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Effects of dehulling and storage conditions on cooking requirements and chemical composition of soybeans

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SUMMARY. Changes in cooking requirements and chemical composition of whole and dehulled soybeans, stored in 2 different environments [25°C /75% R.H. (Environment 1) and 38°C /90% R.H. (Environment 2)], were studied. Rate of water absorption and solid losses during cooking were higher for the dehulled soybeans at both storage conditions. However, cooking requirements to achieve the same degree of texture in the cotyledons were similar for whole and dehulled seeds. Cooking time increased with prolonged storage; the effect was more noticeable in samples stored under Environment 2. Samples kept for 6 months required almost twice as much cooking than control samples. Dehulled soybeans had a lower fiber content, relatively higher amounts of protein and fat, but similar amino acid compositions than whole soybeans. Cooking caused losses of carbohydrates and ash and, therefore, significantly increased levels of protein and fat reflected by losses of solids during soaking and cooking. Among the amino acids, only cysteine suffered substantial decrease as a result of cooking. Cooking and storage inactivated 99% and from 20-35% of the trypsin inhibitors, respectively; the latter effect was more accentuated in samples stored under Environment 2.

RESUMEN. Efecto del descascarado y de las condiciones de almacenamiento en los requerimientos de cocción y composición química de la soya. Se estudiaron los cambios en los requerimientos de cocimiento y en la composición química de la soya entera y descascarada almacenada en dos condiciones ambientales diferentes [25°C /75% H.R. (ambiente 1) y 38°C /90% H.R. (ambiente 2)]. La tasa de absorción y pérdida de sólidos durante el cocimiento fueron mayores para la soya descascarada en ambas condiciones de almacenamiento. Sin embargo, los requerimientos de cocción, para lograr el mismo nivel de textura en los cotiledones, fue similar para semillas enteras y descascaradas. El tiempo o requerimiento de cocción se incrementó conforme las muestras fueron almacenadas por más tiempo; el efecto fue más notorio en aquellas muestras almacenadas bajo el ambiente 2. Muestras almacenadas por 6 meses requirieron casi el doble de tiempo de cocimiento que muestras control. Semillas de soya descascarada tuvieron un menor contenido de fibra, y un contenido mayor de proteína y aceite pero una composición de aminoácidos similar a semillas enteras. El remojo y cocimiento ocasionó pérdidas de carbohidratos y cenizas, y por lo tanto se incrementaron los niveles de proteína y aceite. Entre los aminoácidos, solamente la cisteína se perdió substancialmente después del cocimiento. El cocimiento y almacenamiento inactivaron al 99% y del 20-35% del inhibidor de tripsina, respectivamente; el último efecto fue más notorio en muestras almacenadas bajo el ambiente 2.

INTRODUCTION

World soybean production was estimated as 103.1 million metric tons in 1991 with a 20% increase in the last decade (1). The main producers in order of importance are USA, Brazil and China. In the Western Hemisphere, the direct use of soybeans as human food has been limited. Most soybeans are used for oil extraction and protein meal production. The latter is one of the main feedstuffs used to upgrade the protein quality of animal diets. The main food products manufactured from soybeans include protein concentrates, isolates, floors and texturized vegetable protein. Factors limiting the direct use of soybeans may include their prolonged cooking time, a lack of eating habit, and problems associated with the presence of hulls. These problems might be overcome, in part, if dehulled soybeans were available. Dehulled seeds might require a shorter cooking time as a result of the absence of hulls (2). The protein and starch matrix of the cotyledons and other anatomical characteristics such as seed coat thickness and size

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of micropyle may contribute significantly to the rate and total amount of water absorption (3-4). According to Costa & Arkoll (5) dehulled soybeans require about one fourth of the time to achieve maximum water absorption when compared with intact seeds. Storage of soybeans causes structural changes which include hardening of the seed coat, disintegration of cytoplasmic organelles and inclusions and loosening of attachments between the cell wall and the plasmalemma which negatively affect cooking requirements (6-7). The objective of this study was to determine the cooking quality of both whole and dehulled soybeans stored under two different environmental conditions.

MATERIALS AND METHODS

Raw Materials/Preparation: Soybeans of the «Williams 82» variety grown in Iowa were procured from Illinois Foundation Seed, Inc. Upon arrival, the seeds were cleaned in a horizontal sieving system equipped with an aspiration to separate foreign material, immature and broken seeds and loose hulls.

Dehulling: Soybeans were dehulled according to the procedure described by Nelson et al (8). Clean seeds with around 9.7% moisture were heated for 20 min at 98°C to impart plasticity to cotyledons and loose hulls, and then immediately passed through a dehuller. Hulls and fine particles were removed by aspiration and sieving. The intact cotyledons (splits) were separated from lose hypocotyls and whole seeds by a sieving system.

Storage study: Whole and dehulled soybeans were stored under 2 environmental conditions [27°C/75% R.H. (Environment 1) and 38°C/90% R.H. (Environment 2)] to approximate ambient conditions in temperate and tropical climates, respectively. Soybeans were divided into 0.5 kg lots and packaged in low density (3 mil) polyethylene bags. The bags were stacked in two glass containers fitted with airtight covers and equilibrated with 4 L of a saturated solutions of either KNO_3 or NaCl. The container with NaCl was incubated at 25°C, while the one containing KNO_3 was placed in an incubator set at 38°C. Three bags each of whole and dehulled soybeans were withdrawn on a monthly basis for 6 months. A portion of the beans was immediately analyzed for moisture while the remainder was kept in a freezer at -29°C for later analyses.

Soaking time and solid losses: The soaking time was determined by the method described by Uebersax and Bedford (9), and total solids loss by evaporating the soak water in a vaccum oven at 60°C.

Cooking time: The optimum cooking time was determined using the Mattson cooking device (10) as modified by Jackson and Varriano Marston (6). The methodology was further modified by changing rod weights and by including a system to maintain a constant water volume. A 20 g sample of soybeans was mixed with 50 ml of boiling-deionized water and allowed to soak for 12 hr at room temperature. Thereafter, the soaked seeds were placed in each of 25 saddles on the base of the cooker with the tip of a vertical stainless steel rod positioned into the surface of each bean. Rods weighing 50 and 20 g were used to determine cooking time of whole and dehulled soybeans, respectively. The cooker was placed in a container with 1 L boiling water (98°C). Soybeans were judged as optimally cooked when the tips of the rods penetrated 80% and 60% of the whole and dehulled beans and dropped through the hole at the base of the saddle.

Chemical analyses: Proximate composition of raw, stored and cooked (whole and dehulled) soybeans were determined following AOAC (11) guidelines. Moisture was determined by the constant weight oven-drying method under vaccum at 60°C. Protein (N x 6.25) was determined by the micro-Kjeldahl method, and fat gravimetrically assayed after extraction with hexane in a Goldfisch apparatus. Fiber was determined by the acid detergent method of Goering and Van Soest (12). Ash was determined after incineration of samples at 550°C in a muffle furnace. Carbohydrates were estimated by difference.

Amino acid compositions were assayed by the methodology of Spackman et al (13). Amino acids were separated by ion exchange chromatography and colorimetrically quantified in a spectrophotometer after reaction with ninhydrin.

Trypsin inhibitor contents, expressed as trypsin inhibitor units (TIU) per mg protein, were determined by the procedure outlined by Kakade et al (14).

RESULTS AND DISCUSSION

Effects of dehulling

a. Water absorption/solid losses: Whole soybeans absorbed approximately 85% of the total water during the first 7 hr soaking (15). In contrast, dehulled seeds absorbed 89% of the water during the first 2 hr soaking. The clear difference in water absorption in favor of dehulled seeds has been previously documented by Smith and Nash (4), Saravacus (16) and Varriano Marston and Jackson (7). After 3 and 14 hr soaking, solid losses from dehulled soybeans were 8.6 and 13.2% compared to 0.68 and 0.74%, respectively, for whole seeds. The noticeable difference in solid losses might be attributed to the presence of testa and structures at the hilums in whole seeds which are barriers to solids leakage (6).

b. Cooking time: Dehulling was expected to reduce cooking time due to an increased thermal conductivity (2,17), but results (Table 1) showed that cooking times for whole and dehulled soybeans were not significantly different (P<0.05). The positive effect of dehulling on cookability might have been offset by physical and chemical changes incurred by the cotyledons due to the pre-heat treatment applied prior to dehulling. However, the unexpectedly lengthy cooking time for dehulled soybeans was not likely due to increased leakage and loss of electrolytes during the soaking process, as reported by Müller (18) and Moscoso et al (19). These researchers suggested that softening of legumes was related to exchange of insoluble form (pectate) Ca and Mg from the present in the middle lamella and Na or K in the soluble form.

TABLE 1
EFFECTS OF TIME AND STORAGE CONDITIONS ON COOKING TIME OF WHOLE AND DEHULLED SOYBEANS

Storage Conditions Time (mo.)	Temp. (C)	R.H. (%)	Cooking Time (hr) Whole Soybeans	Dehulled Soybeans
			Environment 1	
0	—	—	5.9 i	6.1 hi
2	25	75	5.9 i	6.8 fg
4	25	75	6.5 fg	6.9 efg
6	25	75	7.1 def	7.2 def
			Environment 2	
0	—	—	5.9 i	6.1 hi
2	38	90	7.6 d	7.4 de
4	38	90	8.5 c	9.2 b
6	38	90	11.0 a	11.3 a

1 Mean separation by least significant difference (0.05); a difference in superscripts among means denotes a significant difference (P<0.05).

Effects of storage

a. Seed moisture content: Whole and dehulled soybeans packed in 3 mil polyethylene bags and stored at the two different environmental conditions showed a linear increase in moisture content with storage time (Table 2). Sample stored at 38°C /90% R.H. showed a faster increase than counterparts stored at 25°C /75%R.H. Moisture content was influenced by relative humidity in the storage container as previously documented (20-22). The rate of water absorption was higher for dehulled soybeans than for whole seeds under both environmental conditions. This agrees with Saravacos (16) who found that the seed coat decreases the rate of moisture absorption. It was observed that water penetration was more rapid between cotyledons, suggesting that the seed coat held the cotyledons tightly together, thus, making the diffusion of water more difficult. The effect was corroborated by Saravacos (16) who determined that the equilibrium moisture content of dehulled soybeans was reached in 2 to 6 days while whole seeds equilibrated in 1-3 weeks.

TABLE 2
EFFECT OF TIME AND CONDITIONS OF STORAGE ON THE MOISTURE CONTENT OF RAW WHOLE AND DEHULLED SOYBEANS[1]

Storage Conditions Time (mo.)	Temp. (C)	R.H. (%)	Moisture Content (%) Whole soybeans	Dehulled Soybeans
			Environment 1	
0	—	—	9.65 g	6.82 o
1	25	75	9.67 g	6.82 no
3	25	75	9.68 g	7.16 n
3	25	75	10.18 ef	7.48 im
4	25	75	10.33 de	7.67 k
5	25	75	10.33 de	7.84 k
6	25	75	10.48 def	7.83 def
			Environment 2	
0	—	—	9.65 g	6.82 o
1	38	90	9.92 fg	7.22 mn
2	38	90	10.26 de	7.57 kl
3	38	90	10.88 c	8.48 j
4	38	90	11.17 bc	8.93 i
5	38	90	11.37 ab	9.28 h
6	38	90	11.57 a	9.74 g

1 Mean separation by least significant difference (0.29); a difference in superscripts among means denotes a significant difference (P<0.05).

b. Cooking requirements: Cooking times of whole and dehulled soybeans were affected by storage for 0, 2, 4, and 6 months under environments 1 and 2 as shown in Table I. For both, whole and dehulled seeds, a significant linear increase in cooking time was observed with storage duration. The negative effect of storage on cooking requirement was more pronounced in soybeans stored at higher temperature and relative humidity. The hard-to-cook phenomena associated with prolonged storage confirms previous reports (6, 19-23). The most acceptable explanation suggests that phytic acid content decreased during storage due to activation of phytases and altered the ratio of mono to divalent cations. This resulted in more divalent cations capable of reducing the solubility of pectic substances.

Proximate and amino acid composition: As expected, proximate compositions of dehulled soybeans showed lower fiber content and relatively higher amounts of protein and fat (Table 3). Cooking caused losses of carbohydrates and ash and, therefore, increased the levels of protein and fat reflected by solid losses during soaking and cooking. Most solid losses from whole soybeans occurred during cooking, while substantial losses from dehulled seeds occurred during both cooking and soaking.

TABLE 3
PROXIMATE COMPOSITIONS OF WHOLE AND DEHULLED SOYBEANS AFTER VARIOUS STORAGE AND PREPARATION TREATMENTS[1]

Storage Conditions				Composition (%)				
Time	Temp.	R.H.	Cooking Time (hr)	Crude Protein[2]	Crude Fat	Ash	Fiber[3]	Carbohydrates[4]
				Raw Whole Soybeans				
—	—	—	—	40.5	22.1	5.6	6.6	25.2
				Cooked Whole Soybeans				
0	—	—	5.9	46.4	28.0	4.1	5.9	15.6
3	25	75	6.3	46.1	27.4	3.1	6.4	17.0
6	25	75	7.1	45.6	27.3	3.2	6.6	17.3
3	38	90	8.0	45.9	27.4	3.0	6.5	17.3
6	38	90	11.0	45.3	27.4	3.0	7.2	17.0
				Raw Dehulled Soybeans				
—	—	—	—	42.3	24.2	5.5	3.8	24.3
				Cooked Dehulled Soybeans				
0	—	—	6.1	47.2	31.0	3.0	2.8	16.1
3	25	75	6.9	47.8	30.8	3.4	2.6	15.3
6	25	75	7.2	47.5	30.6	3.0	2.6	16.4
3	38	90	8.3	46.7	31.4	3.2	2.7	16.1
6	38	90	11.3	47.3	31.4	2.7	2.8	15.9

1 All values are expressed on dry-matter basis.
2 % Nitrogen x 6.25
3 Determined by acid detergent method of Goering and Van Soest (1970).
4 Calculated by difference: 100 -(%crude protein + %crude fat + % ash + % fiber).

Dehulling did not affect the amino acid composition. Among the amino acids, only cysteine suffered a considerable decrease as a result of cooking. Antones and Sgarbieri (24) also noticed losses of cysteine during cooking but, in addition, they found methionine levels to be reduced in cooked beans. Losses of sulfur-containing amino acids were likely due to leaching during soaking and to thermal degradation during cooking. In this study, reductions in cysteine levels upon cooking were not greater for dehulled samples than for whole soybeans.

Cooking inactivated approximately 99% of the trypsin inhibitors in whole and dehulled seeds at both environmental conditions (Tabla 4). Interestingly, prolonged storage solely inactivated 20-35% of the trypsin inhibitors. However, this decrease was greater for beans stored under Environmental Condition 2 and slightly higher for dehulled seeds. These results agree with those of Urbanski et al (25), who also observed lower TI activity as storage time of soybeans progressed.

TABLE 4
EFFECTS OF STORAGE AND COOKING ON TRYPSIN INHIBITOR ACTIVITY OF WHOLE AND DEHULLED SOYBEANS

Storage Conditions Time (mo.)	Temp. (C)	R.H. (%)	Trypsin Inhibitor Activity Raw Soybeans TIU/mg Protein	TIU Inactivation (%)	Cooked soybeans TIU/mg Protein	TIU Inactivation (%)
Whole Soybeans						
0	—	—	129.1	—	1.4	98.9
3	25	75	103.3	20.0	1.2	99.1
6	25	75	97.6	25.4	1.2	99.1
3	38	90	106.3	18.7	1.1	99.2
6	38	90	89.8	31.4	1.1	99.2
Dehulled Soybeans						
0	—	—	122.2	—	1.0	99.2
3	25	75	100.7	22.0	0.9	99.3
6	25	75	83.4	28.3	0.7	99.5
3	38	90	92.6	35.4	0.9	99.3
6	38	90	82.3	36.3	1.0	99.2

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