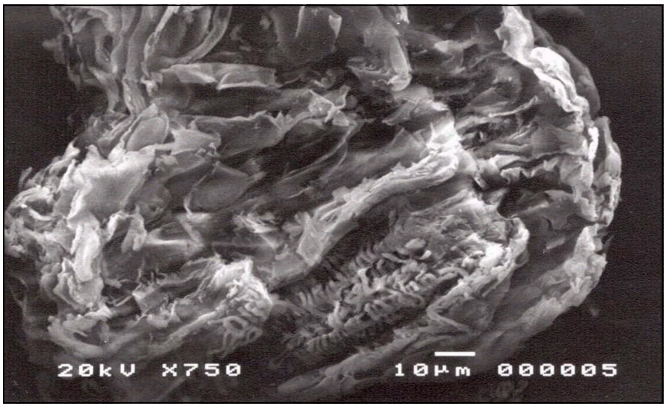

Figure 4—Scanning electron micrograph of PDF, size 100 to 170 mesh; Bar = 10 microns

Table 3 Viscosity of fiber suspensions

Type	Concentration (%)	Viscosity (cps)
PDF size 100 to 170 mesh	2	14.5
PDF size > 170 mesh	2	-*
PC size 100 to 170 mesh	4	17.5
PC size > 170 mesh	4	-*

* Results are lower than the measurable range of the viscometer (6.4 – 2,000 cps).

0.28, respectively. Similar values were obtained because all samples were kept under the same condition (packed in polyethylene bags and stored at room temperature for 20 days). The water activity of all extracted fibers was lower than the minimum level at which microorganisms can grow (about 0.61) (Beauchat 1981). The amount of moisture in fibers varied with the relative humidity of the surrounding atmosphere and temperature (Marsh and Wood 1938).

PDF and PC were dispersed and became swollen rapidly in water without gel formation. High concentration of PDF and PC formed turbid pastes and low concentration gave turbid suspensions. Upon standing without agitation, the fiber settled out of suspensions. Suitable concentrations of fiber were chosen for viscosity determination. Each suspension was poured into the viscometer tube and viscosity was measured. The viscosity of fiber suspensions is given in Table 3. Large-size particles of all fibers could obviously increase the viscosity of suspensions, while the small-size particles produced very-low-viscosity suspensions. These low viscosity values were beyond the measurable range of the instrument (6.4 to 2,000 cps). The results of PDF and PC viscosity were similar to those reported by Ang and Miller (1991) and Ang (1991) for powdered cellulose. The viscosity of a suspension depends on molecular shape, size and charges (Branen and others 1990). Generally, long linear molecules have greater resistance to shear than short or branched molecules. It was found that cellulose fiber smaller than 110 microns, did not appear to have thickening properties. Stabilizers may be applied to maintain the viscosity of suspensions. Even though the results for small particles may not be reliable, in general, it could be concluded that the large-size fibers gave higher viscosity value than the small fiber within the same type.

The colors of PDF and PC powders under daylight are presented in Table 1. The colors of PDF and PC were all light yellow and PDF was darker in color than PC. Size of fiber particles also affected color. Small-size particle had lighter color than the large-size fiber. Pigment and color precursors of fruits were found in cellular plastid (Potter 1986). When the tissue was damaged in the preparation and extraction process, most of the pigments were eliminated and fiber particles were much lighter after drying. In cellulose extraction, the fibers were bleached with hydrogen peroxide and much lighter cellulose was obtained. The light color of fibers may not be necessary with applications in selected food items; for example, the normal color of cake-type doughnuts and golden layer cake is yellow and beef burger is dark brown. If a light color of PC is needed, higher concentrations of hydrogen peroxide with proper bleaching conditions should be considered.

Incorporation of fiber to foods

Cake type doughnuts

Addition of 3% (w/w) large-size PDF or PC to cake-type doughnuts did not significantly decrease fat absorption during deep-fat frying ($p > 0.05$). However, the fat content in all fiber-added products appeared lower and the moisture content was higher than the control. The results are shown in Table 4. The energy values from fat of PC and PDF formulas were reduced by 49.5 and 87.3 kcal/100 g, respectively. These results of oil reduction were similar to the previous observations of others (Ang and Miller 1990; Ang and Miller 1991; Ang 1993; Kamel and others 1993; Pinthus and others 1993; Nunthiwattanawong 1994). Moreover, they also all reported that incorporation of low levels of fiber ingredient could help control the color of fried products. Addition of PDF produced light color and demonstrated the best action in oil reduction during deep-fat frying (40% less fat than control) and yielded the highest-volume doughnuts; however, hard-texture doughnuts were obtained. PC presented all functions like in the PDF formula, but gave softer texture similar to the control formula. Hence, in this study PC appeared to be more suitable for cake-type doughnuts. Cake-type doughnuts before and after frying weighed about the same. The water loss was counterbalanced by fat absorption (Kamel 1993). The initial composition of food has great effects on fat-uptake during frying (Makinson and others 1987), while many other factors including oil quality, temperature, frying time and shape are also important (Mohamed and Others 1998). These factors were kept constant during our study. The mechanism of oil reduction could be explained by the water absorption of fiber. In the doughnut preparation step, wetted fiber particles and high-viscosity dough were produced. This characteristic brought about the reduction in oil uptake during deep-fat frying since free water in the dough was absorbed inside the fiber particles which made it difficult to evaporate during frying. Consequently, less oil was absorbed. These 2 phenomena resulted in a caloric decrease in the finished products.

Golden layer cake

Addition of a few percent of fiber could increase the volume of layer cakes (Jackson and Roufs 1989; Ang and Miller 1991; Kamel and others 1993). Inclusion of 4% cellulose based on total dry ingredient weight gave the highest cake volume. This concentration of large-size fibers was chosen for this study and this purpose. All fiber-added cakes yielded greater volume than the control. The physical properties of cakes are given in Table 5. PC-

Table 4—Cake-type doughnut[1, 2]

	Fat content (g%)		Moisture content (g%)			
Formula	Before	After	Before	After	U_R	Texture (Newton)
Control	3.4	23.8	30.8	19.3	1.77	8.86 ± 1.74
PDF	3.4	14.1	31.5	23.5	1.26(–28.8)	18.63 ± 3.13[a]
PC	3.2	18.3	30.8	21.4	1.59(–10.2)	9.63 ± 3.17

[1]The number in parentheses indicates percent different from control.
[2]Means with superscripts are significantly different from the control formula ($p \leq 0.05$), using Mann–Whitney U test.

Table 5—Golden layer cake[1,2]

Formula	Volume (mL)	Texture (Newton)	Color[3]
Control	490.2	2.31	5Y 9/4
PDF	535.4[a]	1.95	5Y 8/6
PC	599.6[a]	1.39[a]	2.5Y 8.5/6

Mean ± SD, n = 3
Means with superscripts are significantly different from the control formula ($p \leq 0.05$), using Mann–Whitney U test.
Color: 2.5Y and 5Y represents color between yellow (hue)
8 and 9 indicates value (10 = absolutely white, 0 = absolutely black)
4 and 3 indicates chroma (16 = totally dark neutral, 0 = neutral gray)

Table 6—Beef burgers[1,2]

		% Change from control	
Formula	Yield (%)	Thickness	Diameter
Control	68.8	—	—
PDF	76.1 (+10.6)[a]	–1.95	–19.43
PC	71.0 (+33)[a]	+1.31	–7.12

Results are means of triplicate analyses
Means with superscripts are significantly different from the control formula ($p \leq 0.05$), using Mann – Whitney U test.

added cake significantly increased in volume. Both cakes with fiber exhibited a slight color change from the control. Generally, in cakes a high percentage of the total volume is related to the open space in terms of finely divided gas cells. These spaces are created by carbon dioxide (from the leavening system) and steam which is formed during baking. When these gases are distributed widely, each of the bubbles is small and does not rise rapidly to the surface of the cake. The leavening gases are retained in the cake and contributed to the final volume. If the original batter contains many small air cells, the final volume tends to be greater with a fine (close) grain. It was observed that all fiber-added cake batters were increased in viscosity. Therefore, they could retain more air cells than the control. The particles of fibers may help in the distribution of air cells during the preparation steps. Since fibers have high water retention capacity, the cake batter was thickened and had greater ability to hold air cells inside. Moreover, the shelf life of finished cakes is prolonged because moisture is retained in the products due to the hydrophilic property of fiber.

Beef burgers

Two percent of small-size fibers were added into beef burgers to increase the net weight after cooking and improve their texture. The yields of beef burgers and their shrinkage are given in Table 6. Addition of all fibers could significantly improve the technological yield after cooking with PDF yielding a higher value than the PC. The results of burger yields after cooking supported the previous finding on the advantage of addition of powdered cellulose (Solka-FlocBW300FCC) in restructured pork, which decreased the cooking loss, because of its water binding capacity (Todd and others 1989). In general, all patties showed a 40 to 50% increase in height after cooking. The changes in the diameter and thickness of fiber-added burgers followed the same pattern. Only PDF gave a significantly larger diameter than the control with the least shrinkage after cooking. Hardness of burgers was influenced by both type and concentration of fibers. When the same amount of fiber was used, PC tended to make the products harder than PDF. Hence, PDF was found to be more suitable to improve the yield and texture of beef burgers.

Conclusion

PINEAPPLE CORES SHOWED A POTENTIAL TO BE A GOOD SOURCE OF dietary fiber and cellulose, which can be used as functional ingredient for bakery and meat products depending on its type and particle size. Large-size PC (100 to 170 mesh) was found to be more suitable for oil reduction of cake doughnuts and increasing cake volume, while small-size PDF (>170 mesh) was more suitable for reducing shrinkage and improving texture of beef burgers. The water interaction of fibers, especially water retention capacity, appeared to have a marked influence on their functional properties.

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MS 20010117 Submitted 3/8/01, Revised 5/14/01, Accepted 5/14/01, Received 5/21/01

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