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

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ABSTRACT

The canning quality and chemical composition of 11 genotypes of navy beans (*Phaseolus vulgaris* L.) from two locations were determined. The correlations between chemical composition (soluble pectin content of raw navy beans) and canning quality traits of the navy bean genotypes were: splitting $r = -0.64$ ($P < 0.05$), firmness $r = -0.84$ ($P < 0.01$), and overall acceptance of canned bean $r = -0.70$ ($P < 0.05$). The lightness (L value) of canned beans was significantly correlated with the calcium content of the raw navy beans ($r = 0.60$, $P < 0.05$). The drained weight of canned beans showed correlation with the viscosity of canned bean medium ($r = 0.73$, $P < 0.01$). These correlations supply bean breeders statistically useful information that could be applied to screen early generation lines of navy beans for improved canning quality.

The determination of the correlations between the chemical composition and canning quality of navy beans is the key step toward procedures for bean breeders to screen early bean generation lines for improved canning quality. The quality of canned beans is affected by cultivar, production environment, process method, and storage condition (Nordstrom and Sistrunk 1979, Junek et al 1980, Hosfield et al 1984).

Research conducted on the chemical composition of the beans responsible for canned bean quality (Doesburg 1965, Kon 1968, Rockland and Jones 1974, Wang et al 1988). Soluble pectin in the raw seeds of navy beans exhibits highly negative correlations with the firmness of canned navy beans when calcium is not added (Doesburg 1965, Wang et al 1988). Adding calcium increased the firmness of cooked beans (Van Buren 1986, Wang et al 1988, Fenjin et al 1989). The calcium ions may combine with pectic substances to form insoluble calcium pectinate, which increases the firmness (Lindsay 1985).

The hard-to-cook defect was related to associations among phytic acid, minerals, and pectin (Mattson et al 1950). Hentges et al (1991) reported a negative correlation between cook time and phytate of raw common beans. Although correlations between chemical composition and cooking properties were investigated, most studies focus on a single cultivar. The relationships between chemical composition and cooking quality among various navy beans were not fully investigated.

The objectives of this study were to investigate the correlations between chemical composition and canning quality of navy bean genotypes and supply useful information for predicting canning quality of early navy bean generation lines.

MATERIALS AND METHODS

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 in a refrigerator at 4°C until use.

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Chemical Composition Tests

Initial moisture content of the raw navy beans was determined by AACC method 44-15A (1995). Crude protein content of the raw navy beans was determined by the Kjeldahl method (N × 6.25, method 46-10, AACC 1995). Ash and calcium content were determined according to AOAC methods 923.03 and 944.02C (1990).

Pectin content and degree of methylation were determined. The raw navy beans were finely ground by a Brabender sample mill and extracted with 0.1M Na-phosphate buffer (pH 7.0) for 1.5 hr. The extract was centrifuged at 8,000 × g for 20 min. The supernatant portion was analyzed for soluble pectin. The uronic acid content was determined spectrophotometrically (450–440 nm difference) according to Scott's (1979) procedure. The degree of methylation of the soluble pectin was determined by an enzymatic method of Klavons and Bennett (1986) using alcohol oxidase.

Phytic acid content was determined by soaking raw navy beans in distilled water at room temperature for 16 hr, freeze-drying, and grinding in a Brabender sample mill. Total and soluble phosphorus was determined (Thompson and Erdman 1982). The difference between total and soluble phosphorus was insoluble phosphorus (Bartlett 1959). Phytic acid content of the navy beans was calculated from the insoluble phosphorus, assuming 1 mole of phytic acid contained 6 moles of insoluble phosphorus.

Starch was isolated by the method of Schoch and Maywald (1968) with small modification. Cleaned beans (40 g) were steeped in 40 ml of water containing 0.05% sodium metasulfite for 20 hr at 50°C. The beans were drained, rinsed with distilled water twice, and blended with water in a Waring blender for 5 min. The blended beans were screened with spraying water through 40, 100, 200, and 230 mesh sieves. The amylose content was estimated according to the method of Williams et al (1970).

Canned Bean Property Determination

Beans (100 g, dwb) were soaked at 25°C for 30 min, blanched at 87.8° C for 30 min in water containing 2.5 mM $CaCl_2$. The soaked beans then were canned and cooked in a retort at 115.6°C for 45 min (Uebersax and Hosfield 1985). The canned beans were stored for three weeks before canning quality tests.

The drained weight of the processed beans was determined by the procedure of Uebersax and Hosfield (1985). Degrees of clumping (cohesiveness), splitting, overall acceptance of canned beans, and starchiness (turbidity) of canning medium were measured by a visual rating procedure (visual estimation). A 5-point scale was used for the attributes of canned beans: clumping (1 = no clumping, 5 = extremely clumped); splitting (1 = no splitting, 5 = extremely split); overall appearance (1 = highly accepted, 5 = poorest acceptance); starchiness (1 = very clear, 5 = extremely cloudy).

The color difference of the drained, canned beans was determined with a tristimulus colorimeter (model XL-23, Gardner Lab Inc., Bethesda, MD). A standard white tile ($L = 91.94$, $a_L = -1.03$, $b_L = 1.14$) was used to standardize the instrument. Drained canned beans (100 g) were used to determine firmness, using the universal testing machine (model 1000, Instron Co., Canton, MA) equipped with a 500-kg weight beam and Kramer Shear cell cup. The crosshead speed was controlled at 20 mm/min.

The viscosity of the canned bean medium was determined using a cone-plate viscometer (model LVT serial 81308, Wells-Brookfield Engineering Lab. Inc., Stoughton, MA). The medium from canned beans was set in a flask at room temperature for 3 hr to settle the suspended solid materials. A 0.5-ml portion of the clear medium was tested by using cone cp-40 at 0.6 rpm.

Statistical Analysis

Correlations between chemical composition and canning qualities were analyzed by Pearson's correlation program. Differences in each canning property or chemical composition were analyzed using Duncan's multiple range method at 0.05 and 0.01 significance levels. Homogeneity between correlation coefficients from two locations of each genotype was tested by Chi square. When the location effect was observed to be significant, the correlation coefficients were calculated separately for each location.

TABLE I
Correlations Among Canned Bean Quality and Moisture, Crude Protein, Ash, and Calcium Contents of Raw Beans

	Moisture	Crude Protein	Ash	Calcium
Drained weight	0.06	–0.06	–0.15	–0.17
Clumping	0.19	0.51	0.42	0.44
Splitting	–0.26	0.12	0.03	–0.19
Firmness	0.16	0.30	0.11	–0.07
Color (*L* value)	0.24	0.10	0.44	0.60*[a]
Starchiness	0.33	0.52*	–0.15	–0.17
Viscosity of canned bean medium	–0.06	0.24	0.06	–0.09
Overall score	0.05	0.42	0.09	–0.09

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

TABLE II
Correlations Among Canned Bean Quality and Soluble Pectin, Phytic Acid, Amylose Contents, and Methylation Degree of Pectin in Raw Beans

	Soluble Pectin	Phytic Acid	Amylose	Methylation Degree of Pectin
Drained weight	0.49	0.24	0.44	–0.45
Clumping	0.09	0.42	0.23	–0.04
Splitting	–0.64*[a]	–0.11	0.01	–0.09
Firmness	–0.84**	–0.1	–0.37	–0.09
Color (*L* value)	0.53*	–0.29	–0.2	–0.12
Starchiness	–0.24	0.16	0.15	–0.18
Viscosity of canned bean medium	0.33	0.29	0.25	–0.37
Overall score	–0.70*	0.07	0.14	–0.01

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

TABLE III
Correlations Among Moisture, Crude Protein, Ash, and Calcium Contents and Other Chemical Compositions of Raw Beans

	Moisture	Crude Protein	Ash	Calcium
Moisture	···	0.60*	0.28	0.24
Crude protein	0.60*[a]	···	0.52*	0.24
Ash	0.28	0.52*	···	0.77**
Calcium	0.24	0.32	0.77**	···
Pectin	–0.19	–0.44	–0.15	0.14
Phytic acid	0.23	0.18	0.37	0.33
Amylose	–0.06	–0.30	–0.43	–0.14
Methylation	–0.02	–0.11	0.27	0.21

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

RESULTS AND DISCUSSION

Raw Navy Bean Correlations Between Chemical Composition and Canning Quality Traits

Correlations between chemical composition of raw navy beans and canning quality may provide important information for developing simple, sensitive, and rapid methods for breeders to predict early navy bean generation lines for improved canning quality. The results of this study indicated that the starchiness of canned bean medium increased as the crude protein contents increased among genotypes ($r = 0.52$, $P < 0.05$) (Table I). It implied that the increased protein content in genotypes may decrease canning quality, even though high protein content is a positive nutritional factor. Ash and calcium did not correlate with most of the canning quality traits. However, an increase in calcium contents was associated with the increase of the *L* value of canned bean color ($r = 0.60$, $P < 0.05$) (Table I). Navy beans with higher calcium contents may produce lighter canned beans. This result agreed with Wang et al (1988) that ethylenediaminetetraacetic acid and calcium chloride significantly increased the *L* value of canned navy and pinto beans. The white color value also correlated significantly with the pectin content of raw navy beans ($r = 0.53$, $P < 0.05$) (Table II). Breeders may predict canned bean color by testing these two components.

A significant correlation was found between soluble pectin content in raw navy beans and firmness of canned beans ($r = -0.84$, $P < 0.01$) (Table II). The raw beans with higher soluble-pectin content may produce softer canned beans. This result was consistent with the finding of Wang et al (1988) that navy beans with higher soluble pectin contents produced soft canned navy beans when $CaCl_2$ was not added. One possible reason for the firmness change might be the formation of a gel when calcium reacts with pectin. Doesburg (1965) reported that soluble pectin in the raw bean seed coat and cotyledon exhibited highly negative correlations ($r = -0.94$ and $r = -0.92$, respectively) with firmness of navy beans. In whole navy beans, soluble pectin exhibited a highly

TABLE IV
Correlations Among Drained Weight, Clumping, Splitting, Firmness, and Other Canning Properties

	Drained Weight	Clumping	Splitting	Firmness
Drained weight	···	0.39	–0.33	–0.77**[a]
Clumping	0.39	···	–0.18	–0.33
Splitting	–0.33	–0.22	···	0.63*
Firmness	–0.77**	–0.33	0.63*	···
Color (*L* value)	0.35	0.13	–0.51	–0.29
Starchiness	0.20	0.89**(A) 0.19(H)[b]	0.20	0.05
Viscosity of canned bean medium	0.73**	0.68*	–0.37	0.59*
Overall score	–0.15	0.27	0.84**	–0.52*

[a] * = Significant difference ($P < 0.05$); ** = significant difference ($P < 0.01$).
[b] Correlation coefficients are not homogenous between location (A) Arthur and location (H) Hatton.

TABLE V
Correlations Among Color (L Value), Overall Score of Canned Beans, Starchiness, and Viscosity of Canned Bean Medium (CBM)

	Color (*L* Value)	Starchiness	Viscosity of CBM	Overall Score
Color (*L* value)	···	–0.41	0.11	–0.50
Starchiness	–0.41	···	0.71**(A) –0.40 (H)[a,b]	0.54*
Viscosity of CBM	0.11	0.77**(A) –0.40 (H)	···	–0.01
Overall score	0.50	0.54*	–0.01	···

[a] * = Significant difference ($P < 0.05$); ** = significant difference ($P < 0.01$).
[b] Correlation coefficients are not homogenous between location (A) Arthur and location (H) Hatton.

negative correlation coefficient ($r = -0.97$) with firmness of canned navy beans. Our results agreed well with Doesburg's findings. Firmness is one of the most important factors that influence consumers' acceptance of canned beans. Bean breeders may predict firmness of a new navy bean line by determining its soluble pectin content of raw bean. In addition to firmness, soluble pectin content also correlated significantly with splitting ($r = -0.64$, $P < 0.05$), canned bean lightness ($r = 0.53$, $P < 0.05$), and overall acceptance ($r = -0.70$, $P < 0.05$). Beans with high soluble pectin content exhibited less split, lighter color, and higher acceptance.

Poor correlations were found between phytic acid contents and canning quality in this study, although a negative correlation between phytic acid and firmness was reported by Sievwright and Shipe (1986) in black beans (*P. mungo*) and Wang et al (1988) in navy beans.

Raw Navy Bean Correlations for Chemical Composition

The associations for chemical composition of raw navy beans were also investigated in this study. They may not be useful in predicting canning quality, but they provide a good knowledge for breeders to understand the associations among navy bean chemical components. If a component is identified for breeding development, the associations would provide breeders some ideas on how the change of one component might affect other components. The results indicated that moisture and ash contents increased as the crude protein content increased among the genotypes ($r = 0.60$, $P < 0.05$ and 0.52, $P < 0.05$) (Table III). A significant correlation ($r = 0.77$, $P < 0.01$) (Table III) between calcium and ash contents in navy beans was found in this study. The results indicated that a certain ratio between calcium and other ash components may exist, while the total ash contents varied among cultivars. The calcium was ≈3% of total ash content in raw navy beans.

Raw Navy Bean Correlations for Canning Quality Traits

Improving canning quality is one of the main goals for bean breeders. The results of this study showed the associations among the canning quality traits. They give breeders a profile showing how the change of one canning quality trait is related to others. Correlation analysis showed that washed drained weight was associated negatively with firmness of canned beans ($r = -0.77$, $P < 0.01$) (Table IV). Canned beans with a higher drained weight were softer. These results were consistent with those reported by Ghaderi et al (1984) that firmer textured beans produced lower washed drained weights. The correlation coefficients showed that the higher the firmness, the lower the overall acceptance. The higher the firmness, the more viscous the canned bean medium and the more the bean split ($r = 0.59$ and 0.63, respectively) (Table IV). The overall acceptance of canned beans decreased as splits in canned beans and starchiness in canning medium increased ($r = 0.84$, $P < 0.01$ and 0.54, $P < 0.05$) (Tables IV and V).

The starchiness of bean medium significantly decreased the overall acceptance of canned beans ($r = 0.54$, $P < 0.05$) (Table V). The correlation coefficients between starchiness and clumping were not homogenous at the Arthur and Hatton locations. A high correlation ($r = 0.89$, $P < 0.01$) (Table IV) was found at Arthur, while a poor correlation ($r = 0.19$) (Table IV) was found at Hatton. The difference indicated the influence of location on specific properties of canned bean. A similar case was found in the correlation between starchiness and viscosity of canned bean medium ($r = 0.71$, Arthur; $r = -0.40$, Hatton) (Table V). Higher starchiness decreased overall acceptance. Intact beans were assumed to undergo little loss of solid materials during thermal processing. Excessive bean breakdown during cooking would result in starch exudation into the canning medium and could lead to graininess of the sauce and clumping of individual beans. The viscosity of canned bean medium was correlated positively with clumping ($r = 0.68$, $P < 0.05$) (Table IV).

CONCLUSION

The significant correlations between soluble-pectin content in raw navy beans and canning quality traits, and the correlations between other chemical composition and canning quality traits are useful information to bean breeder. These correlations can be used to develop measurements to predict canning quality of early generation genotypes. Testing soluble pectin, which used a small sample size and could analyze many samples at once, may be the best parameter for this purpose.

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