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Effects of blanching and storage conditions on soluble sugar contents in vegetable soybean

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ABSTRACT

Vegetable soybean is becoming increasingly popular in the U.S. because of its rich source of isoflavones, folic acid, and other nutrients. The objective of this study was to investigate various blanching and storage conditions in order to identify the proper post-harvest management strategy in preserving sugar composition of vegetable soybean during storage. Fresh soybean pods of two vegetable soybean genotypes were stored at 4 °C for 30 days or 25 °C for 8–12 days in fresh air or nitrogen atmosphere. Shelled seeds and intact pods were blanched in boiling water or steamed at 100 °C for 10 min. All blanched soybean was stored at −20 °C and sampled monthly for 6 months for sugar analysis. Glucose, fructose and sucrose decreased gradually in fresh soybean when stored at 4 °C in air or nitrogen atmosphere for 28 days. Soybean stored at 25 °C in open air showed a rapid decrease of sucrose in the first 24 h, and then followed by a gradual increase; whereas oligosaccharides accumulated significantly during storage. Significant degradation in all sugars was found in soybean stored in nitrogen atmosphere at 25 °C. Soluble sugars decreased from leaching during the water blanching and cooling treatment of vegetable soybean seeds. Steam blanching and the presence of pod effectively retained soluble sugars in vegetable soybean during thermal treatment.

1. Introduction

Vegetable soybean is a specialty food-type soybean harvested while the seeds are still immature at R6 (full pod) stage (McWilliams, Berglund, & Endres, 1999). It is similar to field matured soybean except for its larger seeds (Shurtleff & Aoyagim, 2001) and lighter hilum color (Konovsky, Lumpkin, & McCleary, 1994). Vegetable soybean has advantages in sensory attributes over mature soybean, such as green color, soft texture, large seed size, slightly sweet taste, and less objectionable beany flavor. In addition, vegetable soybean is higher in nutritional content than mature soybean, including higher ascorbic acid and β-carotene contents, and lower amounts of indigestible oligosaccharides and anti-nutritional substances such as trypsin-inhibitors and phytates (Rackis, 1978; Rackis, Hoing, Sessa, & Moser, 1972).

If properly stored, fresh vegetable soybean can retain its flavor and appearance for a short time period. The two most important sensorial attributes for vegetable soybean are sweetness and savory taste. The sweet taste comes from its high sucrose content, and the savory taste is probably attributed to its amino acid composition (Konovsky et al., 1994). For a desired appearance, vegetable soybean should have a bright green color without any defect and other color spot on the pods (Konovsky et al., 1994). Kassinee, Matsui, and Okuda (2004) reported that vegetable soybean stored at 5 °C for 10 days gradually decreased in green color, sucrose content, and seed weight.

Because of the short harvest period of vegetable soybean, proper processing is essential for year-round availability in the market. Combination of blanching in water and freezing has long been established as an excellent way of preserving vegetables by inactivating enzymes and decreasing the rate of enzymatic deterioration (Williams, Lim, Chen, Pangborn, & Whitaker, 1986). However, blanching vegetables improperly will affect their quality by softening the texture, browning the color, and decreasing the nutrient content. Greaves and Boggs (1945) showed that steam blanching had advantages over water blanching because more soluble materials were lost during water blanching. Song, An, and Kim (2003) showed that vegetable soybean blanched at higher temperatures for shorter time intervals had minimal loss of nutrients, including sugars, amino acids and vitamins. Nevertheless little research has been done comparing changes in sugar composition under different processing and storage conditions.

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The objectives of this work were to investigate the change in soluble sugars of fresh vegetable soybean under different storage conditions, and the effects of different blanching methods on the soluble sugar content in vegetable soybean during frozen storage.

2. Materials and methods

Vegetable soybean genotypes, V95-7456 and 03-CB14, were planted on May 21, 2007 in Fayetteville, Arkansas, USA V95-7456 is a large seeded genotype, and 03-CB14 is high in sucrose and low in oligosaccharides. Plants were grown in 4-row plots in a randomized complete block design with two replications, and only the two middle rolls of a soybean block were harvested for study. Vegetable soybean V95-7456 was harvested on August 29 and 31 for each replication, and 03-CB14 was harvested on September 5 and 7 when immature green seeds expanded fully in the pods. Each replication of harvested vegetable soybean received same treatments for fresh and frozen storage. Mature soybean of V95-7456 was harvested on September 26 and 28, and 03-CB14 was harvested on October 1 and 3 for each replication.

2.1. Fresh and frozen storage

For the fresh storage study, fresh soybean pods were stored at 4 °C in plastic bags flushed with nitrogen or air for 28 days. Soybean pods were also stored at 25 °C in nitrogen-flushed bags or in open air for 8–12 days. For the frozen storage study, vegetable soybean was blanched in boiling water or steam prior to freezing. Both water and steam blanching methods were applied to intact pods and shelled seeds of both soybean genotypes. Half of the vegetable soybean pods were manually shelled immediately after harvest, and the other half of pods were used directly for treatments. Shelled vegetable soybean seeds of 180 g or intact pods of 360 g were blanched in 3.8 L of boiling water for 10 min, or steamed at 100 °C for 10 min on the same day of harvest. The water blanching condition was selected according to the results of Song et al. (2003), and the same duration was used in steam blanching. Steam blanching was carried out in a covered steamer (Dixie Canner Co., Athens, GA, USA) where soybean pods or seeds were placed on a perforated stainless steel tray. After blanching, soybean pods or seeds were rapidly cooled in ice water for 1 min. After the water was drained, all soybean pods were shelled, and the seeds were packaged in zip-lock bags for frozen storage. Blanched soybean were stored at −20 °C and sampled monthly for 6 months for sugar analysis.

2.2. Extraction, separation and quantification of soluble sugars

For each soybean sample, 40 g of soybean seeds were taken and dried at 40 °C for 24 h, ground with a coffee grinder for 60 s, and passed through a 150-μm sieve screen (W.S. Tyler, Nentor, OH, USA). Samples were stored in hermetic bottles at 4 °C before analysis. Ground soybean (0.15 g) was extracted with 1.5 mL of double distilled water in a 2-mL centrifuge tube. The tube was shaken horizontally (Barnstead 1314, Melrose Park, IL, USA) at ambient temperature at 200 rpm for 20 min, and then centrifuged at 20,000×g for 10 min. Supernatant (500 μL) was removed and mixed with 0.7 mL acetonitrile in a 1.5-mL tube, and kept at room temperature for 30 min. The mixture was centrifuged at 20,000×g for 10 min, and the supernatant was filtered through a 0.2-μm membrane. Filtrate (24 μL) was dissolved in 576 μL double distilled water prior to HPLC analysis (Giannoccaro, Wang, & Chen, 2006).

High-performance anion-exchange chromatography with pulsed-amperometric detection (HPAEC-PAD) was used for separation and quantification of soluble sugars. Samples were injected via a Dionex autosampler equipped with a 25-μL sample loop. Sugars were separated on a Dionex CarboPac PA 10 pellicular anion-exchange resin column (250 mm × 4 mm i.d.), preceded by a Dionex CarboPac PA 10 guard column (50 mm × 4 mm i.d.), and a Dionex AminoTrap column (30 mm × 3 mm i.d.) at a flow rate of 1 mL/min (Dionex, Sunnyvale, CA, USA). The mobile phase consisted of 90 mmol/L NaOH solution prepared by diluting carbonate-free 19.1 mol/L NaOH solution in distilled water, which was previously filtered with a 0.45-μm membrane. The detection of sugars was accomplished by ED40 electrochemical detector. Commercial saccharides, including glucose, fructose, sucrose, raffinose and stachyose, were purchased from Sigma Co. (St. Louis, MO, USA) and used as external standards to identify and quantify the sugars based on their retention times and peak areas. The results were expressed as percentage on a dry-weight basis.

2.3. Statistical analysis

Analysis of variance (ANOVA) and LSD test for mean separation were used to detect significant differences among soybean soluble sugar contents under different processing and storage conditions. Data were analyzed with JMP software version 7.0.1 (SAS Software Institute, Cary, NC, USA).

3. Results and discussion

Table 1 lists the sugar composition in both soybean genotypes harvested at both vegetable and mature stages. Glucose, fructose, sucrose and raffinose were present in vegetable soybean seeds of both genotypes at harvest, and sucrose was the predominant sugar (Table 1). Stachyose was not found in vegetable soybean. Genotype 03-CB14 had higher sucrose content, but lower raffinose content than V95-7456 in vegetable soybean seeds. The glucose and fructose levels were similar in both genotypes. Mature soybean of both genotypes had significantly higher raffinose and stachyose, but lower fructose than vegetable soybean. The sucrose content decreased in V95-7456 during maturation but increased significantly in 03-CB14.

3.1. Fresh storage in air

Fresh soybean pods stored in plastic bags at 4 °C in air showed little change in appearance during 28 days of storage. The color of soybean pods and seeds became slightly dark green over time. The color change may be due to the loss of water at the beginning of storage and/or the loss of magnesium ion in the porphyrin ring of chlorophyll (Chen, Guo, Lai, & Chang, 1995). The presence of water drops in plastic bags indicated that vegetable soybean still respired when stored at 4 °C.

In contrast, soybean stored at 25 °C under open air condition displayed drastic changes in appearance. Soybean pods started turning yellow on the second day of storage. On the 4th day, most of the soybean pods already turned yellow, nevertheless only one third of soybean seeds turned yellow. On the 6th day, soybean pods

Table 1
Soluble sugar content (mg/g dry seeds) in vegetable soybean and mature soybean of V95-7456 and 03-CB14 at harvest.

	Soybean	Glucose	Fructose	Sucrose	Raffinose	Stachyose
V95-7456	Vegetable	1.1 ± 0.0[a]	0.8 ± 0.1	52.8 ± 1.9	1.0 ± 0.2	0.0 ± 0.0
	Mature	1.1 ± 0.1	0.1 ± 0.0	49.6 ± 0.5	6.4 ± 0.0	37.7 ± 0.4
03-CB14	Vegetable	1.5 ± 0.2	0.9 ± 0.2	67.7 ± 1.6	0.1 ± 0.1	0.0 ± 0.0
	Mature	1.1 ± 0.2	0.2 ± 0.4	94.7 ± 0.5	2.9 ± 0.0	2.3 ± 0.1

[a] Standard deviation ($n = 2$).