Effect of Soy Flour on Fat Absorption by Cake Donuts[1]

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ABSTRACT

Soy flour is added to cake donut formulas to reduce fat absorption during frying. This study demonstrates that PDI (Protein Dispersibility Index) is not a good indicator of soy functionality for this application. At all PDI levels above 50, the quantity of soy protein added is the best predictor of fat absorption control. Only at a PDI level of 30 does the insoluble portion of soy protein lose functionality in reducing fat absorption.

Soy flour is utilized in cake donuts for its functional properties rather than for its nutritional quality. In cake donuts, soy flour functions to decrease fat absorption (Eley 1968, Wolf 1970). The mechanism by which this occurs is unclear. In the past, protein solubility was reported as the major factor affecting functionality of soy protein (Johnson 1970, Sipos et al 1974, Dubois 1980). Unpublished work by the authors of this paper, however, indicated that protein solubility could account for differences in fat absorption by cake donuts made with different lots of soy flour. This study was undertaken to gain a better understanding of how properties of soy flour affect its ability to decrease fat absorption by cake donuts.

MATERIALS AND METHODS

A single 136 kg batch of blended dry ingredients was prepared according to the formula in Table I. Flours were standard commercial types donated by The Pillsbury Company. Donut Pyro and B.P. 28 are brands of sodium acid pyrophosphate produced by Stauffer Chemical Co., Westport, CT, and Monsanto Co., St. Louis, MO, respectively. Other ingredients were standard commercial materials.

Donuts were fried in Richtex shortening from Humko Products, Memphis, TN.

Defatted soy flours were supplied by Archer Daniel Midland Co., Decatur, IL, and Farmland Soy Processing Co., St. Joseph, MO. Protein dispersibility index (PDI) values were determined for each soy flour by AOCS method Ba 10-65 (AOCS 1982). These and other analytical data for the soy flours are shown in Table II.

All ingredients for the base formula were blended for 30 min in a Wenger ribbon mixer. The sides and blade of the mixer were scraped down at 10-min intervals. The base mix was packed in plastic-lined paper sacks and stored at −22° C. Twenty-four hours before use, the base mix was removed from frozen storage and brought to room temperature.

Batter Viscosity and Weight

The Belshaw type K donut cutter is a volumetric device. Production of similar batter weights between treatments requires constant viscosity. Apparent viscosity was measured with a Brookfield viscometer model RVT, with helipath stand. The no. 7 spindle was used, spindle speed was set at 2.5 rpm, and the batter temperature was 23 ± 1° C.

Batter was placed in a 600-ml beaker and leveled across the top. Using the helipath stand, the spindle was lowered into the batter to the depth indicated on the spindle. After 4 min, the viscometer was turned on. The scale reading that represented the highest resistance was recorded. Because shear thinning occurs, only the first three scale readings as the pointer came into view were recorded. This procedure was repeated after 9 and 14 min floor time. An average of the nine scale readings for each batter was calculated. Apparent viscosity in centipoise was calculated by multiplying the average scale reading by a factor of 1.6×10^3 provided by the manufacturer.

Reproducibility of this procedure was measured over four identical batches. The coefficient of variation was 4.5% for 5 min, 4.0% for 10 min, and 2.7% for 15 min. Water absorption levels for all samples were adjusted to maintain an apparent viscosity of 7.1 ($\pm$ 0.5) $\times 10^3$ cP.

Batter Preparation

A model 50N Hobart mixer equipped with a cake paddle was used to prepare all batters. The donut mix and soy flour were dry blended for 10 min on first speed. The bowl was scraped once after 5 min of mixing. Water was added and incorporated for ½ min on first speed. Water temperature was adjusted to achieve a final batter temperature of 23 ± 1° C. The bowl was scraped down and returned to the mixer for an additional 2 min on second speed. Mixed batter was placed in the donut cutter. Ten minutes floor time was allowed before frying.

Frying

Donuts were fried in a Belshaw model 61 mini fryer. Six donuts were deposited into the frying fat (191° C) at 2-sec intervals. After 50 sec, the donuts were individually turned in the same sequence as deposited, and fried 50 sec on the second side. After frying, donuts were drained on a metal rack for 45 min with the first side fried facing up. During frying, the fat temperature dropped to 186° C. After the temperature of the frying fat returned to 191° C, another six donuts from the same batch were fried.

Sample Preparation

Six donuts were selected randomly from each batch of 12 by use of a random digit table (Snedecor and Cochran 1980). The six donuts, considered a sample, were weighed. Samples were prepared for analysis by hand crumbling and lyophilizing. Lyophilized samples were ground in a coffee mill (Moulinex, Varco Inc.). To prevent sample heating and loss of fat during grinding, the samples were ground with dry ice. Dry ice to sample ratio was approximately 1:1 by weight.

Moisture

Before fat extraction, moisture content was determined by a vacuum-oven procedure (AACC method 44-40, AACC 1983).

Fat Determination

Percent fat by both acid hydrolysis (method 30-10, AACC 1983), and petroleum ether extraction (method 30-26, AACC 1983) were determined on a series of samples during a preliminary portion of the study. Later samples were analyzed by petroleum ether extraction only.

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Frying Fat Quality

Free fatty acid level (AOCS method 5a-40, AOCS 1982) of the frying fat was maintained at 0.40% ± 0.01%. The viscosity of the frying fat was maintained at 10 ± 1 cP at 100° C with the Brookfield viscometer model LVT (equipped with spindle no. 1 and set at 30 rpm). A separate supply of conditioned frying fat was obtained by frying a series of donuts in a batch of shortening until the free fatty acid level increased to 0.43%. Conditioned frying fat was stored in a covered container until used. Before frying each batch, frying fat quality was adjusted. Frying fat was removed from the fryer and replaced with fresh or conditioned frying fat as needed.

Soy Flour Fractionation

Fractions of soy flours separated by the protein dispersibility index (PDI) procedure (method Ba 10-65, AOCS 1982)) were lyophilized. Each fraction was used to replace an appropriate quantity of soy flour based on the relative abundance of the fraction in the intact soy flour. Mass and protein balance values for the separation are shown in Table III.

Fat Absorption Calculations

Weight of fat present in the quantity of batter needed to produce one donut was subtracted from the total fat present in the fried donut. The difference was taken as the amount of fat absorbed per donut. This quantity then was divided by the total solids not fat in the donut to yield grams of fat absorbed per gram donut solids not fat (gFA/gDSNF).

RESULTS AND DISCUSSION

Fat Determination

Acid hydrolysis fat determinations of baked products give consistantly higher values than petroleum ether extractions because of the binding of fat by protein during baking (Hertwig 1923). During an initial set of trials, fat determinations by acid hydrolysis and petroleum ether extraction were run on all samples. Although acid hydrolysis values were slightly higher (about 1.8%), the correlation coefficient between the two determinations on fried donuts was greater than 0.99. Based on the high correlation between the methods and the fact that this study was more interested in relative than absolute values, fat quantity data for fried donuts and most batters were all derived from petroleum ether extraction. Batters containing large amounts of PDI-soluble protein gave remarkably lower batter fat values with ether extraction than did other batters. However, acid hydrolysis fat analysis of these batters indicated that their fat level was not lower than that of other batters. Thus, it appears that the PDI-soluble portion of soy protein has ability to bind fat to a greater extent than intact soy flour during mixing.

Batter Weight

The Belshaw cutter did not allow for precise control of individual donut batter weight. Assuming that the only two mass transfer events occurring in donut frying are loss of water and gain of fat, then the actual batter weight can be calculated from analysis of the final donut. Based on this assumption, batter weight differences between all trials reported in this study were not significantly different at the 5% level.

Water Absorption

Wheeler and Stingley (1963) suggested that variations in water absorption by donut batters would affect fat absorption. Batters containing soy products require additional water to maintain viscosity values equal to batters without soy products. Over the range of soy products tested in this study, there was no correlation between the amount of additional water required in a batter to maintain viscosity and the amount of fat absorbed on frying. Also, there was a correlation coefficient of 0.00 between the moisture content of the finished donut and the fat absorbed per gram of solids not fat in the donut. From these results, it appears that neither the moisture content of the batter nor that of the finished donut is a reliable indicator of fat absorption by frying donuts.

Effect of Soy Flour

Soy flours of 30, 69, and 80 PDI levels were used to replace 2, 6, and 10% of the base donut mix to determine the effect of intact soy flour on fat absorption during frying. Figure 1 is a response-surface graph of the results of this trial. The combination of PDI level and actual quantity of soy protein added plus their interaction explains 93% of the observed variation in fat absorption. As is obvious from the graph, the effect of added protein far outweighed the contribution of the PDI level of that protein. This may explain why some soy flours sold on a PDI specification but with only a minimum protein guarantee may vary in performance. Minor variations in the actual protein level above the minimum specified will have far greater effects on donut fat absorption than will normal variations in PDI.

Effect of Soy Fractions

To further explore the relationship between protein quantity, solubility, and fat absorption, soy flours of various PDI levels were fractionated by the PDI method into soluble and insoluble portions. Separation and recombination of the PDI-soluble and insoluble fractions had no effect on their functionality in reducing fat absorption. Figure 2 shows the relationship between fat absorbed and quantity of protein added for both the soluble and insoluble fractions. The dashed lines indicate the 95% confidence

TABLE I
Donut Dry Ingredient Formula

Ingredient	Baker %	Weight %
Hard wheat flour (11.5% protein)[a]	50.0	30.5
Soft wheat flour (8.6% protein)[a]	50.0	30.5
Sucrose (granular)	40.0	24.6
Nonfat dry milk	5.0	3.1
Vegetable oil	10.0	6.0
Powdered egg yolks	2.0	1.2
Salt	1.67	1.0
Soda	1.40	0.86
B.P. 28[b]	0.39	0.24
Donut Pyro[b]	1.55	0.95
Ground nutmeg	0.80	0.5

[a] (N × 5.7).
[b] Sodium acid pyrophosphate.

TABLE II
Laboratory Analysis of Soy Flours[a]

Flour Sample	PDI[b]	Protein[c] (%)	Ash (%)	Moisture (%)	Fat (%)	Fiber (%)
1	95	53.6	6.4	7.0	1.07	5.0
2	80	55.4	6.7	6.3	0.46	4.1
3	69	55.0	6.7	6.0	0.89	3.9
4	30	55.1	6.4	6.2	0.63	3.9

[a] Dry matter basis.
[b] Protein dispersibility index.
[c] Protein = N × 6.25.

TABLE III
Analysis of Soy Flour Fractions

PDI[a]	Fraction	Yield (%)	Protein (% db)
95	Soluble	69	63.8
	Insoluble	31	31.5
80	Soluble	65	63.0
	Insoluble	35	43.2
69	Soluble	55	58.2
	Insoluble	45	53.3
30	Soluble	37	37.5
	Insoluble	63	66.5

[a] Protein dispersibility index.

interval about the regression line. Only the point representing the insoluble material from the 30-PDI soy flour deviates significantly from the regression line. From this it appears that protein solubility is of little importance in reducing fat absorption at higher PDI levels. The major effect is obviously a function of the quantity of added protein.

Results of a further study comparing equal amounts (2.36%) of PDI-soluble and insoluble protein from both 80-PDI and 30-PDI soy flours are shown in Table IV. These results again showed that although heat processing could damage the factor in soy protein reducing fat absorption, this did not occur until PDI levels were quite low.

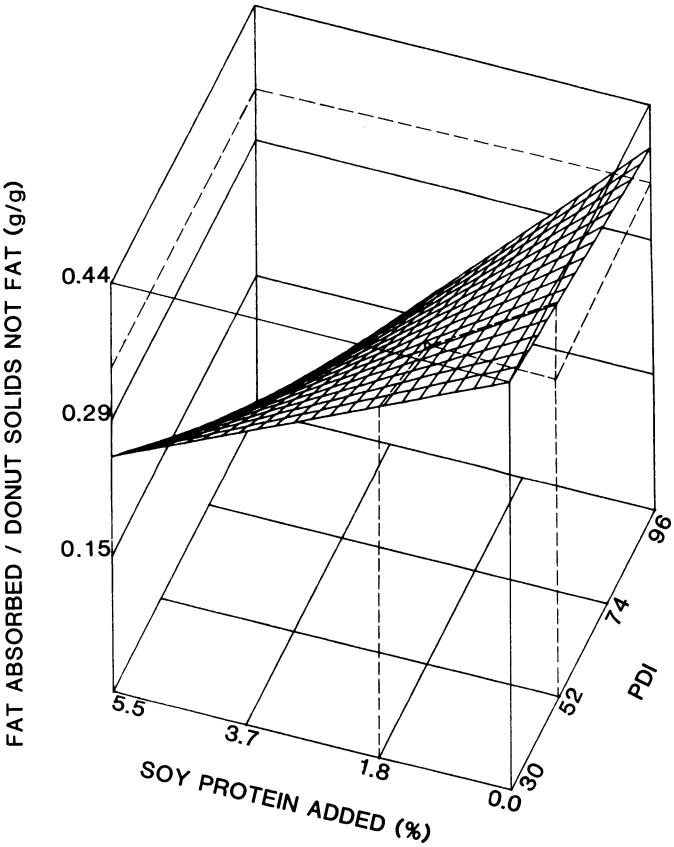

Fig. 1. Response-surface graph of the linear relationship between the quantity of soy protein added, protein dispersibility index (**PDI**), and grams fat absorbed per gram donut solids not fat.

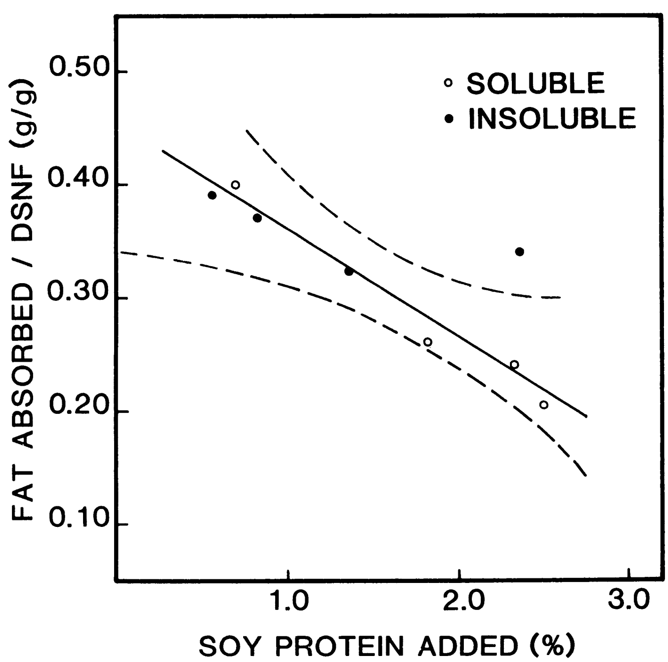

Fig. 2. Relationship between grams of fat absorbed per gram of donut solids not fat and quantity of soy protein added. Standard deviation among means ranged from 0.005 to 0.012 g fat absorbed/g donut solids not fat (**DSNF**).

Effect of Nonprotein Fractions of Soy Flour

Examination of the data from various trials in this study where the quantity of nonprotein matter in added soy flours could be calculated showed no relationship between fat absorption and the nonprotein fraction.

Effect of Quantity of Intact Soy Flour

Figure 3 shows the effect on fat absorption by various quantities of soy flours with various PDI levels. The three higher PDI soy flours were not significantly different from each other around the regression line shown. The 30-PDI soy flour was significantly less effective in reducing fat absorption, as shown by the displacement of its regression line upward. Note that the level of 3.0% soy protein added was equivalent to 6.0% soy flour at 50% protein, a common specification for soy flour. This is about the highest amount normally used in commercial donut production (French 1977).

TABLE IV
Effect of Protein Dispersibility Index (PDI) Solubility of Protein on Fat Absorption

PDI	Fraction	Protein Level[a] (% db)	gFA/gDSNF[b]
80	Soluble	2.31	0.24
	Insoluble	2.31	0.25
30	Soluble	2.36	0.26
	Insoluble	2.36	0.34

[a]Protein = N × 6.25.
[b]Grams fat abosrbed per gram donut solids not fat. Standard deviation = 0.012 gFA/gDSNF.

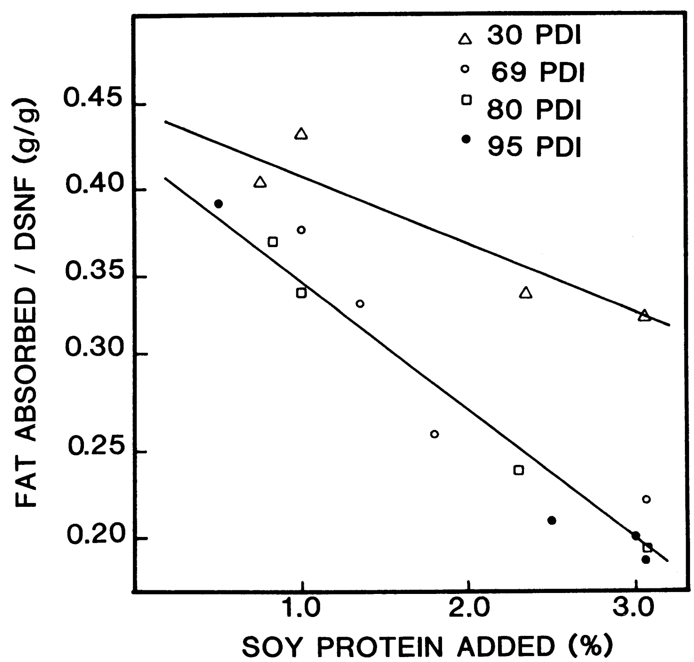

Fig. 3. Effect of quantity of protein added (% db) on grams fat absorbed per gram of donut solids not fat (**DSNF**) by cake donuts. Intact soy flours and protein dispersibility index (**PDI**) soluble and insoluble fractions below 3.25% protein replacment level are included in the graph. Standard deviation among means of replicates ranged from 0.005 to 0.012 g fat absorbed/g donut solids not fat.

CONCLUSION

This study clearly pointed out that the major effect of soy flour on fat absorption by cake donuts was a function of the quantity of protein added to the batter. At higher PDI values, there was little or no difference between PDI-soluble and PDI-insoluble protein. When the PDI level was in the lower range, the insoluble portion of the protein lost much of its effect on fat absorption but the effect of the protein that remained soluble was not altered. The actual mechanism for the effect of the soy proteins is as yet unclear. Work in progress will attempt to clarify this mechanism.

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