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Variability in Physico-chemical Properties and Nutritional Components of Tropical and Domestic Dry Bean Germplasm[1]

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Abstract. **Food-quality comparisons between tropically adapted genotypes of dry bean (*Phaseolus vulgaris* L.) and accessions from domestic breeding agencies showed there is sufficient variability in important nutritional and canning traits among tropical beans to justify their use in temperate-climate breeding programs. Specifically, tropical bean germplasm may be of use to transfer stress tolerance and lodging resistance to commercially acceptable genotypes while the breeder is simultaneously breeding to maintain or improve nutritional composition and canning quality. Seed of 35 bean accessions representing plant introductions, breeding lines, and cultivars were screened for proximate chemical composition, yield, and several horticultural characters. Seventeen of these accessions, including several commercial dry bean cultivars, were selected for canning evaluations. Beans were adjusted to 16% moisture before soaking and processing. Soaked and processed beans were evaluated for water uptake, texture (with a Kramer Shear Press), and general canning quality. Protein content was highest in domestically adapted beans (31%) and lowest in the nonblack tropical array of genotypes (22%). Tropical beans showed a greater tendency to clump in the can after cooking. This indicates excessive breakdown of tropical beans during thermal processing. Nonsignificant correlation coefficients indicated that textural differences and soaking properties of the beans were not associated; however, textural differences were correlated with the final moisture percentage in processed tropically adapted beans. Several tropical genotypes were much firmer or much softer after cooking than 'Sanilac', which is considered the industry standard for making canning comparisons. Further evaluation of texture by examining Kramer Shear Press tracings showed that textural differences among genotypes could be broken down into a configuration showing a large shear force component, and a curve characterized by mostly compression. The curve types appeared to be a characteristic of the genotype rather than of seed-coat color, size of bean, or final moisture percentage.**

Dry edible beans are an important food crop. The U.S.A. grows about three-quarters of a million metric tons annually on about 610,000 hectares. Approximately 80% of the crop is consumed domestically while the remaining 20% is exported to foreign markets (21).

Dry bean production in the U.S.A. is centered in areas that have considerable agricultural diversity (22). Michigan accounts for about 34% of the national production on about 210,000 hectares. Average dry bean yields throughout the U.S.A. have remained static while Michigan yields have shown a downward trend during the past 20 years (21). Such long-term trends in yield strongly suggest that a barrier to higher yields or "yield plateau" has been reached in beans. While there are a number of reasons for yield barriers in crops (9), the least common denominator is the cultivar. Hence, cultivar improvement through plant breeding provides an important avenue for success in increasing yields of a crop.

Data collected in Michigan during the past several years shows that bean yields in excess of 23.5 quintals per hectare can be achieved (M. W. Adams, personal communication, August 1978; 8). Moreover, some of the highest bean yields being achieved in state wide trials are for beans with tropical bean germplasm in their pedigrees (8). In addition, preliminary results from several field experiments suggest that black beans derived from tropical accessions have root systems more tolerant to partial soil compaction and water stress (12, 18), 2 of the factors reported to be causing the decline of bean yields in Michigan (17).

Canning characteristics of dry beans, especially navies, largely influence final product acceptability. Hence, the canning industry has established a definite set of acceptability standards for dry beans that are rigorously adhered to when a cultivar is considered for processing.

In addition to canning quality, nutritional quality of foodstuffs is becoming increasingly important. Consumers are becoming more educated about nutrition and more sophisticated in choosing foods that are wholesome and nutritious.

Incorporating the dimension of quality improvement into a bean breeding program places an additional heavy burden on the breeder to develop efficient selection practices. To maximize time and resources, the breeder must possess some knowledge of the range of variability and the nature of gene action for food-quality traits, sufficient seed to sacrifice for the required evaluations and suitable screening methods. In addition, the methodology and criteria used by the breeder in making canning-quality evaluations must simulate commercial processing practices (2).

Except for the percentage of protein and certain amino acids, little information exists as to the source and nature of

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variation in food-quality traits in dry beans (1, 2, 14). While breeding programs are underway to improve dry beans nutritionally (14), comprehensive efforts to investigate the genetics of canning quality are lacking. Modern technology has provided the means by which canning trials may be conducted rapidly, on small amounts of seed, and at a reasonable cost, with the precision required to simulate a commercial processing operation (10). This report presents the results of research aimed at examining the relationship between physical and chemical properties of dry bean genotypes obtained from tropical germplasm research centers and standard cultivars and breeding lines obtained from collaborative programs in the United States. Specific objectives were to measure variation associated with nutritional and canning quality traits, and to ascertain the potential of genotypes of tropical origin as a source of germplasm in domestic dry bean breeding programs.

Materials and Methods

Dry beans used in this study were grown in a nursery during the summer of 1977 at the Saginaw Valley Bean and Sugarbeet Research Farm near Saginaw, Michigan. Seed was precision drilled with a modified air planter as described by Taylor (19) into 4 row plots. Rows were 4.9-m long and spaced 50.8 cm apart. The design was completely random and consisted of tropical and domestic adapted genotypes. Standard practices for herbicide and fertilizer applications were followed. Bulk samples of pods were harvested manually from the middle 2 rows of individual plots in late September and early October and threshed by hand. After threshing, beans were sized (Table 1) using appropirate metal sieves and were stored at room temperature until elevated.

From this nursery, 35 accessions described in Table 1 were selected for laboratory evaluations, based on their yielding ability, adaptation, plant morphology, and root system. Of these selections, 17 were chosen for canning trials based largely on type, seed-coat properties, overall harvest quality, sufficient seed supply, and protein and ash (mineral) content of raw bean meal. Beans used for processing evaluations were adjusted rapidly to 16.0 ± 0.02% SD moisture content in a controlled air-circulating humidity chamber before soaking and processing. This was done to eliminate any effect that differential seed moisture might have on cotyledonary tenderization during soaking and cooking and to insure that each and every sample of beans contained an equivalent weight of total solids (TS) 115.0 ± 0.02 g).

Rapid water uptake is an important attribute to dry beans used for human consumption. The hilum and micropylar areas usually admit water readily, but seed coats differ strikingly in water permeability (2). Hence, soaking properties of the beans as well as canning characteristics were evaluated. A description of the processing traits and detailed methodology pertaining to their calculations are presented in Table 2.

There was insufficient seed to replicate each genotype equally for the processing evaluations. Accession nos. 771001, 771004, 771007, and 771008 were replicated 4 times and in general, the remaining accessions were replicated 3 times for soaking and canning evaluations. From each replicate of each genotype, 135 g of moisture-equilibrated beans (equivalent to 115 g of TS) were placed in nylon mesh bags and soaked. The soaking treatment used in this study was a 2-stage procedure that has been shown to maximize differences between genotypes for water uptake, cotyledonary hydration, and the degree of cotyledonary softening during cooking. The initial soak was for 30 min in 21°C water to facilitate seed-coat softening and expansion. Immediately after the cold soak, beans were transferred to water maintained at 88° in a stainless-steel kettle for an additional 30 min. All soaking was done in tap water containing about 50 ppm calcium. The soaking procedure just described yields an end product that has minimum bean damage and is similar to beans soaked continuously in the high-temperature systems common throughout the U.S. canning industry (20). After soaking, beans were momentarily cooled under cold tap water and drained for 2 min on a number 8 mesh screen (0.239 cm) positioned at a 15° angle. The weight gained through water imbibition during bean soaking was used to calculate hydration coefficient (water pickup) and moisture content (Table 2).

After weighing, beans were filled into 303 × 406 cans and covered with boiling brine prepared by adding 142.0 g of sucrose and 113.4 g of salt to 9.1 kg of tap water containing 50 ppm calcium. Cans were sealed and processed in a retort without agitation for 45 min at 116°C. After thermal processing, cans were uniformly cooled to 38° under cold tap water and stored for 2 weeks at room temperature before evaluation. The storage period after processing permits canned beans to completely equilibrate with water in the canning medium.

After the cans were opened, the washed drained weight of processed beans was determined by decanting the can contents on a number 8 mesh sieve, rinsing them in 21°C tap water to remove adhering brine, and draining for 2 min on the sieve positioned at a 15° angle. Texture was determined by using a Kramer Shear Press fitted with a standard multiblade shear compression cell (Food Technology Corp., Reston, VA.). A 100-g sample of washed processed beans was placed in the compression cell and force was applied until blades passed through the bean sample (Table 2). The water content of canned beans (final moisture percentage) was determined from the 100-g texture samples. These were oven dried at 81° until the weight remained constant (Table 2).

We made subjective bean-quality evaluations on contents of all processed cans while beans were draining on the mesh screens. We compared the beans used in this study with reference samples of cooked beans that were purchased at a local supermarket and commercially processed in brine. The degree of packing (bean clumping) was rated on a 3-point scale (Table 2). Overall bean appearance was evaluated to measure the suitability of beans for commercial processing. Criteria included loose or free coats ("free skins"), individual bean integrity, and fluid consistency (Table 2). Processed beans were ranked by size (Table 2).

All data were subjected to an analysis of variance appropriate to a completely random design. Triplicate determinations were made on all cans for texture and final moisture content. There was good agreement among the 3 readings taken on each can of each genotype; hence, analyses of variance were performed on mean values of the determinations made on each can.

Since texture is an important canning-quality criterion to the processor and consumer, pair-wise correlation coefficients between hydration coefficient, percent moisture after soaking, water content of canned beans, and shear-press values were calculated to ascertain relationships.

Results and Discussion

Significant differences among the 17 genotypes were noted for all characters except for water content of beans after soaking. Inspection of Table 3 shows that when the accessions were broken down into subgroups according to their adaptation and seed color, nonblack tropical bean genotypes differed significantly for 9 of the 11 characters studied, while the black tropical and the domestic subgroups differed for 5 and 2 characters, respectively. That fewer differences were noted among bean genotypes of domestic parentage indicates a similarity in the genetic makeup of these accessions with respect to genes affecting the soaking and cooking properties. This finding is not surprising because the domestic materials evaluated were representative of the navy commercial class and comprised a narrow germplasm base (3,4). It has been suggested by some investigators

Table 1. Description, seed characteristics, protein and ash contents, and commercial class designation for 35 accessions of dry beans.

Accession No.	Accession Pedigree[z]	Type[y]	Seed Color	Seed Size	Seed Weight of 100 (g)	No. of samples	Raw meal[x,w] Protein (%)	Raw meal[x,w] Ash (%)	Commercial[v] class designation
Tropical									
771001	IBYAN GO-4802	BL	Drk. red	Lg	58.5	4	26.1	3.5	Kidney
771002	IBYAN GO-4421	BL	Beige	Sm	18.4	4	25.1	4.0	Undef.
771003	IBYAN NEP-2	BL	White	Sm	16.2	4	28.0	4.3	Navy
771004	Brasil-2	CV	Beige	Sm	19.0	4	24.1	4.0	Undef.
771006	IBYAN Ex-Rico 23	BL	White	Sm	19.1	4	27.2	4.4	Navy
771007	Lamaniere	CV	Pur. mottle	Med	41.7	4	24.8	3.8	Kidney
771008	Mexico 12-1	CV	Brown	Sm	19.6	4	25.6	4.2	Undef.
771009	284703	P.I.	Yellow	Med	35.0	4	22.7	3.4	Sw. Brn.
771010	196936	P.I.	Lt. brown	Sm	21.2	4	25.8	3.9	Undef.
771011	IBYAN GO-4076	BL	Lt. red	Med	48.4	4	26.6	3.8	Kidney
771018	Bunsi	CV	White	Sm	18.5	2	26.2	3.9	Navy
771019	Porrillo Sintetico	CV	Black	Sm	17.4	2	27.4	4.1	BTS
771021	N257 Sel-Rico de M. Gerais	CV	Black	Sm	20.4	2	25.1	4.2	Undef.
771022	IBYAN P738	BL	Black	Sm	17.8	2	25.9	3.7	BTS
771023	Jamapa	CV	Black	Sm	18.8	2	25.5	3.8	BTS
771024	Colleccion 168N	CV	Black	Sm	20.9	2	28.0	3.9	Undef.
771025	201333	P.I.	Black	Sm	19.5	2	24.8	3.8	Undef.
771026	IBYAN P455	BL	Black	Sm	20.3	2	25.6	3.7	BTS
771027	313868	P.I.	Black	Sm	20.6	2	27.9	4.1	Undef.
771028	IBYAN 21-M-(3F5)	BL	Black	Sm	18.4	2	25.5	4.2	BTS
771029	Pecho Amarillo	CV	Black	Sm	20.3	2	26.0	4.0	BTS
771030	San Pedro Pinula-72	CV	Black	Sm	19.5	2	25.1	3.9	BTS
771031	San Fernando	CV	Black	Sm	16.5	2	26.9	3.9	BTS
771032	I.C.A. Huasano	CV	Black	Sm	21.3	2	27.4	4.3	Undef.
771033	Jalpatagua-72	CV	Black	Sm	23.1	2	30.0	3.9	Undef.
771034	IBYAN GO-3627	BL	Black	Sm	20.8	2	27.3	4.3	BTS
Domestic									
771012	Tuscola	CV	White	Sm	19.8	2	27.7	4.2	Navy
771013	CS-73185-E10-B3	BL	White	Sm	17.4	2	25.8	3.4	Navy
771014	CS-73185-E14-B3	BL	White	Sm	17.3	2	26.2	4.0	Navy
771015	CS-73185-E9-B3	BL	White	Sm	17.2	2	26.9	3.8	Navy
771016	Sanilac	CV	White	Sm	17.9	2	28.5	4.1	Navy
771017	MSU-NEP-2	BL	White	Sm	14.0	2	30.9	3.7	Navy
771035	Seafarer	CV	White	Sm	18.4	2	29.3	3.9	Navy
771005	Red Kloud	CV	Lt. red	Lg	63.5	4	25.4	3.7	Kidney

[z]IBYAN = International Bean Yield and Adaptation Nursery, Centro Internacional de Agricultura Tropical (C.I.A.T.), Cali, Colombia. CS-73185-E14-B3; CS-73185-E9-B3; and CS-73185-E10-B3 = Campbell Soup Co. breeding lines.

[y]BL = breeding line; CV = cultivar; P.I. = plant introduction.

[x]Protein percentage is expressed on a dry-weight basis.

[w]Duplicate analyses were made on each sample for percentages of protein and ash.

[v]BTS = Black Turtle Soup.

that processing quality of most navy bean cultivars is associated with various seed characteristics that appear to be highly heritable (2). Hence, breeders developing navy bean cultivars seem to have maintained an acceptable level of processing quality in their breeding populations by carefully selecting for physical characteristics of the seed peculiar to the navy bean class, in addition to screening plants for yield, maturity, plant type, and pest resistance.

Overall, protein content ranged from superior (31%) to acceptable (22%); it was highest in the domestic bean subgroup and lowest in the nonblack tropical subgroup (Table 3). Our results indicate that it might be possible to transfer genes for important morphological and physiological traits that many of the tropical genotypes possess (7, 12) into domestic strains while simultaneously breeding for protein content. Transferring genes from this sample of tropical beans into temperately adapted breeding populations may lead to genetic recombinants with acceptable protein content. Workers (1, 11, 13, 16) have reported a negative correlation between yield and protein content. Nevertheless, some workers feel that ample variation exists in segregating populations from high and low crude-protein lines to allow selection of genotypes that combine high yields with above-average crude-protein content (6, 13).

There were differences between the tropical and domestic subgroups for initial seed moisture content (Table 3). A knowledge of the initial moisture content of bean seeds is important because moisture content is known to affect the rate of water uptake during soaking (2). Processing beans with large differences in initial seed moisture or differing storage histories may lead one to make erroneous conclusions regarding true varietal differences for canning-quality characters. Hence, care should be exercised to standardize the initial moisture of the seed and control storage conditions before soaking and processing.

Average mineral content (ash) of the 3 subgroups was nearly identical. However, significant differences were noted

Table 2. Bean processing evaluations and calculations.

Character	Description
Soaking	
Hydration coefficient	Ratio of $\frac{\text{wt of soaked beans (g)}}{\text{wt of dry beans (g)}}$
Water content (%)	$100 - (\frac{\text{wt of solids (g) in dry beans}}{\text{wt (g) of soaked beans}} \times 100)$
Canning	
Objective	
Drained weight (g)	Weight of rinsed beans drained for 2 min on a number 8 mesh screen (0.239 cm) positioned at a 15° angle. One determination per can was made.
Texture (kg force/100 g)	Determined by placing 100 g of washed processed beans into a standard shear-compression cell of a Kramer Shear Press and applying force with a dynamic hydraulic system. Values reported indicate the Kg force required to shear 100 g of beans. Three determinations per can were made.
Water content (%)	Determined by oven drying each texture evaluation at 80.6°C until weight remained constant. $\% = \frac{\text{initial wt} - \text{dry wt}}{\text{initial wt}} \times 100$
Subjective	
Degree of packing (1-3)	Extent of packing (clumping) of beans in can. 1=no clumping; 2=bean clumping but easily decanted from can; 3=beans clumped or packed solidly in bottom of can. One determination per can was made.
Overall appearance (1-5)	Evaluation for general suitability of commercial processing made on each can. Criteria included examination for loose (free) seed coats, bean integrity, and brine consistency, Low values indicate poor appearance; high values indicate excellent appearance.
Size (1-5)	Relative rank of processed bean size. Low values indicate small beans (navy type); mid range values indicate medium-sized beans (great northern and pinto type); high values indicate large beans (kidney type). One evaluation was made per can.

Table 3. Nutritional, canning, and appearance characters of tropical and domestic dry bean genotypes.

	Adaptation											
	Tropical								Domestic			
	Nonblack				Black				White			
Character	Mean[z]	Range	CV[y] (%)	GD[x]	Mean[z]	Range	CV[y] (%)	GD[x]	Mean[z]	Range	CV[y] (%)	GD[x]
Dry beans												
Nutritional components												
Protein (%)	25.6	21.7–28.2	1.6	**	27.0	25.0–29.7	0.2	**	28.2	24.9–31.0	1.3	**
Moisture (%)	8.6	8.0–9.3	2.3	NS	9.6	9.3–9.8	0.4	*	8.0	7.9–8.1	0.4	NS
Ash (%)	4.0	3.3–4.5	1.6	**	4.0	3.8–4.2	1.6	NS	3.9	3.4–4.2	3.9	NS
Processed beans												
Soaking and cooking properties												
Hydration coefficient	1.81	1.76–2.03	4.5	*	1.87	1.81–1.95	1.8	NS	1.88	1.82–1.94	0.7	**
Water content of soaked beans (%)	52.5	47.5–57.7	2.8	NS	55.0	49.8–56.8	2.0	NS	55.1	53.2–56.6	0.8	NS
Washed drained weight (g)	328.0	303.4–354.4	2.5	**	328.9	311.9–362.9	2.4	**	329.9	317.5–348.7	3.1	NS
Texture (kg force/100 g)	82.4	49.1–112.2	5.0	**	90.6	77.1–134.6	9.9	**	80.5	59.1–89.9	12.5	NS
Water content of canned beans (%)	68.2	66.8–70.5	0.7	**	68.2	66.0–69.3	0.5	**	68.5	67.6–69.3	0.8	NS
Appearance properties												
Degree of packing[w]	1.5	1.0–3.0	34.7	**	2.2	1.0–3.0	36.6	NS	1.1	1.0–2.0	37.1	NS
Overall appearance[v]	3.4	2.5–4.5	16.5	*	3.0	2.0–3.5	17.6	NS	3.4	3.0–4.0	14.1	NS
Size after canning[u]	2.9	1.0–5.0	19.4	**	2.2	2.0–4.0	21.4	NS	1.5	1.0–2.0	54.5	NS

[z]Values are replicate averages except for protein, ash, texture and water content of canned beans; these values are averages of replicates and determinations.

[y]CV = Coefficient of variability; standard deviation as % of mean.

[x]GD = Genetic difference; F-test significance at 5% (*) or 1% (**) level of probability. NS denotes nonsignificance.

[w]Scale: 1 (no clumping) to 3 (packed solidly).

[v]Scale: 1 (poor) to 5 (excellent).

[u]Scale: 1 (small) to 5 (large).

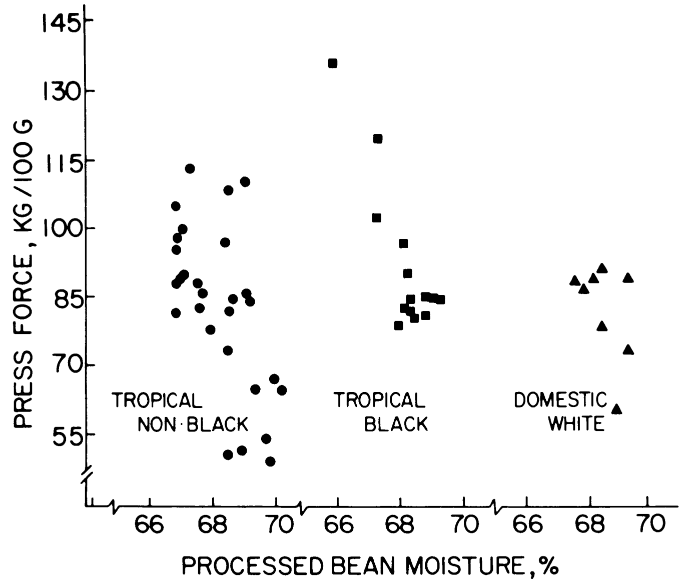

Fig. 1. Relationship between shear force and water content of processed beans. Tropical nonblack, Y = 717.9 – 931.9X, r = –0.58**; Tropical black, Y = 1,226.3 – 1,665.3X, r = –0.86**; domestic, Y = 607.7 – 769.4X, r = –0.45 NS.

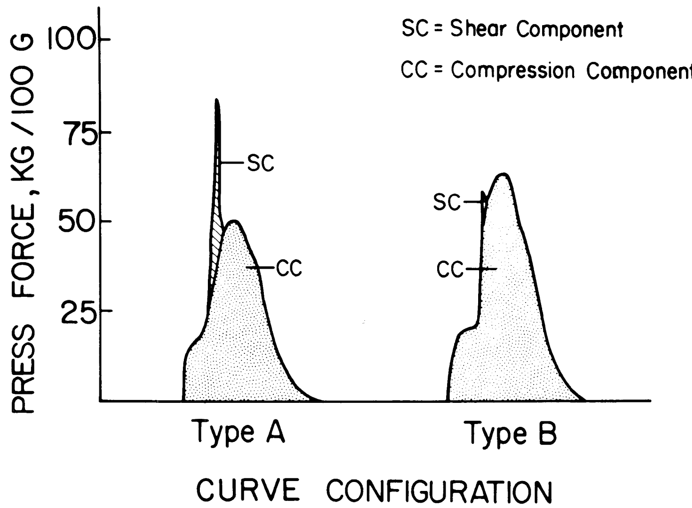

Fig. 2. General curve configurations showing dominant shear and compression characteristics exhibited by the various genotypes used in the experiment.

among genotypes within the nonblack tropical bean array (Table 3). Studies are underway to ascertain the effect of mineral content on quality.

Soaking is the first step in bean processing. During soaking, uncooked beans generally undergo an 80% increase in weight due to water imbibition and attain a moisture level between 53 and 57%, with 55% considered optimum (2). Since moisture content is calculated on the basis of weight gain, the moisture level represents a maximum moisture content for uncooked beans; after a period of time, the weight loss due to the loss of TS is greater than the weight gain due to moisture absorption (15). There were no significant differences among genotypes for water content of soaked beans (Table 3); however, the nonblack tropical subgroup had the lowest overall mean (52.5%) for this character, and several accessions had a moisture content of less than 52%, the minimum desired. Significant within-group differences were noted for hydration coefficients among the nonblack and domestic accessions (Table 3). We did not expect to find significant differences for this character in view of the absence of corresponding differences among genotypes in water content of soaked beans, because both traits measure essentially the same physical phenomenon.

Correlation coefficients (not shown) revealed that soaking properties and hydration coefficients of soaked beans were not associated with textural differences that were noted among tropical bean genotypes (Table 3). This finding is in agreement with that of Quast and da Silva (15), who studied the effect of hydration rate on the degree of cooking (texture) for 2 tropical bean cultivars with colored seed coats. These authors showed that after 45 min of cooking at 116°C, the degree of hydration of the beans had no effect on the degree of cooking.

There was considerable variation among genotypes within both the nonblack and black tropical bean subgroups for washed drained weight of processed beans (Table 3). This variation was statistically significant. After thermal processing, cooked beans continue to increase in weight as they equilibrate with water in the canning medium until they reach an end-point moisture content of about 65% (2). Drained weight of processed beans is the weight of beans after the sauce or brine is washed away. It is assumed that intact beans undergo little loss of solids during thermal processing while excessive bean breakdown during cooking would result in starch exudation into the canning medium and may lead to graininess of the sauce and clumping of individual beans. Beans must soften during processing yet still maintain their individual integrity. The variation noted among genotypes of the tropical bean accessions suggests that heritable differences exist in these beans for factors influencing softening of the cotyledonary matrix.

Texture is a primary canning-quality character because texture affects the perceived stimulus for chewing and, hence, influences to a large degree a consumer's acceptance of a food product. Textural properties of processed beans must fall within prescribed acceptability limits (2). Deviations from the range of acceptance reduces bean quality and may lead to cultivar rejection (2). Beans may be unacceptable as they are too firm ("tough beans") or too soft ("mushy beans") after cooking.

The textural characteristics of soaked or processed beans can be readily evaluated with the Kramer Shear Press as reported by Binder and Rockland (5). Scatter diagrams (Fig. 1) illustrate the relationship between texture and final moisture percentage of canned beans in the 3 bean subgroups. The correlation coefficient (not shown) between these two characters in the beans as a group was highly significant and negative (r = –0.63**). The correlation coefficients computed on observations within subgroups revealed a strong negative correlation (r = –0.86**) for black and a moderate negative correlation (r = –0.58**) for nonblack tropically adapted beans. No correlation between texture and final moisture percentage existed in the navy bean genotypes studied. These observations indicate that the final degree of hydration of the bean cotyledon was more important than the other water relationship factors involved in the cotyledonary softening process only in the tropical beans.

Texture was further investigated by examining shear-press tracings of each genotype. The curve shapes observed showed that textural differences among genotypes could be separated into a curve (Type A) which showed a large contribution due to shear force involved in the extrusion of beans between the slots in the sample cut as the head descended, and a curve (Type B) which was characterized by a predominant component due to compression (Fig. 2) Except for these 2 peak shapes, we did not observe any other configurations.

Table 4. Seed-coat color, size, and moisture, and shear-press texture, curve type, and characteristic force component for 17 accessions of processed beans.

Accession number	Seed color	Seed size	Water content of canned beans (%)	Shear-press characteristics		
				Texture (kg force/100 g)	Curve type	Characteristic force component
Tropical						
771001	Red	Large	68.2	79.7	A	Shear
771004	Beige	Small	66.9	99.2	B	Compression
771008	Brown	Small	67.5	83.4	B	Compression
771009	Yellow	Medium	67.0	88.0	A	Shear
771007	Purple	Large	69.3	51.3	B	Compression
771027	Black	Small	68.5	80.9	B	Compression
771028	Black	Small	68.2	87.2	B	Compression
771030	Black	Small	68.9	83.2	A	Shear
771031	Black	Small	66.9	118.1	B	Compression
771033	Black	Small	68.6	80.1	B	Compression
771006	White	Small	68.7	88.5	A	Shear
771018	White	Small	68.3	109.8	A	Shear
771003	White	Small	69.9	65.1	B	Compression
Domestic						
771012	White	Small	68.4	82.0	A	Shear
771013	White	Small	69.3	71.8	A	Shear
771016	White	Small	68.4	72.2	B	Compression
771017	White	Small	68.5	87.8	B	Compression

Curves with large shear force components (Type A) result when a differential component within a product causes an excessive pressure requirement in order to bring the product to a yield point prior to extrusion. Compression type curves result when a product is uniformly extruded through the cell compartment. The curve types appear to be a characteristic of the genotype rather than of seed-coat color, size of beans, or final moisture content (Table 4).

Binder and Rockland (5) reported compression-type curves for cooked lima beans when seed coats were removed and curves with large shear components when bean coats were intact. Since our work was done with beans with intact seed coats and types of textural characteristics were noted, the properties affecting texture may differ in dry and lima beans. It could be that certain genotypes had highly cohesive seed coats that kept individual beans from rupturing until a catastrophic failure to shear action resulted. This could lead to the shear component dominating the curve type of a sample. Further study is needed to develop a better understanding of texture and of the relationship between shear-press curve types and the rheological properties of beans.

Of further interest were the mean scores associated with the bean subgroups for the subjectively determined canning-quality characters. Potential for packing in the can was greater for tropical accessions than for domestic beans. Subgroup mean t-test comparisons between tropical and domestic beans for degree of packing indicated that differences were significant ($t=2.27$, $P=5\%$ and $t=4.22$, $P=1\%$ for the nonblack and black groups, respectively). These results were probably due to a wider range in thermal breakdown (appearance of split beans) values for tropical beans than for domestic genotypes (Table 3). The degree of packing is an indication of the amount of clumping that occurs after processing and receives close scrutiny by the processor. A cultivar that clumps severely may be rejected. While tropical beans as a whole must be downgraded with respect to their appearance characteristics, individual genotypes were identified that showed excellent packing quality (Accession nos. 771001, 771003, 771006, 771007, 771018, 771030, 771031). In addition, tropical black as well as nonblack beans were significantly larger than the domestic subgroups (Table 3). Seed size merits consideration in the choice of parents to be used in a breeding program because size and shape of the seed are heritable traits (2) and are important in determining commercial class designations for beans.

Tropical beans may be useful as parent in domestic dry bean breeding programs to transfer upright and narrow-profile plant architecture, lodging and pest resistance, tolerance to stresses caused by too little or too much water, and yield stability to economically useful populations (7, 12, 18). On the basis of the material evaluated in this study, preliminary indications are that little reduction in quality would accrue from using tropical beans in domestic breeding programs provided the breeder makes the monitoring of quality characteristics a major objective. Because of the importance of final moisture content, texture, and appearance to canning quality, the breeder should pay special attention to these traits. Several tropical genotypes were much firmer or much softer after cooking (Table 4). than 'Sanilac' (texture = 72 kg/100 g), which is considered to be the industry standard for canning quality. Since knowledge of the inheritance of this trait is lacking, the breeder should screen against "too soft" or "too firm" beans as early as possible in a breeding program.

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Effect of Vitamin K_5 and Menadione on Ripening, and Ethylene and Carbon Dioxide Production by Apple and Tomato Fruit[1]

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Abstract. **A 10-minute soak in 1.0 mM vitamin K_5 reduced ethylene production over 90%, while doubling carbon dioxide production by cortical tissue from pre-climacteric apples (*Malus domestica* Borkh.). Reduced ethylene production persisted for at least 4 hours, while carbon dioxide production declined to rates not significantly different from the controls. Vitamin K_5 also reduced ethylene production by 50% from quartered fruit of tomato (*Lycopersicon esculentum* Mill.) at different stages of maturity, and from cortex tissue from apples at or near their climacteric peak of ethylene production.**

Vitamin K_1 (2-methyl-3-phytyl-1,4-naphthoquinone) and menadione (2-methyl-1,4-naphthoquinone) have been reported to retard the ripening of banana fruit (3) and tomato fruit (M. B. Farhcomand and M. E. Patterson, personal communication). Farhcomand and Patterson observed that soaking mature-green tomatoes for 10 min in either a 0.1% (wt/vol) emulsion of oil soluble menadione, or a 0.4% solution of water soluble menadione sodium bisulfite (MSB) delayed ripening for 35 days when the tomatoes were held at 20°C. These treatments also significantly reduced ethylene and carbon dioxide production. Beccari (3) reported that soaking mature-green bananas for 5 min in either a 0.1% emulsion of vitamin K_1, or a 0.1% solution of a water soluble form of menadione delayed ripening of fruit held at 20 and 30°C for 33 and 24 days, respectively. In contrast, Peacock (7) found that a 0.1% solution of menadione actually promoted banana ripening when precautions were taken to control fungal infection. He suggested that the results reported by Beccari were caused by reduction of anthracnose infection by menadione. Beccari was aware that a 0.1% solution of either vitamin K_1, or menadione would markedly reduce the growth of *Gloeosporium musarum* Cke Massee, and *Fusarium* sp. prope *monififorme* Sh. in culture, but he did not attribute the delay in ripening to this anti-fungal property. A 2-min soak in a 0.1% menadione solution has been reported to be much more effective than 8 other anti-fungal compounds in inhibiting the growth of *Rhizoctonia bataticola,* the fungus responsible for blackspot on mango (4). More effective than menadione is the synthetic compound vitamin K_5 (4-amino-2-methyl-1-naphthol), which has been shown to greatly inhibit microbial growth at concentrations of less than 50% ppm (0.24 mM) (10).

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