Correlations Between Physical Properties and Canning Quality Attributes of Navy Bean (*Phaseolus vulgaris* L.)

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ABSTRACT

The correlations between physical properties of raw navy beans and canning quality were investigated. The pasting viscosity of navy bean flour measured by Rapid Visco-Analyzer (RVA) correlated significantly with washed drained weight and firmness of canned beans. The extract viscosity of the bean flour with a pH 10 sodium carbonate buffer (4%, w/v) correlated significantly with washed drained weight, firmness, split, viscosity of canned bean medium, and overall acceptance. Correlation also existed between RVA pasting viscosity and pH 10 buffer extract viscosity. These physical tests are simple, fast, and economical. They showed high potential for navy bean breeders to predict early navy bean generation genotypes for improved canning quality.

Most of the navy beans (*Phaseolus vulgaris* L.) produced in the United States are canned (Ghaderri et al 1984). However, bean varieties without desirable food quality attributes may not meet the requirements of canners and consumers. Research has bean conducted on the physical properties of navy bean related to canning quality. Physical factors such as bean size (Faris and Smith 1964), hydration ability (Quast and da Silva 1977, Sefa-Dedch et al 1978, Hosfield and Uebersax 1980, Moscoso et al 1984), starch gelatinization (Lineback and Ke 1975), and cooking time (Burr et al 1968, Hentges et al 1991) were reported to play roles in the canning quality of dry beans.

The purpose of this study was to investigate the correlation between physical property traits of raw navy beans and canning qualities. The correlations among the physical property traits were also studied. Some correlations could be further used to develop methods for screening early bean generation genotypes for improved canning quality.

MATERIALS AND METHODS

Beans

Eleven navy bean genotypes were produced in two North Dakota locations, Arthur and Hatton, in 1991. The genotypes were Midland, Pearl, Mayflower, Schooner, Crestwood, 88-104-05, 88-100-11, 88-092-08, 88-125-03, 88-106-04, and 88-099-28. The genotypes were sampled from each location so that 22 samples were received. Upon receipt, the beans were hand-cleaned to remove cull beans and foreign materials, sealed in plastic bags, and stored at 4°C until use. All determinations were made in duplicate.

Raw Bean Physical Properties

Seed size and seed coat damage. The number of navy beans in 20 ± 0.05 g (dwb) of sample was counted as an index of seed size. Seed coat damage was determined using indoxyl acetate-ethanol and ammonia (French et al 1962, Paulsen and Nave 1979).

Hydration degree, nonhydration seeds, and pin-cooking time. Beans were soaked with distilled water for 16 hr at 25°C. The soaked beans were weighed every 2 hr. The time with the largest variation in weights was chosen, and the moisture contents were used for hydration degree analysis. After soaking for 16 hr, the beans were drained, and the number of nonhydrated beans was recorded. Pin-cooking time was measured after navy beans were soaked for 16 hr at 25°C in water and drained before pin cooking. The Morris-Mattson pin-cooking apparatus was used for the pin-cooking time test. The 50% cook time (median) was recorded for statistical analysis.

RVA pasting viscosity and bean extract viscosities. The pasting viscosity of the bean flour was determined by the Rapid Visco-Analyzer. Bean flour (4 g) was added with 24–25 ml of distilled water so that the total weight of water and flour was constant at 28 g. A 12-min procedure was used for the determination. The determinations of extract viscosities were based on the procedures of Ullrich et al (1981) and Greenberg and Whitmore (1974), with slight modifications. Alkaline extracts were made with 1.4 g of bean flour extracted with 25 ml (4%, w/v) of sodium carbonate buffer (pH 10) for 80 min. Acid extracts were made with 1.6 g of bean flour extracted with 30 ml of buffer pH 1.5 (0.08*M* HCl and 7.46 g/L of KCl) for 80 min. After centrifugation at 1,000 × *g* for 15 min, an aliquot of each supernatant was taken, and the viscosities were measured by a cone-plate viscometer (Well-Brookfield Engineering Lab. Inc., Stoughton, MA).

Analysis of residue in the liquid after cooking beans. Beans were soaked for 2 hr at room temperature. Beans (10 g) were placed in a 125-ml flask, and a 50-ml portion of boiling water was added. The flask was covered with tin foil and cooked in retort at 121°C for 15 min. After cooling, the contents were drained through a U.S. No. 40 (420 μm) sieve. The liquid was diluted to 100 ml and analyzed. The filtrate was mixed thoroughly. A 1-ml portion of filtrate was added to a tube containing 5 ml of distilled water and mixed. The light transmittance (%*T*) of the suspension was measured using spectrophotometer at 660 nm for turbidity. After the filtrate settled for 1 hr, 1 ml of the clear portion of the filtrate was analyzed for viscosity using the viscometer. The rest of the filtrate was mixed again, and a 25-ml portion of the filtrate was dried in an air oven at 150°C overnight for solid weight. The remixed filtrate (1 ml) was diluted to 25 ml, and 0.1 ml of the diluted filtrate was used for the total carbohydrate content determination using the phenol-sulfuric acid method described by Dubois et al (1956).

Canned Bean Properties Determination

Canned bean properties, including drained weight, clumping, splitting, overall appearance, color, firmness, and viscosity of canned bean liquid were determined according to Lu and Chang (1996).

Statistical Analysis

Correlations among canning qualities and raw bean property traits were analyzed by Pearson correlation analysis. Differences

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in each physical or canning property were analyzed using Duncan's multiple range method at 0.05 and 0.01 significant levels. The homogeneity between each pair of correlation coefficients from two locations was tested by Chi square for each genotype.

RESULTS AND DISCUSSION

Generally, physical tests are relatively simple, fast, and inexpensive when compared to chemical tests for navy bean property evaluation. The significant correlations between the physical properties of raw navy beans and canning quality can be used by the bean breeders for predicting canning quality and screening early generation genotypes.

Raw Navy Bean Correlations Between Physical Properties and Canning Quality Traits

A significant correlation existed between RVA pasting viscosity of raw bean flour and washed drained weights and firmness of canned navy beans ($r = 0.80$, $P < 0.01$and $r = -0.77$, $P < 0.05$) (Table I). Navy beans with high pasting viscosity exhibited high drained weights and low firmness. Washed drained weights correlated with the viscosity of the bean flour extract in pH 10 sodium carbonate buffer ($r = 0.69$, $P < 0.05$) (Table I). The results reveal that the beans with high pasting and extract viscosities may take up more canning medium during canning processing to soften the beans and give high drained weights. The RVA pasting viscosity test using a small amount of beans is a faster than the procedure using the Brabender Amylogragh.

The viscosity of pH 10 buffer extract correlated positively with washed drained weight ($r = 0.69$, $P < 0.05$) and correlated negatively with firmness ($r = -0.76$, $P < 0.01$) and splitting ($r = -0.52$, $P < 0.05$) of canned beans. The viscosity of pH 1.5 buffer extract correlated with firmness ($r = -0.63$, $P < 0.05$), splitting ($r = -0.69$, $P < 0.05$) and overall acceptance ($r = -0.68$, $P < 0.05$). The chemical nature and amount of the extracts from 10 and 1.5 pH buffers contributed to the differences of correlation coefficients.

The seed coat damage was not related to the splitting of canned navy beans (Table II). Faris and Smith (1964) reported a positive correlation between mechanical damage and the splitting of dark red kidney beans when canned. However, the influence of seed coat damage on splitting may depend on the processing method and the

TABLE I
Correlations Among Canned Bean Quality Traits and Rapid Visco Analyser (RVA) and Extract Pasting Viscosities

	RVA Pasting Viscosity	Viscosity of Extract pH 10	Viscosity of Extract pH 1.5
Drained weight	0.80**[a]	0.69*	0.47
Clumping	0.11	0.17	0.27
Splitting	–0.42	–0.52*	–0.69*
Firmness	–0.77*	–0.76**	–0.63*
Color (*L* value)	0.32	0.44	0.42
Starchiness	0.02	0.01	0.03
Viscosity of canned bean medium	0.46	0.68*	0.25
Overall score	–0.40	–0.48	–0.68*

[a] * = Significant difference ($P < 0.05$); ** = significant difference ($P < 0.01$).

TABLE II
Correlations Among Canned Bean Quality Traits and Seed Size, Hydration Degree, Nonhydrated Beans, Seed-Coat Damage, and Pin-Cooking Time

	Seed Size	Hydration Degree	Nonhydrated Beans	Seed Coat Damage	Pin-Cooking Time
Drained weight	0.05	–0.22	0.09	–0.20	–0.23
Clumping	–0.13	0.13	–0.13	–0.17	–0.25
Splitting	0.15	–0.37	0.36	0.01	0.14
Firmness	–0.01	–0.04	0.16	0.13	0.11
Color (*L* value)	–0.31	0.89**[a]	–0.89**	0.22	–0.32
Starchiness	–0.12	–0.28	0.34	–0.19	–0.10
Viscosity of canned bean medium	–0.08	–0.07	–0.03	–0.03	–0.20
Overall score	0.09	–0.36	0.37	–0.10	–0.08

[a] ** = Significant difference ($P < 0.01$).

TABLE III
Correlations Among Turbidity, Viscosity, Dry Residue Weight, Total Carbohydrate of Micro-Cooking Liquid (MCL), and Canning Quality Traits

	MCL Turbidity	MCL Viscosity	MCL Dry Residue	MCL Total Carbohydrate
Drained weight	0.20	–0.13	–0.29	–0.39
Clumping	0.53*[a]	–0.29	–0.32	–0.37
Splitting	0.21	–0.27	–0.15	0.32
Firmness	–0.01	0.01	0.21	0.42
Color (*L* value)	0.09	0.1	0.1	–0.08
Starchiness	0.52*	–0.43	–0.48	–0.18
Viscosity of canned bean medium	0.36	–0.25	–0.38	–0.28
Overall score	0.38	–0.35	–0.21	0.24

[a] * = Significant difference ($P < 0.05$).

TABLE IV
Correlations Among Seed Size, Hydration Degree, Nonhydrated Beans, Seed Coat Damage, and Other Raw Navy Bean Property Traits

	Seed Size	Hydration Degree	Nonhydrated Beans	Seed Coat Damage
Seed size	···	–0.42	0.48	–0.52*[a]
Hydration degree	–0.42	···	–0.95**	0.39
Nonhydrated beans	0.48	–0.95**	···	–0.46
Seed coat damage	–0.52*	0.39	–0.46	···
Pin-cooking time	0.32	–0.17	0.21	–0.09
Pasting viscosity[b]	–0.01	0.09	–0.25	–0.05

[a] * = Significant difference ($P < 0.05$); ** = significant difference ($P < 0.01$).
[b] Measured by Rapid Visco Analyser.

TABLE V
Correlations Among Pin-Cooking Time, Rapid Visco Analyser (RVA) Pasting Viscosity, Viscosity of Extract, and Other Raw Bean Properties

	Pin-Cooking Time	RVA Pasting Viscosity	Viscosity of Extract pH 10	Viscosity of Extract pH 1.5
Pin-cooking time	···	–0.30	–0.25	–0.06
RVA pasting viscosity	–0.30	···	0.90**[a]	0.63*
Viscosity of extract				
pH 10	–0.25	0.90**	···	0.69*
pH 1.5	–0.06	0.63*	0.69*	···
Micro-cooking bean liquid				
Turbidity	–0.06	0.04	0.07	0.24
Viscosity	–0.27	–0.09	–0.05	–0.17
Dry residue	–0.39	–0.20	–0.22	–0.34
Total carbohydrate	0.24	–0.43	–0.46	–0.27

[a] * = Significant difference ($P < 0.05$); ** = significant difference ($P < 0.01$).

TABLE VI
Correlations Among Turbidity, Viscosity, Dry Residue Weight, and Total Carbohydrate of Micro-Cooking Liquid (MCL)

	MCL Turbidity	MCL Viscosity	MCL Dry Residue	MCL Total Carbohydrate
MCL				
Turbidity	···	–0.78**[a]	–0.81**	–0.13
Viscosity	–0.78**	···	0.87**	0.09
Dry residue	–0.81**	0.87**	···	0.04
Total carbohydrate	–0.13	0.09	0.04	···

[a] * = Significant difference ($P < 0.05$); ** = significant difference ($P < 0.01$).

chemical composition of the beans. Some chemical components, such as soluble pectin, calcium contents, and starch gelatinization, may affect the canned bean splitting more than seed coat damage.

The weight of navy beans during soaking was correlated to canned bean characteristics. Highly hydrated beans exhibited light color after canning ($r = 0.89$, $P < 0.01$) (Table II). Increasing number of nonhydrated beans darkened canned beans ($r = -0.89$, $P < 0.01$) (Table II). A poor correlation was determined between the hydration degree of raw beans and the firmness of canned beans in this study ($r = -0.04$) (Table II). Hosfield and Uebersax (1980) also reported that hydration coefficients of soaked beans were not associated with textural differences among tropical bean genotypes.

The correlation coefficient between the starchiness of the liquid in canned beans and the turbidity of micro-cooking bean liquid was 0.52 (Table III). It indicated that high turbidity in micro-cooking related to high starchiness of the liquid in the canned beans. When most of the materials in the micro-cooking liquid were soluble, the liquid in the canned beans was clear. The turbidity of the liquid of the micro-cooking beans correlated with clumping of canned beans ($r = 0.53$, $P < 0.05$) (Table III).

Raw Navy Bean Correlations for Physical Properties

Correlations among the physical properties of raw navy beans supplied bean breeder information about the associations among the physical properties. As expected, high negative correlation existed between hydration degree of raw beans and the number of nonhydrated seeds ($r = -0.95$, $P < 0.01$) (Table IV). The RVA pasting viscosity correlated significantly with the viscosities of both the pH 1.5 and pH 10 buffer extracts ($r = 0.63$ and 0.90) (Table V). The positive correlations among the viscosities indicated that the factor involved in the RVA pasting viscosity also might influence the extract viscosities. The turbidity correlated negatively with the viscosity and the dry residue weight of the micro-cooking bean liquid ($r = -0.78$ and -0.81) (Table VI). The viscosity correlated positively with the dry residue weight ($r = 0.87$) (Table VI), which indicated that the soluble materials in the cooked bean liquid may cause high viscosity and a high dry residue weight. However, high turbidity in liquid led to a low viscosity and low dry residue.

CONCLUSIONS

The RVA pasting viscosity correlated significantly to washed drained weight, firmness, and overall acceptance of canned beans. Small sample size and little time were needed for the RVA viscosity determination. The test of the RVA pasting viscosity possesses high potential for use as an early generation screening method for improved canning quality. The viscosities of bean flour extracts with pH 10 sodium carbonate (4%, w/v) and pH 1.5 potassium chloride buffers also may be used for predicting canning quality attributes, including splitting and firmness. Hydration ability of raw navy beans can be used for prediction of white color degree, and turbidity of micro-cooking bean liquid can be used for predicting clarity of canned bean medium.

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