Composition, Cooking Time, and Maturation of Azuki (*Vigna angularis*) and Common Beans (*Phaseolus vulgaris*)

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ABSTRACT

ur azuki and two common bean cultivars harvested at three stages aturity (moisture range of about 15 to 8%) were analyzed for imate composition, fatty acid composition, and cooking quality. i contained less ash, free lipid, and insoluble and soluble dietary than common beans. Ash, protein, and free lipid content (dry weight) did not change consistently during azuki maturation. Cotyledons uki and common beans account for almost the entire nutritive value e whole seed. Insoluble dietary fiber of azuki and common beans nost entirely derived from the hulls, which make minor contributions otein and free lipids. The free lipids of azuki were lower in unsaturated acids and higher in saturated fatty acids than the free lipids of common beans. Major changes in the concentrations of caproic and linolenic acids and minor changes in the concentrations of palmitic, stearic, oleic, and linoleic acids in free lipids were observed during azuki maturation. Immature azuki (moisture 13–15%) was higher in saturated fatty acids than mature (10–11%) or overmature (8–9%) azuki. Dry seeds of common beans required longer cooking than azuki. Overmature azuki required longer cooking than immature or mature seeds. Presoaking reduced cooking times less in overmature than in immature or mature azuki. Differences between azuki and common beans in the effect of presoaking on the cooking time of beans of varying maturity may be related to differences in water imbibition characteristics.

zuki or small red beans (*Vigna angularis* (Willd.) Ohwi & shi) are a popular ingredient in many confections in the nt. Large and stable consumption of azuki is concentrated apan, where the bean has an important economic value. The ominant use of azuki in traditional Japanese confections is aste, a bean jam.

e most important step in the processing of *an* paste is cooking, h directly affects the other steps in the process and contributes e final quality and yield of the bean paste. To achieve the acteristic texture of *an,* the azuki are well boiled and softened ch a way that the cells are separated freely without damage ll membranes. Azuki that require prolonged cooking yield vith impaired texture. Stored beans requiring extended ing times have been extensively reported in studies of the -to-cook phenomenon by Morris and Wood (1956), Burr (1968), Sefa-Dedeh et al (1979), and Hohlberg and Stanley 7) and in studies of the hard-shell phenomenon by Morris (1950), Werker et al (1979), and Rodriguez and Mendoza). However, the cooking times of freshly harvested beans been studied only to a limited extent. Cooking quality of beans was not correlated with moisture content in studies luneta (1964) and Proctor and Watts (1987).

the Western world, the consumption of fat is shifting from products containing animal fats to food products containing able oil because of the potential effect of saturated fatty on obesity, atherosclerosis, coronary heart disease, and cardial infarction. Legume lipids and dietary fibers are being ested for dietary reduction of blood cholesterol because legumes contain substantial amounts of desirable polyunsaturated fatty acids and fiber (Salunkhe and Kadam 1989). The nutritive value of azuki has been investigated in studies concerned with the chemical composition of the whole seed by Sacks (1977), Kay (1979), Duke (1981), Hayakawa and Breene (1982), and Tjahjadi (1983). Little information is available about the dietary fiber content and fatty acid composition of azuki seeds.

During processing of strained azuki paste, the hull is removed, and a paste with very fine particles is produced. Paste quality is related to the chemical composition and distribution of components in the whole seed. Singh et al (1968) reported that the legume seed is heterogeneous and the botanical tissues differ widely in chemical composition.

In the United States, the cultivation of azuki and the processing of azuki paste that meets the requirements of the Japanese market are being encouraged (Breene and Hardman 1987, McClary et al 1989). Azuki cultivation is being evaluated in Washington State, where the climate is similar to that of the major azuki production area on Hokkaido Island in northern Japan. In addition to climate and growth conditions, the maturity of harvested azuki should be considered. Tanteeratarm et al (1989) reported that certain antinutritive components that govern storage stability and processing quality of soybeans are related to maturity. Immature seeds contain lower concentrations of trypsin inhibitors and urease and lipoxygenase activities and higher concentrations of free fatty acids.

The objective of this research was to evaluate the characteristics of azuki harvested in Washington at three stages of maturity. We determined the proximate composition, dietary fiber, fatty acid composition of free lipids, cooking quality, and water imbibition of azuki cultivars Erimo, Express, Hatsune, Takara, and VBSC. We also studied the distribution of several components in azuki seeds and the effects of maturity on the proximate composition, fatty acid composition of free lipids, and cooking

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quality of azuki. Common bean (*Phaseolus vulgaris*) cultivars Black Turtle Soup and Small Red were included for comparison.

MATERIALS AND METHODS

In a preliminary study of the azuki and common bean cultivars mentioned above, seeds from several sources were assayed, including azuki harvested in Hokkaido, Japan, in 1988, azuki from several farms and seed companies in Washington State, harvested in 1989, and common beans from a seed company in Moses Lake, WA, harvested in 1989. In the main study, azuki and common beans at three stages of maturity were harvested continuously in September 1990. Azuki cultivars Erimo, Express, Hatsune, and Takara were from Washington State University Irrigated Agriculture and Extension Center, Prosser, WA. Common bean cultivars Black Turtle Soup and Small Red were from Moses Lake, WA. Beans were removed from harvested pods and stored in sealed jars at 4°C until further experimentation.

We prepared flours by grinding beans with a Udy cyclone mill (Udy Corp., Fort Collins, CO) to pass through a sieve with round openings 0.5 mm in diameter.

Chemical Analysis

Bean flours were analyzed for protein ($N \times 6.25$) by combustion with thermoconductivity detection with a nitrogen determinator (Leco Corporation, St. Joseph, MI), for ash by dry combustion (AACC 1983, Method 08-01), for moisture by oven drying for 1 hr at 130°C (AACC 1983, Method 44-15A), and for free lipids by petroleum ether extraction, followed by evaporation to a constant weight under vacuum (AACC 1983, Method 30-25). Carbohydrate concentrations of the flours were calculated by difference. Insoluble and soluble dietary fiber (IDF and SDF, respectively) were determined by the procedure of Prosky et al (1988) for the five azuki and two common bean cultivars from the preliminary study. Results for proximate analyses and dietary fiber assays are means of at least duplicate determinations (all expressed on a dry weight basis [dwb]).

Gas Chromatography

Lipid extract (approximately 100 mg) was butylated by gentle boiling in a 0.5*N* butanolic potassium hydroxide solution for 2 min. The mixture was cooled to 25°C, 3 ml of 12.5% boron trifluoride-butanol reagent (Supelco, Inc., Bellefonte, PA) was added, and the mixture was gently boiled for 3 min. After the mixture cooled to 25°C, fatty acid butylesters (FABEs) were extracted from the reaction mixture with hexane (Iverson and Sheppard 1977).

The FABEs were analyzed with a Varian 2700 GC chromatograph with a stainless steel column (1.8 m × 2 mm i.d.) containing 10% SP2330 impregnated on 100- to 120-mesh chromosorb W-AW and a flame ionization detector (Supelco). Nitrogen carrier gas flow rate was 20 ml/min. The temperature of the injector and the detector was 250°C. The column temperature was 150°C for 1 min, increased to 200°C at the rate of 20°C/min, and was maintained at 200°C for 20 min to complete elution of FABEs. Individual fatty acid esters were identified based on standard retention times (Sigma Chemical Co., St. Louis, MO), and quantity was estimated based on peak areas of known concentrations of the standards (AOCS 1989).

Water Imbibition

Beans (100 g, dwb) were placed in 1-L graduated cylinders containing 500 ml of distilled water and soaked for 24 hr at 25°C. Bean volume and water volume were recorded at intervals of 2–3 hr. After soaking, the cotyledons of azuki and common beans were separated from the hulls by hand. The cotyledons, hulls, and 24-hr soaking solutions were each freeze-dried, and their moisture was determined before they were analyzed for ash, protein, and lipid content.

Cooking

Beans were soaked at 25°C for 0, 5, 10, or 24 hr in a volume of distilled water five times their dry weight. Raw beans and soaked beans were cooked in a boiling water bath at atmospheric pressure. The experimental cooker we used is a modified version of the apparatus described by Mattson (1946) and is composed of a cooker rack and 25 plungers (90 g), each terminating with a stainless steel rod 1/16 in. (0.16 cm) in diameter that rests on top of a bean. The cooker is loaded with beans and then plunged into a boiling water bath. As cooking progresses, beans become sufficiently tender and are penetrated by the rod. The cooking time (minutes) and the number of beans softened per minute were recorded. Data reported here are the means and standard deviations of the cooking times of 50–75 individual beans cooked 100%.

Statistical Analysis

Data were analyzed with the statistical analysis system of the SAS Institute (1985). Least significant differences were computed at the 5% level.

RESULTS AND DISCUSSION

Proximate Composition of the Whole Seed

In the preliminary study, the moisture content of azuki and common beans from various sources and years ranged from 8.2 to 12.0% except for a single sample of azuki cultivar Express, which had a moisture content of 14.0%. Azuki and common beans had mean values of 4.0 and 4.5%, respectively, for minerals (expressed as ash); 24.5 and 23.9%, respectively, for protein; 0.5 and 1.5% for free lipids; and 71.0 and 69.9% for carbohydrate. The proximate compositions of azuki and common beans in our study were similar to the results reported by Sacks (1977), Kay (1979), Duke (1981), Hayakawa and Breene (1982), Tjahjadi (1983), and Salunkhe et al (1989). Common beans contained significantly ($P < 0.05$) higher concentrations of minerals (ash) and free lipids than azuki (*data not shown*).

Azuki cultivars grown in different years and in different production areas varied some in their concentrations of ash, protein, free lipids, and carbohydrate. Protein content ranged from 20.5 to 28.4%. Variations in protein content apparently were due more to differences in production areas than to genetic heterogeneity among azuki cultivars. Variations in the protein content of azuki due to the growing region were also observed on Hokkaido Island by Yoshida et al (1988).

TABLE I
Proximate Composition of 1990 Azuki and Common Beans[a]

Cultivar	ST[b]	Moisture (%)	Ash[c] (%)	Protein[c] (%)	Free Lipid[c] (%)	Carbohydrate[c,d] (%)
Common						
Black Turtle Soup	IM	13.49 a	4.36 a	25.32 b	1.44 a	68.88
	M	10.82 b	4.22 a	24.78 c	1.25 b	69.75
	OM	8.73 c	4.27 a	26.64 a	1.29 b	67.80
Small Red	IM	13.08 a	4.16 b	22.94 b	1.32 a	71.58
	M	10.34 b	4.09 b	23.17 b	1.26 ab	71.48
	OM	7.39 c	4.30 a	28.68 a	1.10 b	65.92
Azuki						
Erimo	IM	13.64 a	3.85 a	26.63 a	0.36 a	69.16
	M	10.84 b	3.74 b	26.73 a	0.39 a	69.14
	OM	8.61 c	3.70 b	25.64 b	0.30 a	70.36
Express	IM	15.34 a	3.94 a	27.58 a	0.33 b	68.15
	M	9.73 b	3.90 a	26.57 b	0.32 b	69.21
	OM	7.38 c	3.87 a	26.72 b	0.44 a	68.97
Hatsune	IM	13.60 a	3.76 a	24.53 a	0.60 a	71.11
	M	10.58 b	3.68 a	22.75 b	0.40 b	73.17
	OM	8.67 c	3.79 a	21.68 c	0.39 b	74.14
Takara	IM	11.25 ab	3.83 b	26.47 a	0.32 a	69.38
	M	10.84 b	3.96 a	26.89 a	0.34 a	68.81
	OM	7.51 c	3.87 b	26.83 a	0.35 a	68.95

[a] Results followed by the same letter within a column for a single cultivar are not significantly different ($P < 0.05$).
[b] Stage of maturation: IM, immature; M, mature; OM, overmature.
[c] Dry weight basis.
[d] Calculated by difference.

TABLE II
Fatty Acid Composition of 1990 Azuki and Common Beans[a]

Cultivar	ST[b]	Saturated Fatty Acids (S)						Unsaturated Fatty Acids (US)				
		6:0	12:0	14:0	16:0	18:0	Total	18:1	18:2	18:3	Total	US/S
Common												
Black Turtle Soup	IM	1.82 b	0.15	0.13	7.89 a	1.11 a	11.10 a	8.41 b	18.64 a	35.29 b	62.34 b	5.62
	M	0.85 c	0.29	0.37	8.25 a	1.21 a	10.97 a	9.45 a	20.47 a	40.49 a	70.41 a	6.42
	OM	2.52 a	0.11	0.12	6.35 b	1.16 a	10.26 b	7.99 b	19.38 a	41.51 a	68.88 a	6.71
Small Red	IM	5.01 a	0.13	0.08	9.11 a	0.87 ab	15.20 a	5.26 a	21.53 a	39.17 b	65.96 b	4.34
	M	0.74 c	0.50	0.69	8.51 a	0.98 a	11.42 b	5.66 a	22.51 a	41.92 a	70.09 a	6.14
	OM	2.08 b	0.25	0.13	6.64 b	0.79 b	9.89 b	4.34 b	18.49 b	37.03 b	59.86 c	6.05
Azuki												
Erimo	IM	12.47 a	0.05	0.24	10.72 a	1.42 a	24.90 a	2.21 a	14.88 a	12.42 b	29.51 a	1.19
	M	4.56 b	0.25	0.27	8.15 b	1.30 a	14.53 b	2.24 a	13.00 b	14.08 a	29.32 a	2.02
	OM	5.53 b	0.13	0.15	8.24 b	1.26 a	15.31 b	2.41 a	13.52 ab	14.88 a	30.81 a	2.01
Express	IM	7.63 a	0.25	0.18	8.90 a	1.22 b	18.18 a	2.21 b	14.90 ab	15.10 b	32.21 b	1.77
	M	4.63 c	0.15	0.40	8.56 a	1.47 a	15.21 b	2.59 a	15.34 a	17.75 a	35.68 a	2.35
	OM	6.01 b	0.05	0.12	7.98 a	1.40 ab	15.56 b	2.39 ab	13.89 b	15.08 b	31.36 b	2.02
Hatsune	IM	13.98 a	0.92	0.56	9.83 c	1.67 b	26.96 a	2.88 c	13.81 c	11.63 c	28.32 c	1.05
	M	2.20 c	0.36	0.31	11.45 b	1.83 a	16.15 c	3.98 a	20.19 a	17.30 a	41.47 a	2.57
	OM	7.77 b	0.14	0.19	12.53 a	1.85 a	22.48 b	3.76 b	17.37 b	16.38 b	37.51 b	1.67
Takara	IM	14.64 a	0.29	0.23	9.31 b	1.16 b	25.63 a	2.05 b	13.83 c	13.71 b	29.59 b	1.15
	M	5.48 b	0.19	0.30	10.11 a	1.44 a	17.52 b	2.50 a	15.98 a	16.99 a	35.47 a	2.02
	OM	6.13 b	0.06	0.17	8.09 c	1.40 a	15.85 c	2.49 a	14.98 b	17.34 a	34.81 a	2.20

[a] Data are percentages of free lipid. Percentages followed by the same letter within a column for a single cultivar do not differ significantly ($P < 0.05$).
[b] Stages of maturation: IM, immature; M, mature; OM, overmature.

Proximate Composition and Maturity

Table I summarizes the proximate composition of azuki and common beans at three stages of maturity. Moisture contents of both types of beans were 13.1–15.3%, 9.7–10.8%, and 7.4–8.7% in immature, mature, and overmature seeds, respectively, except for the immature azuki cultivar Takara, which was harvested later than others and contained 11.3% moisture. Concentrations of minerals (ash), protein, and free lipids were not directly related to the maturation process. Similarly, Iskander (1987), Howell and Caldwell (1972), Yao et al (1983), and Tanteeratarm et al (1989) reported that the concentrations of most mineral elements, lipids, and protein in soybeans were not directly related to the late stages of maturation, and Kermasha et al (1986) reported that succulent green seed and mature dried seed of French beans (*P. vulgaris*) contained similar lipid concentrations. Privett et al (1973), however, reported that total lipids of soybeans increased significantly during the late stages of maturation. Changes in lipid classes and fatty acid composition were more related to soybean maturation than were changes in total or free lipid concentrations (Hirayama and Hujii 1965, Roehm and Privett 1970, Privett et al 1973, Kermasha et al 1986, Sangwan et al 1986).

Proximate Composition of Cotyledon and Hull

The mean weight percentages of cotyledons and hulls of azuki and common beans (dwb), determined by hand-separation of soaked seeds, were 86% and 9%, respectively, which is comparable to a typical distribution of cotyledon and hull in legume seeds (Singh et al 1968). Mean contents of ash and protein in cotyledons were similar for azuki (3.5% and 26.8%, respectively) and common beans (3.5% and 25.6%). The concentration of free lipids in the cotyledon was substantially higher in common beans (1.60%) than in azuki (0.58%). Ash content of the hull was higher for common beans (5.8%) than for azuki (2.3%). The protein content of the hull was similar for both (7.4% for azuki and 7.8% for common beans). Our values for ash, protein, and free lipids in cotyledons and hulls of common beans are generally comparable to those reported by Singh et al (1968); some small differences may be attributed to the effects of cultivar, soil, climate, and cultural practices.

Azuki and common beans soaked for 24 hr leached 1.2 and 2.0% solids (dwb), respectively. The solids in the material leached from azuki contained 20.6–34.1% (mean 24.6%) minerals (ash) and 9.6–22.2% (mean 15.3%) protein. The solids in the material leached from common beans contained 19.2–25.2% (mean 22.2%) minerals and 18.6–20.4% (mean 19.5%) protein.

The results of this study confirm that in azuki, as in other legume seeds, cotyledons account for almost the entire food value of the whole azuki. The hulls are a minor part and are low in most components except carbohydrates.

Dietary Fiber Composition of Whole Seed and Cotyledon

IDF in whole seeds of azuki and common beans averaged 14.1 (0.9) and 20.3 (1.0)%, respectively (numbers in parentheses are standard deviations), and SDF averaged 3.7 (0.9) and 6.1 (0.4)%, respectively. Hughes and Swanson (1989) reported IDF of 10.3% and SDF of 7.0% for whole seeds of common beans of cultivar Tamazulapa. The divergence between our IDF data and theirs may be the result of differences in cultivars and assays. As expected, mean IDF and SDF were lower in cotyledons (7.1 [0.4] and 3.4 [0.6]%, respectively, in azuki, and 15.6 [2.1] and 4.9 [0.1]%, respectively, in common beans) than in whole seeds. Based on the IDF contents of whole seed and cotyledons, we estimated that hulls of common beans and azuki contained 60–81% (mean 71%) and 69–94% (mean 79%) IDF, respectively.

Fatty Acid Composition and Maturity

Free lipids (petroleum ether-extractable) in both azuki and common beans contained large amounts of linoleic (18:2) and linolenic (18:3) acids, medium to small amounts of palmitic (16:0), oleic (18:1), and stearic (18:0) acids, and negligible amounts of lauric (12:0) and myristic (14:0) acids (Table II). Oleic and linolenic acids were more concentrated in lipids of common beans than in azuki lipids. Azuki lipids contained more total saturated fatty acids than lipids of common beans. The ratios of unsaturated to saturated fatty acids were significantly higher in lipids of common beans (4.3–6.7) than in lipids of azuki (1.1–2.6).

Variable concentrations of caproic acid (6:0), generally smaller for common beans than for azuki, were not reported by Kermasha et al (1986) or Drumm et al (1990). Caproic acid may not have been observed previously because its concentration in lipids of mature common beans is low (0.7–0.9%) and because of the limited scope of previous analyses of the fatty acid composition of azuki (Kay 1979).

We observed major changes in the concentrations of caproic and linolenic acids during azuki seed maturation, which can be classified into two patterns. In one pattern (cultivars Erimo and Takara), the lipids of immature seeds contained 12.5–14.6% caproic acid, which decreased as seeds matured and then remained constant as seeds became overmature, and 12.4–13.7% linolenic acid, which increased as seeds matured and then remained constant as seeds became overmature. In the other pattern (cultivars Express and Hatsune), the lipids of immature seeds contained 7.6–14.0% caproic acid, which decreased as seeds matured and increased again as they became overmature, and 11.6–15.1% linolenic acid, which increased as seeds matured and decreased again as they became overmature. For azuki cultivars (unlike common beans), the decrease in caproic acid apparently was related to the increase in linolenic acid. However, the relationship between caproic and linolenic acids in fatty acid synthesis during azuki maturation is not clear and requires additional investigation.

The proposed pathway for fatty acid synthesis in higher plants involves the formation of palmitoyl-ACP from acetyl-CoA and malonyl-CoA catalyzed by type II fatty acid synthetases. The elongation of palmitoyl-ACP through stearoyl-ACP and the formation of long-chain fatty acids are catalyzed by type III fatty acid synthetases. The substrate for fatty acid elongation may vary depending on plant tissue (Gunstone et al 1986). Hitchcock and Nichols (1971) indicated that fatty acids constituting the lipids of mature seeds are not usually synthesized at constant rates throughout maturation.

Changes in the concentrations of palmitic, stearic, oleic, and linoleic acids in lipids of azuki and common beans during maturation varied. Large concentrations of total saturated fatty acids in immature seeds were associated with the presence of considerable amounts of caproic acid, which also resulted in lower ratios of unsaturated to saturated fatty acids for the immature stage than for the mature and overmature stages of azuki seeds.

Because this study was designed to determine the maturation stage most suitable for optimum processing of azuki seed, we selected maturity stages that differ from those in other studies of maturing legume seeds. Seed maturity stages studied by Privett et al (1973), Kermasha et al (1986), and Sangwan et al (1986) ranged from very immature to mature, and the intervals of each maturation period were broader than those in this study.

Cooking Time

Dry seed. In the preliminary study, cooking times of mature seeds of 1988 and 1989 azuki cultivars ranged from 40 to 61 min. Cooking times of azuki cultivars were affected by maturity stage (Table III). Maturation increased cooking time. Hayakawa and Breene (1982) reported that azuki cooking quality decreased as moisture content fell below 8%.

Common beans required substantially longer cooking than azuki. Previous studies revealed that the relationship between moisture content and cooking quality of freshly harvested seeds differed among common bean cultivars. Morris and Wood (1956) reported that firmness of freshly harvested cooked beans increased as the moisture content rose from 8 to 18% for cultivars Red Kidney, Red Mexican, California Small White, and Maculate. No direct relationship was established between cooking time or texture of cooked beans and moisture content for cultivars Great Northern and Pinto (Morris and Wood 1956) or Navy (Proctor and Watts 1987).

Soaked seed. The mean cooking times of azuki soaked for 10 and 24 hr were 26.1 (10.7) and 18.8 (14.0) min, respectively (numbers in parentheses are standard deviations). In general, soaking seed for 24 hr resulted in a small additional reduction in cooking times compared to soaking for 10 hr. The correlation between cooking times of unsoaked and soaked azuki was 0.96 for 10-hr soaking and 0.75 for 24-hr soaking. High correlations between cooking times of dry seeds and seeds soaked for 16 hr were reported for faba beans ($r = 0.89$) and lentils ($r = 0.85$) but not for chickpeas (Singh et al 1988).

The influence of maturity on cooking times of azuki and common beans soaked for 5 hr is shown in Table III. Overmature azuki seeds soaked for 5 hr required significantly longer cooking than immature or mature seeds. Cooking times of common beans soaked for 5 hr increased slightly as beans matured. Cooking times of immature, mature, and overmature seeds soaked for 5 hr differed much less for common beans than for azuki, which may reflect the rapid water imbibition of common beans during 4–8 hr of soaking (Fig. 1).

TABLE III
Cooking Times[a] of 1990 Azuki and Common Beans Harvested at Three Stages of Maturity

Cultivar	State of Maturity[b] IM	M	OM
No Presoaking			
Common			
Black Turtle Soup	61.2 ± 10.4 d	64.1 ± 6.1 d	71.0 ± 7.8 c
Small Red	66.6 ± 5.0 d	72.3 ± 8.7 c	65.0 ± 7.9 d
Azuki			
Erimo	34.9 ± 6.0 d	51.2 ± 12.0 c	55.4 ± 18.3 c
Express	42.2 ± 12.7 d	50.3 ± 12.0 c	54.9 ± 10.8 c
Hatsune	35.5 ± 6.5 e	45.6 ± 13.6 d	59.0 ± 14.8 c
Takara	42.7 ± 12.6 e	51.9 ± 13.8 d	59.6 ± 9.1 c
5-hr Soaking			
Common			
Black Turtle Soup	22.2 ± 3.8 d	23.3 ± 3.9 cd	24.4 ± 5.3 c
Small Red	34.5 ± 9.0 d	38.4 ± 15.9 cd	45.9 ± 16.4 c
Azuki			
Erimo	19.6 ± 8.4 e	41.2 ± 12.0 d	53.0 ± 13.5 c
Express	30.8 ± 17.1 d	45.0 ± 11.4 c	45.9 ± 10.3 c
Hatsune	21.9 ± 8.6 d	25.8 ± 13.1 d	42.3 ± 8.7 c
Takara	33.3 ± 12.0 d	36.2 ± 7.9 d	57.1 ± 19.4 c

[a] Data are numbers of minutes and are shown as mean ± standard deviation. Means within a row followed by the same letter do not differ significantly ($P < 0.05$).
[b] IM, immature; M, mature; OM, overmature.

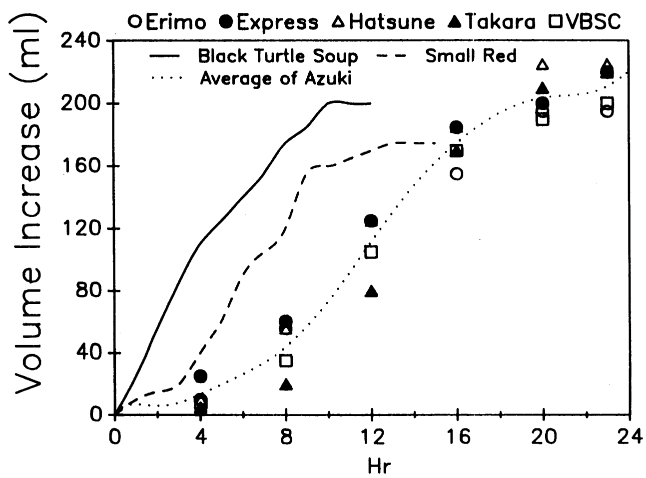

Fig. 1. Water imbibition of 1988 azuki (averages for cultivars Erimo, Express, Hatsune, Takara, and VBSC) and common beans (cultivars Black Turtle Soup and Small Red).

Insofar as processing of azuki paste is concerned, overmature seeds requiring longer cooking should be considered inferior to mature seeds.

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