

Collaborative Study on the Protein Dispersibility Index

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Paulsen et al (1) summarized the types of methods developed for studying the water extractability of proteins from soybean products. In general, flour was either soaked, hand-stirred, or blended with water, and then filtered or centrifuged; the soluble fraction (water-dispersible proteins) or insoluble residue was analyzed for nitrogen composition. Methods for protein quantitation of the soluble fraction and the insoluble residue were described as direct and indirect, respectively. Once determined, the water-dispersible protein value was used to calculate the protein dispersibility index (PDI) (2).

Two problems affected the consistency of results among experiments in the earlier study (1) when the Waring Blendor was used to determine PDI: erratic temperatures and lack of standardized equipment. A Hamilton Beach Drinkmaster modified with Waring Blendor blades and operated at 8,500 rpm for 10 min was used to reduce these problems. The temperature rose approximately 12°C. No exact maximum PDI was obtained in these experiments.

A collaborative study of this method was accepted by the American Oil Chemists' Society as Official Method AC-4-41 for determining percentages of water-dispersible protein and PDI (2). AACC also accepted this procedure, as AACC Method 46-24 (3). AACC Method 46-24 requires a Hamilton Beach Drinkmaster No. 30, modified to accommodate the Waring Blendor blade and cup and the Cenco-Pinto blade assembly, a specially made product (no. 17251-L55) of Central Scientific Co. Because blenders that require these modifications are not readily available in all laboratories, blenders that do not have to be modified for use but produce uniform PDI values

among laboratories are needed.

The Protein Solubility Methods Subcommittee evaluated laboratory and equipment variables affecting the PDI of soybean flour (100-mesh, 52.9% protein). The results of these studies, all of which were conducted in duplicate, are shown in Table I. The studies showed that, depending on the type of blender used, the range of PDI values is 62.74-79.17; those run with the Hamilton Beach Drinkmaster, modified according to the official AACC method (3), had a range of 64.90-79.17. Low PDI values were obtained when the Burrel wrist action shaker and Corning PC-353 magnetic stirrer were used. High values were obtained when Waring Blendors and modified (3) Hamilton Beach Drinkmasters were used; however, the PDI obtained from British Arkady Co., Ltd., with a modified Hamilton Beach Drinkmaster, was low. High PDI values occurred when the temperature of the suspensions increased 5-23°C; large PDI

increases were noted in blended suspensions that had temperatures of 18-23°C. Data confirmed past experiments' findings that the flour:water ratio can be an important factor in determining PDI, but the data also suggested that the 1:15 ratio of water to flour recommended by the official method (3) was sufficient to obtain uniform PDI. Other sources of variability were the technicians and adjustments to the official method to meet an industry's needs (personal communications); the latter finding made it difficult to develop a collaborative study.

The Subcommittee concluded that because of limited equipment availability in laboratories, research is needed to standardize the Osterizer Galaxie dual-range 14 and Waring Blendor by correlating PDI values with those produced by the modified Hamilton Beach Drinkmaster.

The results of these studies are summarized in Table II. These data show

Table I. Laboratory and Equipment Variables Affecting the Protein Dispersibility Index (PDI) of a Soybean Flour^{a,b}

Laboratory	Equipment ^c	PDI	Blending Temperature (°C)	
			Before Study	After Study
Southern Regional Research Center	Burrel wrist action shaker	a 62.74 ± 0.95	23.4	24.2
	Corning PC-353 magnetic stirrer	a 63.41 ± 0.49	24.7	24.8
	Virtis "45" homogenizer	b 66.06 ± 3.24	23.7	23.1
	Sorvall Omni-Mixer	b,c 68.93 ± 1.92	24.2	25.2
	Ultra-Turrax homogenizer	b,c 69.02 ± 1.57	22.9	27.7
	Osterizer Galaxie dual-range 14 Waring Blendor	c 69.44 ± 0.64 e 78.21 ± 1.16	24.1 24.3	29.6 47.3
Archer Daniels Midland Co.	Hamilton Beach Drinkmaster (modified) ^d	c 71.10	N.A. ^e	32.9
Far-Mar-Co., Inc.	Waring Blendor	c,d 71.14	N.A. ^e	N.A. ^e
Nabisco Brands, Inc.	Hamilton Beach Drinkmaster (modified) ^d	d 74.62	23.7	31.0
Cargill, Inc.	Hamilton Beach Drinkmaster (modified) ^d	e 79.17	26.5	35.8
British Arkady Co., Ltd.	Hamilton Beach Drinkmaster (modified) ^d	a 64.90	N.A. ^e	N.A. ^e

^a Ratio of flour to water was 1:15. PDI values are averages of two technicians; range of variability is shown as ± values. Values with the same preceding letters are not different (0.01 level of significance).

^b pH value of sample suspensions before homogenization from the different laboratories was 6.50-6.68, and after blending was 6.39-6.66.

^c RPM values for the equipment were: Burrel wrist action shaker, 3,200; Corning PC-353 magnetic stirrer, 11,500; Hamilton Beach Drinkmaster (modified), 8,500 (available value from ADM Co.); Virtis "45" homogenizer, 8,500-10,300; Sorvall Omni-Mixer, 11,500; Ultra-Turrax homogenizer, 11,500; Osterizer Galaxie dual-range 14, 11,100; and Waring Blendor, 11,550.

^d Modified with Cenco-Pinto blades, Central Scientific no. 17251-L55, according to Official and Tentative Methods of the AOCS (2nd ed.), Official Method AC-4-41 (1964).

^e N.A. = not available.

¹ Dr. Cherry chaired the Subcommittee on Protein Solubility Methods when it made this study. Other Subcommittee members were: R. L. Kellor, R. Cordera, M. P. Steinburg, M. W. Sei, P. G. Banks, L. L. Hansen, J. S. O'Mahony, C. N. Peterson, A. Finlayson, J. C. Fritz, R. Madl, A. P. Cahill, L. K. Ferrier, and W. T. Skaggs.

that increasing the blending speed and time raises the temperature of the suspensions and PDI values. The procedure for determining duplicate values of PDI for soybean flour is as follows: 1) Weigh 20 ± 0.1 g soy product. 2) Fill 300-ml volume flask with water at 25 ± 1°. Pour approximately 50 ml of water into blender cup. (Note: Water-dispersible protein is related to temperature, so blender cup should be at room temperature.) Transfer sample, weighed quantitatively, to blender cup. Stir with spatula to form paste. Add remainder of water in increments, stirring, to form smooth slurry. Use last of water to rinse spatula and blender cup walls. Place cup in position for blending. 3) Turn blender on with switch in high position, and

gradually adjust variable transformer to point indicated by water standard at 8,500 rpm. Blend at this speed for 10 min. 4) Remove blender cup, and pour slurry into 600-ml beaker. After slurry has separated, decant or pipet portion into 50-ml centrifuge tube, and centrifuge 10 min at 2,700 rpm. 5) Pipet 15 ml of the supernatant liquid into a Kjeldahl flask, and determine protein by using Method 46-11 (15 ml = 1.0 g sample).

Calculation:

$$\% \text{ Water-Dispersible Protein} = \frac{(B-S) \times N \times 0.014 \times 100 \times 6.25}{\text{Weight of Sample}}$$

Where B = ml alkaline back-titration of

blank, S = ml alkaline back-titration of sample, N = normality of alkaline.

% Protein Dispersibility Index (PDI) =

$$\frac{\% \text{ Water-Dispersible Protein} \times 100}{\% \text{ Total Protein}}$$

Table III shows data from studies in which the temperature increase was kept to a minimum (1–4°C). Sample pHs changed only slightly, and the PDI values were lower than those obtained when the temperature rise was not controlled. Results from the Osterizer Galaxie dual-range 14 and Waring blenders were comparable. Changes due to increasing blender rpm values and blending times were not great. Why the PDI values of samples differed, even though the temperature remained constant (Tables II and III), is not understood. Repeatability of all experiments was good within and among laboratories.

The key to successfully determining PDI values is control of the temperature during blending. This variable has not been completely evaluated in past studies. When the temperature is limited to a 1–4°C increase, methods that use the Osterizer Galaxie dual-range 14 and Waring blenders give comparable PDI values, especially at a 8,500-rpm blending speed for 15 min, and when temperature changes are kept to a minimum. To relate PDI values to the functional properties of processed food, which is almost always heated to at least 100°C, an additional method that uses high-temperature extraction, or "boiling PDI," should be studied.

Table II. Protein Dispersibility Indexes of Soybean Flour by the Osterizer Galaxie Dual-Range 14 Mixer and the Waring Blender Under Varying Blending RPM and Time Conditions and Uncontrolled Temperature, at Different Laboratories^{a,b,c}

Laboratory	Blender RPM	Blending Time (min)			Temperature Increase (°C) ^d
		5	10	15	
Osterizer Galaxie Dual-Range 14					
Southern Regional					
Research Center	8,500	a 61.6a	a 69.4b	a 72.4c	24.1–29.6
Archer Daniels Midland Co.	8,500	b 66.0a	a,b 72.4b	a,b 74.7b	26.3–38.3
	11,000	b,c 68.1a	b 73.0b	c 80.2c	24.4–42.2
	11,500	c,d 70.5a	b,c 74.3b	a,b 74.7b	26.7–43.3
Waring Blender					
Southern Regional					
Research Center	8,500	d,e 72.5a	d 78.2b	a,b 75.1a	24.3–47.3
Archer Daniels Midland Co.	8,500	d,e 72.2a	b,c 74.3b	a,b 75.4b	26.1–50.8
	11,000	d 71.8a	a,b 72.8a	b 76.4b	25.5–56.7
	11,500	d,e 72.2a	c,d 76.6b	e 99.6c	25.8–60.6
Nabisco Brands, Inc.	8,500	e,f 75.4a	e 82.1b	d 87.2c	28.0–37.0
	11,000	f,g 78.8a	f 87.0b	d 89.1b	28.0–41.7
	11,500	g 81.3a	f 86.8b	d 88.9b	28.0–50.0

^aPDI values by the AOCS Official Method AC-4-41 (2) are 72.6 (Archer Daniels Midland Co.) and 74.4 (Nabisco Brands, Inc.).

^bCentrifugation after blending of 1:15 flour to water mixtures for all analyses was at 2,700 rpm.

^cValues with the same letters (preceding, read down; following, read across) are not different (0.01 level of significance).

^dLow and high temperatures at blending times 5 and 15 min, respectively.

Table III. Protein Dispersibility Indexes of Soybean Flour (1:15 Ratio, Flour to Water) by the Osterizer Galaxie Dual-Range 14 Mixer and the Waring Blender Under Varying Blending RPM, Blending Time, and Centrifugation Conditions, and Controlled Temperature^{a,b}

Blender	RPM	Centrifuge	Blending Time (min)			Temperature Increase (°C) ^c	pH Range
			5	10	15		
Osterizer Galaxie Dual-Range 14							
8,500	2,700		b,c,d,e 58.92a	d 64.59b	b,c 63.26b	26.6–28.5	6.75–6.80
	5,400		c,d,e 59.26a	d 63.10b	b,c 62.89b		
11,000	2,700		b,c,d 58.00a	c 58.21a	a,b 60.51a	25.8–28.3	6.75–6.80
	5,400		b,c 57.35a	b,c 57.59a	a,b 60.73b		
11,500	2,700		a,b 55.65a	d 65.17b	c 64.30b	23.4–27.2	6.71–6.79
	5,400		a,b 55.78a	d 63.54b	b,c 63.46b		
Waring Blender							
8,500	2,700		b,e 60.91a	e 69.07c	c 64.73b	26.0–27.0	6.70–6.71
	5,400		e 61.85a	e 69.28b	c 64.35a		
11,000	2,700		b,c 57.48b	a,b 55.85a	a 58.84b	24.0–26.0	6.71–6.80
	5,400		b,c 57.05b	a 54.23a	a 58.50b		
11,500	2,700		a 52.63a	a 55.41b	a,b 60.61c	23.0–25.5	6.78–6.81
	5,400		a 53.41a	c 58.60b	a,b 60.17b		

^aTemperature rises minimized by placing the entire system during the blending interval under refrigeration at 2°C.

^bValues with the same letters (preceding, read down; following, read across) are not different (0.01 level of significance).

^cLow and high temperatures at blending times 5 and 15 min, respectively.

Acknowledgments

Special appreciation is extended to the following researchers for their contributions to all phases of this research: L. L. Hansen, Archer Daniels Midland Co.; R. Cordera, Nabisco Brands, Inc.; and C. James and J. G. Simmons, Southern Regional Research Center, ARS/USDA. Part of the data for Table I is from P. G. Banks, British Arkady Co., Ltd.; C. N. Peterson, Nabisco Brands, Inc.; R. L. Kellor, Cargill, Inc.; G. V. Rao, KFC Corp.; and M. P. Steinberg, University of Illinois, Urbana.

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