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VARIABLES ON PROCESSED BEAN QUALITY

By

Albert Bolles

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ABSTRACT

INFLUENCE OF SELECTED GENETIC AND PROCESSING VARIABLES ON PROCESSED BEAN QUALITY

By

Albert Bolles

Processing factors affecting dry edible bean quality were evaluated in a series of four studies.

The effect of initial bean moisture content for selected varieties was observed in Study I. The effect of thermal processing on various commercial bean strains was undertaken in Study II. Study III evaluated the quality of 11 variety-location entries of beans grown in North America. Study IV evaluated the effect of soak treatment and processing on five commercial bean classes.

Results indicated that navy beans became darker during thermal processing while the heavily pigmented types (black, pinto, and kidney) became lighter. Beans which were processed with agitation had less clumping, splitting and were firmer than nonagitated product. All beans processed at 121°C/30 minutes were firmer and had a higher lethal rate than samples processed at 115.6°C/45 minutes.

To My Parents

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INTRODUCTION

Legumes are generally recognized as a good source of protein and dietary fiber. Cooked beans also blend well with other vegetables and meat which makes them a highly nutritious component of the human diet. Dry edible beans (Phaseolus vulgaris L.) are consumed as a specialty food in many industrial countries of Western Europe, the Western Hemisphere, as well as South Africa and Australia. In lesser developed countries of Central and South America, beans are a staple food which provide a major protein source for much of the population. Beans are often the primary source of protein for poor and middle-income families throughout the world.

Dry edible beans must be suitable for human consumption and possess desirable cooked quality attributes if they are to be utilized in the human diet. Some of the factors which affect cooked bean quality are genotype, dry bean storage conditions, process methodology and product formulation.

The purpose of this study was to investigate various factors influencing dry and processed bean quality. Four individual studies were conducted to assess bean quality.

Study I was undertaken to assess the effect of initial bean moisture content for selected varieties on thermal processing. The effect of initial moisture content on four common bean varieties was tested. Beans were adjusted to eight initial moisture contents, processed and evaluated for quality.

The effect of thermal processing on a diverse sample of cultivars was evaluated in Study II. This study included 27 breeding lines and cultivars representing seven of the 11 major dry bean classes grown in the U.S. Cultivars representing the classes were grown in a small seeded or large seeded nursery, depending on seed size. After harvesting, all bean lots were thermally processed and evaluated for quality.

Study III was the effect of variety and production location and different thermal processing methods on processed bean quality. The effect of quality on 11 variety-location entries representing commercial North American varieties and bean growing regions was investigated. Two types of thermal processing methods were employed: 1) an agitating retort which axially revolved the cans during processing and 2) a conventional still (non-agitating) retort.

Study IV was the effect of soak treatment and processing on quality attributes of five bean classes. Three different soak conditions were employed before processing: 1) a long term soak (12 hours/25°C), 2) a short term soak (30 minutes/25°C plus 30 minutes/87.8°C, and 3) no soak (dry pack). Cans were processed under two different temperature/time conditions. The primary emphasis of this study was to characterize processed bean texture. All samples were evaluated and analysis of various texture curve types was conducted using a texture analysis equation.

LITERATURE REVIEW

Dry Bean Composition

Seedcoat

The seedcoat (testa) provides an outer protective barrier for the seed, primarily to inhibit the uptake of water. According to Powrie et al. (1960), the seedcoat consists of 7.7% of the total dry weight in the mature bean (Phaseolus vulgaris). This relatively small portion of the dry weight is composed of 4.8% protein and 8.44% ash (Ott and Ball, 1943). The protein content is in accord with later findings by Powrie et al. (1960) of 5% protein. The outer portion of the seedcoat contains 0.4% ether extractable wax-like material. Seedcoat color is expressed by the presence of polyphenolic compounds, primarily the tannins. In common beans, the tannins are located in the seedcoat of the grain, with low or negligible amounts in the cotyledon (Bressani et al., 1961). White beans show the lowest amount of tannins with increased levels present in the black, red and brown varieties. The tannins (condensed polyphenols) are desirable agronomically from the standpoint of bird-resistance, inhibition of preharvest seed germination, and weather resistance (Harris, 1969). However, tannins have been shown to decrease protein digestibility by either inhibiting digestive enzymes or by reacting with protein, thereby reducing amino acid availability. A combination of these two mechanisms could also decrease the protein digestibility (Bressani et al., 1961).

Cotyledon

The cotyledon (embryonic leaf tissue) is the main portion of the seed. Powrie and co-workers (1960) found that the dry cotyledons contain 39.3% starch, 27.5% protein, 1.65% lipids, and 3.5% ash. Snauwaert and Markakis (1976) reported that the oligosaccharide content of bean cotyledons was 3.3% stachyose and 0.5% raffinose. These oligosaccharides account for much of the hydrogen production (flatus potential) found in rats (Fleming, 1981). This researcher studied the relationship between flatulence and carbohydrate distribution in various legumes and reported a very high positive correlation coefficient between polysaccharides and flatulence.

Structurally, the outmost layer of the cotyledon consists of epidermal cells. The inner and outer epidermal cells have been designated as those along flat and curved surfaces of the cotyledon. Conformationally, the inner epidermal cells are elongated, while the outer cells are cubical. The cell contents of the epidermis appear granular, containing protein but no starch. The layer of cells from the outer epidermal cells inward is classified as the hypodermis. The cells of the hypodermis are elliptical in shape and are larger than the outer epidermal cells. The entire cell structure appears to be a granular matrix containing tyrosine.

The remaining portion of the cotyledon consists of parenchyma cells and vascular bundles. Within each parenchyma cell, starch granules are imbedded in a protein matrix. Parenchyma cells are observed to possess very thick secondary walls compared to primary walls, and contain small cavities and pits which aid in water hydration during soaking.

Influence of Germination

The effect of germination on chemical-physical composition has also been investigated by various groups: in particular, the changes in oligosaccharide concentration during the germination process (Snauwaert and Markakis, 1976). Snauwaert and Markakis reported that both stachyose and raffinose decreased in concentration during the germination process. Furthermore, gamma irradiation was employed to investigate the effects it had upon oligosaccharide content during germination. It was found that gamma irradiation, as compared with germination, only slightly affected the disappearance of oligosaccharides. Reddy et al. (1978) and Tabekha and Luh (1980) studied the influence of germination on phytase activity and its effect upon phytic acid. Phytic acid is a phosphorylated form of myo-inositol which is an ubiquitous antinutritional factor in legumes. Tabekha and Luh (1980) showed that during a 96-120 hour soaking period, inorganic phosphorus cleavage from myo-inositol increased primarily due to an increase in phytase activity. This is in agreement with the earlier work presented by Reddy et al. (1978) which showed the slow breakdown of phytate phosphorous and phytase activity during the first four days of germination.

Molina et al. (1976) worked with black beans to develop a process to control the development of the hard-to-cook phenomenon, and reported that during a dry heating process the seed germinating capacity decreased. Amylases are the primary enzymes responsible for hydrolysis of starch during germination. This decrease in germination was due primarily to thermal inactivation of the starch hydrolytic enzymes.

Dry Bean Storage

The storage conditions under which dry beans are stored are a major factor which a bean processor must consider to assure consistent canned bean quality. The primary factors influencing the storage quality of beans are bean moisture content, atmospheric temperature, and length of storage time.

Temperature/Time

The effects of atmospheric temperature during the storage period plays an important role in bean cookability. Studies by Burr et al. (1968) suggested that as temperature increased, the cooking time increased in *Phaseolus vulgaris*. This is in accord with work by Antunes and Sgarbieri (1979), where a negative bean hydration correlation was observed when storage temperature was increased. They also introduced data which suggested a direct relationship between lower holding temperature and lower relative humidity to reduced bean cooking time.

In comparison with storage temperature, storage time plays a vital role in bean quality. Burr and Kon (1966) observed that pinto beans, subjected to prolonged storage for one year, needed 62 minutes at 121°C to cook until tender as opposed to a cooking time of 23 minutes for freshly harvested beans. This increase in cooking time with increased storage time has been consistently reported by other researchers (Morris, 1963 and 1964; Burr <u>et</u> <u>al</u>., 1968; Bedford, 1972).

As the length of dry bean storage increases, in addition to increased cooking time a decline in the nutritive value results. Antunes and Sgarbieri (1979) observed a drop in available methionine and cysteine with increased storage time. Burr (1973) reported that during prolonged storage, the thiamin concentration declined with no change in niacin or riboflavin. Molina <u>et</u> <u>al</u>. (1975) also reported a decrease in protein efficiency ratio for stored beans due to a long cooking time requirement.

<u>Relative Humidity/Bean Moisture</u>

Bedford (1972) reported that the mold growth of beans stored in a closed constant relative humidity desiccator greatly increased at relative humidities greater than 75%. Uebersax (1972) used saturated salt solutions to control relative humidity (RH) for bean storage in desiccators at 12.8°C, 21°C, and 29.5°C temperatures. After 84 days of storage, bean quality was maintained with 75% relative humidity for all temperatures. Low temperature showed increased storage potential at all RH levels. As storage time, temperature and RH increased, bean deterioration, off-flavor, mold count and processed bean firmness also increased.

It was reported by Gloyer (1928) that the lower the humidity of the storage atmosphere, the higher the percentage of hardshell beans. These cooking features were characterized by Bourne (1967) who showed that hardshell beans (hard-to-cook phenomenon in beans) tend to be smaller in size than the non-hardshell beans. Molina <u>et</u> <u>al</u>. (1975) observed the hardness of black beans stored at 25°C and 70% RH for nine months. He observed that if a heat treatment was applied to beans prior to storage, the hard-to-cook phenomenon could be reduced. Varriano-Marston and Deomana (1979) reported that black beans stored at high relative humidities, such as 85%, underwent a greater rate of electrolyte leakage during soaking than beans stored at normal relative humidities. This implies that, during high relative humidity storage, aging occurs which results in cotyledon deterioration. This deterioration may contribute to the hard-to-cook phenomenon.

During storage of high moisture beans there may be a development of off-flavors, lipid oxidation, darkening in color and hard-shell effect. Morris (1963) reported low moisture beans maintained good quality. As the moisture content rises, off-flavors are observed along with a large increase in fatty acids. According to Muneta (1964), these off-flavors occurred because of the high concentration of polyunsaturated fatty acids which underwent autoxidation leading to off-flavors. Thus, storage conditions conducive to establishing low moisture beans should be maintained. Storage of low moisture beans could contain a few high moisture beans and increased microbial activity (McCurdy et al., 1980). McCurdy et al. concluded that strict monitoring of bean moisture should be employed.

Burr and Kon (1966) reported that keeping beans at low moisture contents is essential to preserve their cooking quality. Pinto, navy and large lima beans, Morris (1963) observed little change in cooking time of low moisture beans during storage. Burr et al. (1968) reported an increase in cooking time with high moisture stored beans. It was found that pinto beans stored at 25°C and 16% moisture required 60 minutes to cook as compared to 20 minutes for beans stored at the same temperature at 8.2% moisture. This is in accord with the work of Rockland (1963) who observed that beans with an initial moisture content of 9.9% required only one-fifth the time to cook than those stored for five months at 32.2°C with an initial moisture content of 13.3%. Von Mollendroff and Priestley (1979) also reported on this phenomenon. They concluded that the acceleration of hardness occurs rapidly as the moisture content is raised above 13%; however, by Jackson and Varriano-Marston (1981) concluded that cooking time was inversely proportional to moisture content in black beans.

Research by Burr et al. (1968) and Von Mollendroff and Priestley (1979) have shown that high moisture storage of beans causes a darkening in seedcoat and cotyledon color. They concluded darkening was probably due to changes in the phenolic constituents such as the tannins. Von Mollendroff and Priestley (1979) also reported that there is a large increase in bean acidity as the moisture content is raised.

Bean Soaking

Hydration

The soaking process, in which beans imbibe water, is greatly dependent on the inherent physical-chemical composition of the bean. Sathe and Salunkhe (1981) reported that the polar amino groups of protein molecules are the primary water binding sites in Great Northern beans. Moreover, Kon et al. (1973), who tried to develop an inexpensive mechanical way for making quick-cooking beans, reported when soaked and unsoaked samples are compared, the peeling of the seedcoats reduces the cooking time by 26% and 36%, respectively. This supports the theory that the seedcoat is the primary barrier for water uptake. Varriano-Marston (1979) studied the effects of accelerated storage on water absorption and cooking time. She indicated that the seedcoat was the major barrier in water uptake, thus supporting the work by Kon and his co-workers (1973). However, when subjective analysis (such as taste panels) is used the seedcoat did influence the judgment of the judges (Muneta, 1964). The beans with an intact seedcoat were found to be more firm than beans without a seedcoat. Decorticating beans will increase the rate of water uptake but will negatively affect the consumer acceptability of the product by producing a softer bean.

Soak Water Additives

The use of various additives in the soak water has also been widely studied. Examples of such additives include sodium bicarbonate (Greenwood, 1935); sodium hexametaphosphate (NaHMP), sulfite, oxalic acid, ammonium oxalate and hydrochloric acid (Reeve, 1947); and ethylene diamine tetracetic acid (EDTA) (Elbert, 1961; Luh et al., 1975).

Hoff and Nelson (1965) investigated the acceleration of water uptake in the dry pea bean. They reported that EDTA had no pronounced effect on water uptake. However, Luh et al. (1975), studying factors affecting color, texture and drained weight of canned dry lima beans, reported that EDTA prevented discoloration by its chelating action to immobilize metal ions. It was also found that when using pinto and red kidney beans, the addition of EDTA greatly reduced the chemical oxygen demand (COD) in the wastewater. This was primarily due to the chelating action of EDTA with divalent metals in the soak water (Neely and Sistrunk, 1979). Junek et al. (1980) reported that EDTA had no pronounced effect on an increase in firmness among navy, pinto and kidney beans. However, a decrease in drained weight was observed with the addition of malic and citric acids in navy beans. This is in accord with the theory that bean ability to imbibe water decreases in an acidic environment due to a decrease in starch swelling potential.

Lee (1979), working on the effects of processing factors on the quality characteristics of soaked and processed navy beans, found that the addition of NaHMP increased water uptake, softened the beans and resulted in leaching of soluble solids. This researcher also reported that the combination of Ca^{++} and NaHMP decreased the drained weight. Hoff and Nelson (1965) observed that polyphosphates greatly increased water uptake. This was primarily due to the chelating action of the polyphosphates with divalent metal ions which form tough metal crosslinked pectates. This is in agreement with the earlier work by Mattson (1946) who stressed the dephosphorylation of phytic acid. He found that in the presence of heat, the enzyme phytase was inactivated and phytic acid was allowed to precipitate out calcium and magnesium ions, thus preventing the metal-ion to form the tough metal-pectin bridges.

The addition of minerals to the soak water, specifically calcium and magnesium ions, has been shown to have a pronounced effect on water uptake in dry beans. Luh et al. (1975) reported that addition of calcium chloride to the brine produced a firmer bean due to the formation of firm calcium pectates. This was also found to be the case in studies by Davis and Cockrell (1976). They found that increased concentrations of calcium chloride resulted in increased shear press values for canned lima beans. This is also supported by Quenzer et al. (1978) who correlated a positive relationship between calcium content and shear peak values, and a negative correlation between calcium content and the ability of the bean to take up water.

Work by Dawson et al. (1952) in the development of rapid methods of soaking and cooking beans showed that the addition of sodium bicarbonate increased water uptake by 42%. Varriano-Marston and Deomana (1979) reported black beans which were soaked in $Na_5P_3O_{10}$ and Na_2CO_3 solutions absorbed the most water and were also the most alkaline. Nordstrum and Sistrunk (1977) reported an increase in shear press values upon examination of pinto, red kidney and an experimental line, Dwarf Horticulture #4, in an acidic medium (tomato sauce, pH 5.0 to 5.2). Moreover, Snyder (1936) showed the acidity of the soak water reduced the rate of water uptake due to the presence of hydrogen ions (increased acidity) which reduced the rate of water imbibition. It also was found by Junek et al. (1980) that the addition of citric and malic acids increased the force needed to shear navy beans, indicating a firmer bean. Luh et al. (1975) found that product texture became firmer and the drained weight decreased as pH decreased due to loss of hydration during the soaking period. The increased swelling power of starch with increased pH serves as a mechanism for imbibition. Varriano-Marston and Deomana (1979) showed that during the soaking period there was an increase in soak water acidity. This phenomenon was primarily due to loss of hydrogen ions by the cellular components during the soaking period. There was a direct positive increase in solubility with increased swelling power (Lai and Varriano-Marston, 1979). These researchers also reported that starch swelling and solubilization are restricted during the cooking period, thus rendering starch as one of the chemical-physical barriers in water uptake. Lang (1970) reported that cooking of starch leads to an increase in consumer palatability by producing a softer bean.

The addition of sodium salts to beans was suggested to produce quick cooking dry beans (Rockland and Metzler, 1967). The method used to prepare quick-cooking beans was: (1) loosening of the seedcoats by vacuum infiltration in a solution containing NaCl, $Na_5P_3O_{10}$, $NaHCO_3$ and Na_2CO_3, (2) soaking the beans in the same salt solutions, (3) rinsing, and (4) drying, cooking or freezing the beans depending on their ultimate utilization. The resulting product cooked in less than fifteen minutes. Rockland and Jones (1974) using the scanning electron microscope on dry dehydrated large lima beans indicated that the quick-cooking process did not affect the structure and appearance of the beans when compared with the untreated samples. It was proposed by Varriano-Marston and Deomana (1979) that the addition of sodium salts, or possibly an ion-exchange mechanism with the sodium ion replacing devalent ions, could result in a solubilization of pectic substances during soaking and cooking. It was also observed by Rockland and Jones (1974) that composition of quick-to-cook beans had a higher sodium chloride concentration which resulted in an enhancement of bean flavor. A method of converting quick-cooking beans into refried product was undertaken by Zaragosa et al. (1977). They reported that the quick-cooked refried beans had a more bland flavor than the commercial beans and a slightly darker color.

Nutritional

During the soaking process there is a considerable loss of soluble solids to the soaking medium. The retention of the water soluble vitamins and other nutrients is a major concern to the processor. Daoud et al. (1977) reported that loss of vitamin B_6 occurs during the soaking and washing of garbanzo beans. Nordstrum and Sistrunk (1977) showed that riboflavin decreased during the soaking period. Luh et al. (1978) reported that increasing the concentration of $NaHSO_3$ (as a color agent) in the process medium decreased the thiamine retention without significantly affecting riboflavin and niacin in canned small white and garbanzo beans. It was observed in winged beans that during soaking there is considerable loss of potassium, with no effect on iron content (Ekpenjong and Borchers, 1980). It has been suggested by many researchers that the retention of the soaking medium during processing will allow for an increase in nutrient content of the cooked bean (Dawson et al., 1952; Rockland et al., 1974).

Dry Bean Cooking and Canning

Hydration

Cooking of dry edible beans is necessary in order to bring about acceptability in flavor and texture. Junek et al. (1980) found that increasing the soak temperature from 15°C to 35°C decreased the shear peak height, indicating increased tenderness of the beans. Moreover, Quast and da Silva (1977) found that for black beans, raising the temperature 10°C caused a 3.36-fold decrease in cooking time. However, Davis (1976) found blanching below the boiling point of water gave a higher drained weight than blanching at the boiling point, suggesting more water uptake and less solids leaching.

The removal of the seedcoats produced a decrease in cooking time, from 80 minutes to 30 minutes, suggesting that the seedcoat is the major barrier in water uptake in beans (Brown and Kon, 1970). Dawson et al. (1952) found for all bean varieties tested, addition to boiling water for two minutes, followed by a one hour hot water soak, produced results superior to those produced by the standard method of bean preparation. Quast and da Silva (1977) reported that cooking beans for nine minutes at 127°C gave the same results as cooking beans for 260 minutes at 98°C. However, these researchers reported that one must be careful to employ a process long enough to guarantee the commercial sterility of the product. Rockland and Jones (1974), using the electron microscope, found that there was no observable difference in cellular structure of cooked, salt water soaked beans than normally soaked beans. Therefore, the cooking rates must be related to the differential rates at which internal cell separation occurs.

An investigation of accelerated water uptake in dry pea beans was undertaken by Hoff and Nelson (1965). Three methods were employed for gas release: (1) steam pressure, (2) vacuum treatment, and (3) sonication treatment. After two minutes under steam pressure, there did not seem to be any significant effects in accelerated water uptake. In fact, after long holding time the treatment resulted in deterioration of bean quality. The vacuum treatment provided positive results in the ability of the bean to take up water. However, after extended periods this ability diminished.

Davis (1976) investigated the effect of blanching methods on quality of canned dried beans. He found that with red kidney and pinto beans the processing time had the greatest effect on firmness. However, he concluded that the processor should increase temperature rather than time when processing for the desired texture in navy beans.

Enzymes

Mattson (1946) emphasized the role of heat inactivation of phytase to promote the precipitation of calcium and magnesium by phytin. The precipitation of these divalent ions would prevent them from forming tough metal-pectin complexes. Kon (1979) reported that cooking the beans at 90°C caused the beans to cook more rapidly due to phytase inactivation. This researcher also reported that addition of phytase increased hydrolysis of phytate by 15%, thus confirming the role of phytase in beans. However, Varriano-Marston and Deomana (1979) showed that cooking the beans at 90°C may not necessarily be sufficient to inactivate phytase activity if the beans had been previously subjected to prolonged storage. Long term storage allows for increased phytase activity and hydrolysis of phytic acid. Tabekha and Luh (1980) reported cooking dry beans for three hours at 100°C had little effect on phytate retention, whereas soaking in water for 12 hours at 24°C resulted in a slight decrease in phytate. The use of enzymes to improve the quality of canned beans has been studied by Powers et al. (1961). Amylopectic and pectolytic enzymes were applied to reduce the gelling of pinto beans. However, the catalytic activity was found to be insufficient to make this practice commercially feasible.

Nutritional

Quast and da Silva (1977) studied the temperature dependence on hydration rate and the effect of hydration on the cooking rate of legumes. They found that after soaking for a period of time, the weight gain, due to water uptake, was less than the weight loss due to the escape of soluble solids into the soak water. Burr (1973) reported that during the cooking period, there is a decrease in nutritional value. This is in accord with Hackler et al. (1964) who observed a decrease in the protein efficiency ratio (PER) if the beans were cooked 40 minutes or longer at 121°C (15 PSI). Reddy et al. (1978) reported that during the initial stages of cooking there is a decrease in mineral leaching. After 40 minutes, the mineral content increased due to reabsorption of minerals from the cooking water.

Kon (1979) showed that during the soaking process, when high temperatures are employed, there is a leaching of oligosaccharides. Among the sugars which are lost are the flatus producing raffinose and stachyose oligosaccharides. Studies have also shown that during a long soaking time there is a leaching of antinutritional factors to the soaking medium. Many researchers suggest an improvement in gut digestibility of protein during the cooking period (Hackler et al., 1964; Ekpenjong and Borchers, 1980; Sathe and Salunhke, 1981).

Investigations of the physical-chemical composition of quick-to-cook beans has been undertaken by various researchers. It was found that niacin and riboflavin levels in quick-cooking beans were very similar to those of the standards. Quick-cooking beans also contained less magnesium and more phosphorus than the standards

(Rockland et al., 1979). Rockland et al. (1974) also observed that during rehydration of the quick-cooked beans, if the soak water is discarded, the beans only contained 80% of the flatulent activity that standard beans contain. These data confirm the reports of a loss of antinutritional factors into the soak water during processing. Dawson et al. (1952) observed that the thiamine and ash contents of rapidly cooked beans were higher if the soaking medium was retained. Consequently, saving the soaking medium does allow for an increase in vitamin and protein retention while negatively maintaining the flatus producing oligosaccharides.

Quality Attributes of Dry Beans

Bean Color

Bean seedcoat color results from the presence of polyphenolic compounds, primarily the tannins. It was observed that addition of citric acid during the soaking period improved the color of beans (Junek et al., 1980; Luh et al., 1975). Luh et al. hypothesized that this was due to the ability of the citrate ion to bind trace elements (copper, iron), rendering the ions unavailable for reactions with phenolic compounds and sulfides which cause discoloration in canned beans. Therefore, although increased pH has a profound effect on bean hydration, it also allows increased undesirable discoloration reactions to occur in the alkaline conditions which could render the bean unacceptable to the consumer.

Luh et al. (1975) also showed that calcium chloride addition to the brine improved bean color. Calcium chloride addition to bean brine will also result in a firmer bean and a decreased drained weight. Drained weight and color are two parameters which are very crucial indexes for consumer product acceptance.

Bean Texture

Lee (1979) reported that calcium and magnesium ions decreased the drained weight and ultimately increased the shear resistance of processed beans. Thus, an increase in shear press values is in agreement with the observed inverse relationship of drained weight and firmness by the shear peak height as reported by Nordstrum and Sistrunk (1979). Davis and Cockrell (1976) also showed that the drained weight ratio decreased with storage time in canned dried lima beans with 0.1% calcium chloride. The number of splits also decreased with increasing concentrations of calcium chloride which is in agreement with the theory of the formation of tough metal-pectin bridges leading to a firmer product.

Lee (1979) employed treatments with alpha-amylase, glucoamylase, pectinase, cellulase and protease. These enzyme treatments showed no significant effects on the processes of water uptake or shear resistance in navy beans.

The effect of textural differences in beans packaged from year to year by a processor was observed by Voisey (1973). He reported that uniform texture was not being achieved year to year and attributed this variability to varietal-environmental year effects.

METHODS AND MATERIALS

Dry Bean Planting and Harvesting

Dry bean varieties were grown for the USDA Quality Nursery in 1981 and 1982 at East Lansing, Michigan, and on the Saginaw Valley Bean and Beet Research Farm near Saginaw, Michigan. Seed was precision drilled into four row plots with a tractor-mounted air planter. Rows were 4.9 m in length and spaced 50.8 cm apart. Within row spacing was 7-8 cm which gave 14-16 plants per meter of row. All plots were arranged in a randomized complete block with four replications. Standard practices for herbicide and fertilizer application were used.

In late September and early October, mature plants were removed by hand from the middle two rows of individual plots. After threshing, beans were analyzed for moisture and sized using appropriate metal sieves.

Bean Sources

Dry beans were obtained directly from the USDA Quality Nursery after field plot harvesting. The harvested material was received at the MSU Legume Quality Laboratory where a lab code was assigned to each field code (plot number). Coded bean samples were then prepared for processing.

Selected varieties of beans were obtained from Michigan

Foundation Seed Association, 2905 Jolly Road, Mason, Michigan. These samples were obtained in 50 pound lots and were of the following bean types and varieties: navy (Fleetwood), navy (Seafarer), navy (Sanilac), navy (Neptune), navy (Swan Valley), black turtle soup (T39), cranberry (Michigan Improved), pinto (Oletha), kidney (Montcalm), and kidney (Charlevoix). Also, samples were obtained from North Dakota and Ontario, Canada. Samples from North Dakota were of the following bean types and varieties: navy (Fleetwood), navy (Seafarer), and navy (Upland). The varieties from Ontario, Canada, were of the following bean types and varieties: navy (Fleetwood), navy (Seafarer), and navy (Kentwood). All variety-location samples were coded and prepared for processing.

Objective Color Measurements

Objective reflectance color measurements of beans were determined with a Hunter Lab Model D25 Color and Color Difference Meter (Hunter Associates, Fairfax, Virginia). The instrument was standardized using a standard white tile ($L = +94.5$, $a_L = -0.6$, $b_L = +0.4$). Beans were placed in an optically pure glass sample dish and covered to shield interferring light from activating photo cells. Coordinate values (L, $+a_L$, and $+b_L$) were recorded for each replicate. Dry bean color measurements were performed for each variety by placing a one hundred gram sample of bean solids into the sample dish. Two readings per sample were performed. Processed bean color measurements were performed on one hundred grams of washed drained beans as for dry beans. Duplicate samples were taken per processed can.

Moisture Measurements

The initial moisture content of dry beans was measured with a Motomco Moisture Meter (Model 919, Motomco Inc., Clark, NJ). All measurements were obtained following the procedure recommended by the manufacturer. After moisture measurements, 100 g bean solids (Equation 1) were filled into 4x6 inch nylon mesh bags. Samples were then placed in plastic zip-lock bags to minimize environmental moisture change and held until processing.

$$\frac{\text{solids required (g)}}{\text{solids at given moisture (g)}} = \text{fresh weight to yield required solids (g)}$$

Equation 1. Equation for Calculation of 100 grams of Dry Bean Solids

The processed moisture and total solids were determined on the sheared bean residue from the Kramer shear press. One hundred grams of shear residue were weighed into a tared aluminum pan. The sample was dried to a constant weight at 80°C in a Proctor-Swartz Cabinet Drier (Proctor and Swartz, Inc., Philadelphia, PA). The dried samples were weighed and calculation of percent total solids was performed according to Equation 2. One measurement per can was determined.

$$100 \text{ g shear residue} - \text{oven dried weight (g)} = \%\ \text{total solids}$$

$$100\% - \%\ \text{total solids} = \%\ \text{processed bean moisture}$$

Equation 2. Equation for Calculation of Processed Bean Moisture and Percent Total Solids

Soaking and Blanching

All nylon mesh bags were soaked for 30 minutes in 100 ppm of calcium ion water at 29.3°C. The samples were then transferred by hand to a steam jacketed kettle for blanching. The samples were blanched for 30 minutes at 87.9°C in 100 ppm calcium ion water. Cooked beans were removed from the blanch water and were submerged into cold tap water at 10°C for one minute. Cooling was performed to ensure termination of the hot soak cycle and to reduce vapor losses. Cooled beans were removed from the cooling water and drained on perforated screens prior to can filling.

Can Filling, Brining and Exhausting

Each drained nylon mesh bag was opened and the blanched beans were rapidly transferred to a coded 303x406 can. Beans and cans were weighed to the nearest 0.1 gram on a top loading Mettler Balance (Type P3, E.H. Sargent and Co.). Calculation of soaked bean moisture and hydration ratio were performed according to Equations 3 and 4. Cans were then transferred to an exhaust box conveyor and were hand filled until overflowing with heated brine (90°C). The cans were exhausted for four minutes in 85°C water. The heated brine solution contained 0.31% sucrose and 0.25% sodium chloride in 100 ppm calcium ion water heated to 87.8°C-90.5°C (Appendix I).

$$\frac{\text{soaked bean wt (g)} - \text{initial bean wt (g)}}{\text{soaked bean wt (g)}} \times 100 = \text{soaked bean moisture (\%)}$$

Equation 3. Equation for Calculation of Soaked Bean Moisture

$$\frac{\text{soaked bean wt (g)}}{\text{initial bean wt (g)}} = \text{hydration ratio}$$

Equation 4. Equation for Calculation of Soaked Bean Hydration Ratio

Sealing and Thermal Processing

The headspace of the cans was automatically adjusted to ¼ inch with a Number -00 Canco Vacuum Closing Machine (Model 6, American Can Co.) and the cans were double seamed to provide a hermetic seal.

The sealed cans were hand transferred to a retort for thermal processing to ensure commercial sterility. Two types of retorts were employed for all bean samples. The first type was a FMC still retort (Food Machinery Corp., Hooperston, IL). Beans were processed at 115.6°C for 45 minutes or 121.1°C for 30 minutes; all samples were cooled for 15 minutes in 20°C water. The second type was a Stork-Amsterdam Simmulator agitating retort (Stork-Amsterdam and Co., Apparatenfabriek N.V. Amsterdam, Netherlands). Samples were processed for seven minutes at 122°C and seven minutes at 35°C. The cans were axially rotated at 19 rpms during the process-cooling cycle. Computer monitoring of the process was achieved with a Hewlett-Packard 85.

Thermal Process Determination

Thermal process data was measured with Ecklund thermocouples (O.F. Ecklund Co., Coral Gables, FL) placed in the geometric center of the can. The voltage created by heating the dissimilar metal thermocouples was transmitted to a data acquisition unit for voltage to temperature transformation. The data acquisition unit was connected to the HP-85 for data storage on a magnetic cassette cartridge and creation of a datafile.

The datafile was then merged with a stored program called "Lethal" (Appendix II) which computes the lethal rate for the process (Ball, 1928). "Lethal" will take temperature readings every 30 seconds and compute a lethal rate according to Equation 5, through integration of the area under the heating curve. This computation uses a temperature of 121°C and z value of 10°C. This sterilizing value of a process is generally expressed as the F_o value which is equivalent to the number of minutes required to destroy a specified number of spores at 121°C when z equals 10°C.

$$\frac{1}{10^{(250°F - T/Z)}} = \text{Lethal Rate}$$

Equation 5. Equation for Calculation of Processed Bean Lethal Rate during Thermal Processing (Fennema, 1975)

The z value for Clostridium botulinum spores is generally regarded to be 10°C. The time required at 121°C to reduce the survival population by a factor of 12 log cycles (12D) in a phosphate buffer is 2.45 minutes.

The program "Lethal" will sum all of the areas for each time interval which will yield a total lethal rate or F_o value for a given process.

Canned Bean Storage

Dried processed cans were stored in designated controlled temperature cabinets at 21.1°C for one or two weeks prior to quality evaluation. This was necessary to ensure proper bean-brine equilibration.

Washed Drained Weight of Processed Beans

The contents of a can were poured onto an 8 inch diameter U.S. Standard No. 8 screen (0.094 inch opening) and evenly distributed. The screen was placed over a plastic pan to collect free sauce as the beans were distributed on the surface of the mesh screen. The screen and contents were immersed into 21.1°C water and were slowly agitated for three rotations to uniformly distribute and wash the bean. The screen and contents were withdrawn from the water and were positioned at a 15° angle for two minutes to facilitate drainage. The screen was then transferred to tared bottom plate, weighed on a counter balance over-under scale (+0.1 oz) and the drained weight ratio was calculated according to Equation 6. One determination per can was made.

$$\frac{\text{washed bean drained wt (g)}}{\text{soaked bean fill wt (g)}} = \text{drained wt ratio}$$

Equation 6. Equation for Calculation of Processed Bean Drained Weight Ratio

Visual Examination of Processed Beans

During the drained weight procedure, the beans were visually judged by hedonic scales for clumping (1-5) and splitting (1-5). Each can received a subjective clumping and splitting score (hedonic scale: 1 = none, 5 = excessive).

Processed Bean Texture

After color determination, beans were evaluated for texture using an Allo-Kramer Recording Shear Press (Model TR-1, Food

Technology Corp., Reston, VA). The 3,000 pound transducer and No. C-15 standard shear compression cell were used. The rate of shear compression blade travel was 0.52 cm/sec. A sample size of 100 g of processed beans was placed in the cell, evenly distributed, and sheared. The entire cell was cleaned and rinsed between each measurement. Two readings were taken per can.

The Instron Universal Testing Machine (Model TTBM, Instron Corp., Canton, MA) was also used for texture determinations. The processed beans were evaluated using 200 grams in a C-15 universal multiblade shear compression cell. A 500 kg load cell was used with a head speed of 200 mm/min, a chart speed of 200 mm/min, a gauge length of 7.5 cm, and a return of 9.7 cm. One reading per can was performed.

Texture Curve Analysis

The shear force displacement curves allow for objective texture evaluation by measurement of curve peak height (Figure 1). A firm bean will require greater force to produce shearing, as indicated by a higher peak height, than a soft bean. Certain bean varieties produce two peaks: a compression peak and a shear peak (Hosfield and Uebersax, 1980). Therefore, an equation was developed using the points illustrated in Figure 2 to give a seventh-degree polynomial (Equation 7) to produce parameters useful to describe the texture curve, as shown in Figure 3.

$$f(x) = \frac{\alpha x^7}{7} + \frac{\beta-\alpha A x^6}{6} + \frac{\alpha\beta-\beta A + \gamma x^5}{5} + \frac{(-\alpha)C + \beta B-\gamma A x^4}{4} + \frac{\alpha D-\beta C+\gamma B X^3}{3} + \frac{\beta D-\gamma C x^2}{2} + \gamma D X + E$$

Equation 7. Equation for Derivation of the Seventh-Degree Polynomial for Characterization of the Texture Curve

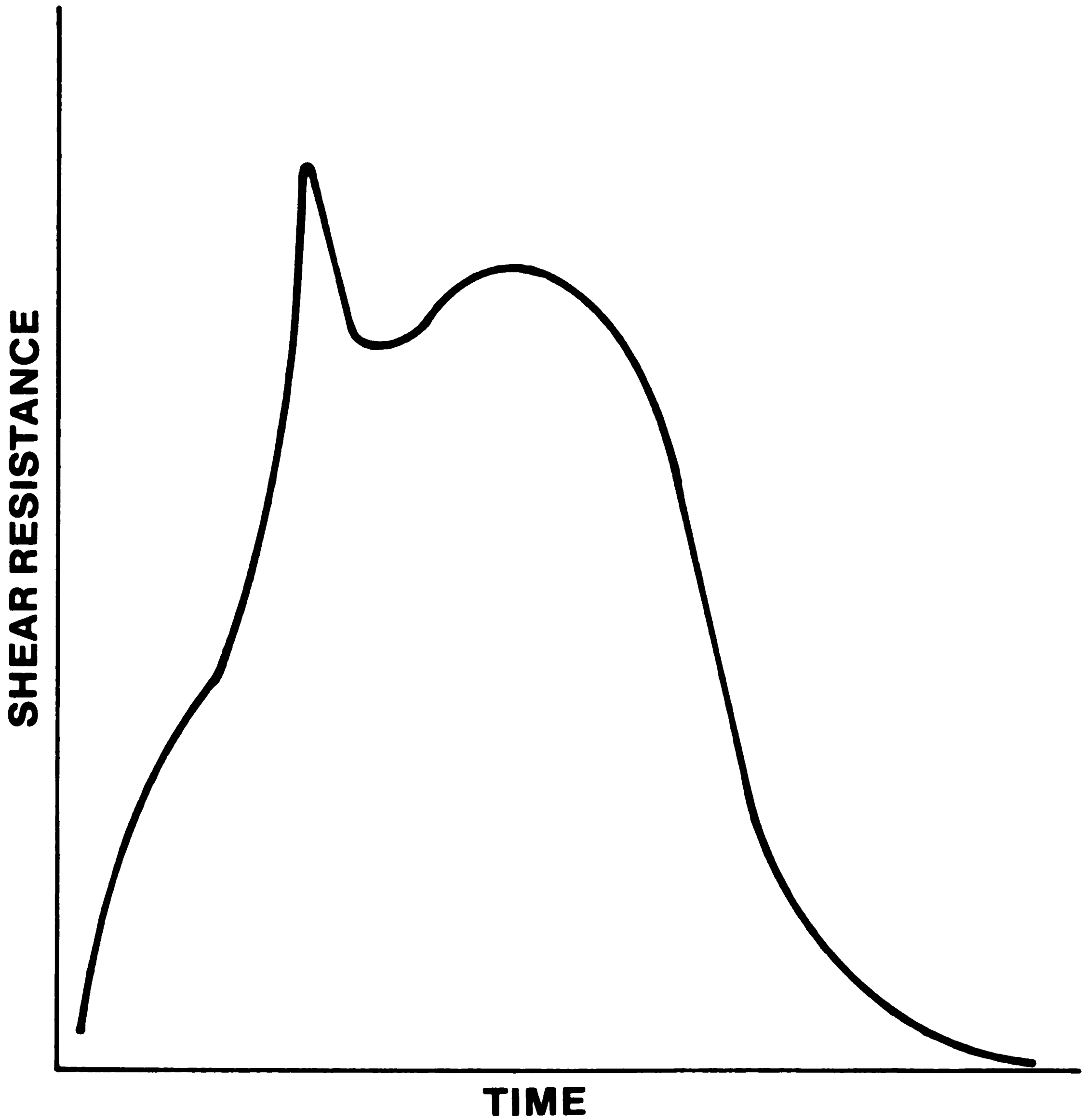

Figure 1. Typical Kramer Shear Peak Curve for Objective Evaluation of Processed Bean Texture

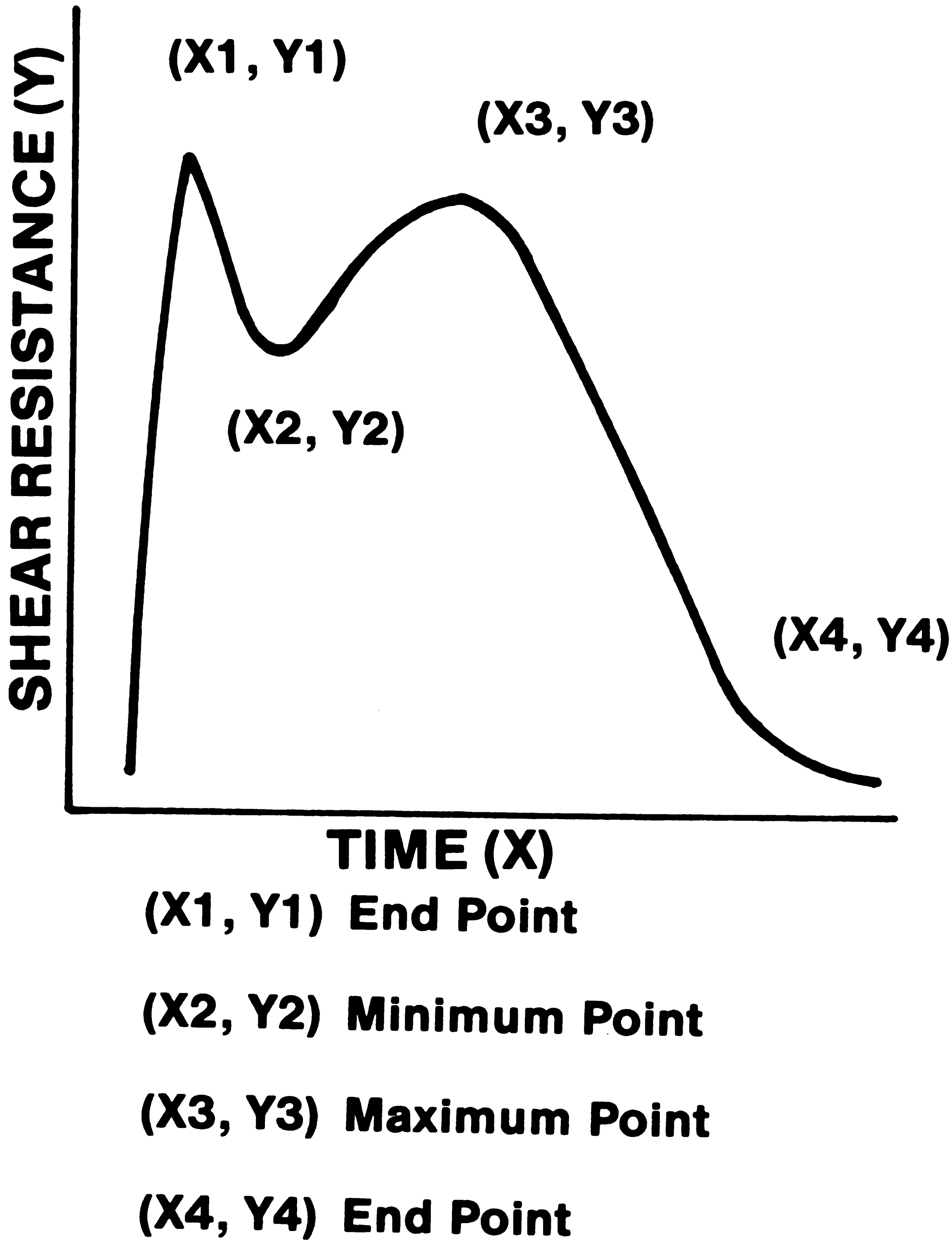

Figure 2. Various Data Points from the Kramer Shear Curve Entered into the Texture Curve Equation for Derivation of the Seventh-Degree-Polynomial

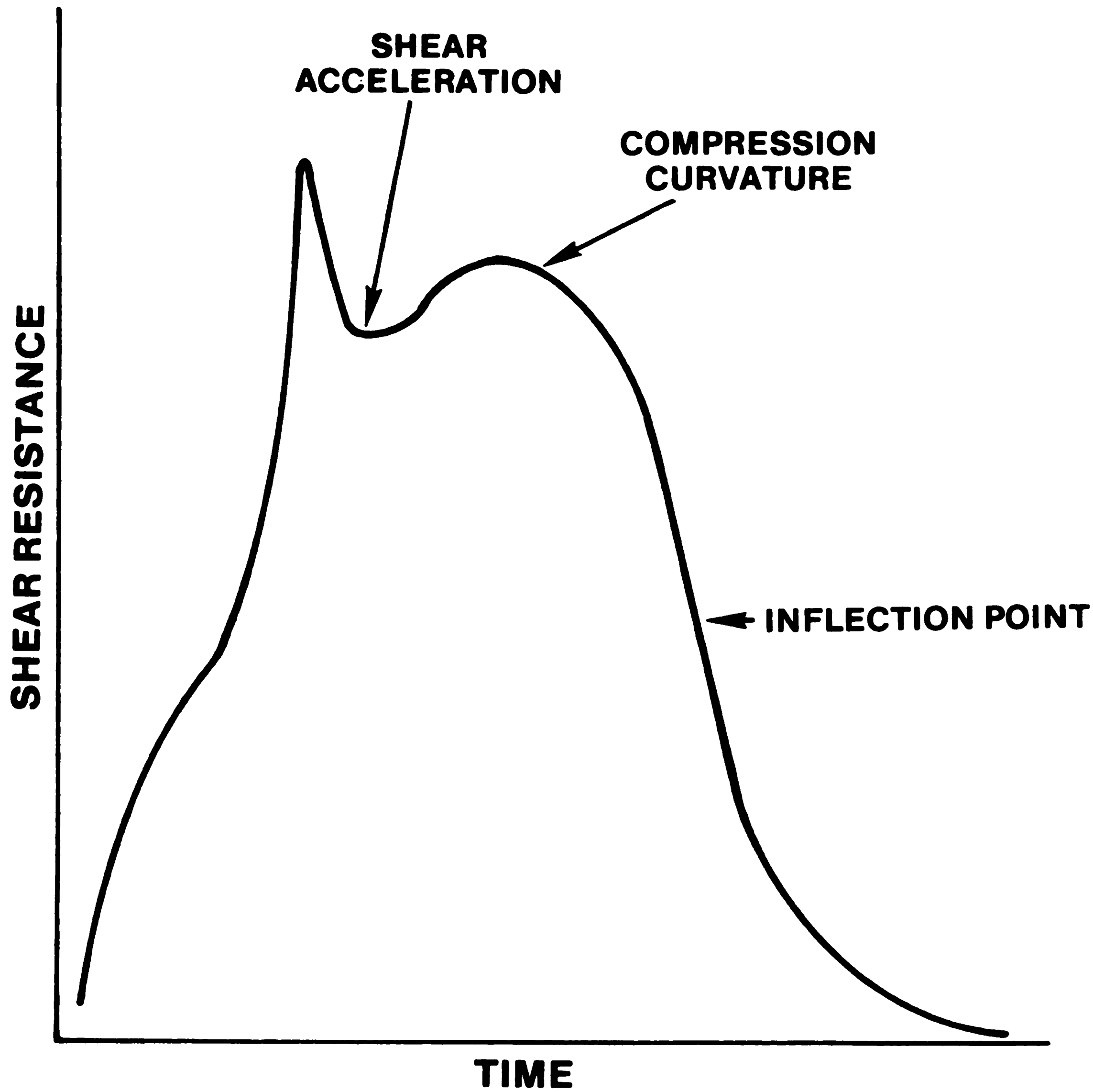

Figure 3. Mathematical Parameters Derived from Characterization of the Seventh-Degree-Polynomial of Processed Bean Texture Curve

The four points shown in Figure 2 were entered into a seventh-degree polynomial (Appendix III) specifically for that curve type. This polynomial was differentiated twice to give a polynomial of the fifth-degree. This equation then utilizes the compression peak time and initial resistance time values and determines the inflection point. Thus, a new parameter was calculated, the inflection point, being the point of directional change between initial contact with beans and the compression peak time. The other two new parameters produced were a measure of the radius of curvature sharpness as it passes through the compression peak and the shear minimum. These parameters are the compression curvature and shear acceleration, respectively (Figure 3).

Processed Bean Apparent Density and Volume

The coordinate X4 from the texture curve analysis (Figure 2) was the point of shear blade contact with processed beans. This value represented the distance traveled before shearing occurred. A constant shear blade distance of 82 mm always occurred during shearing. The bean volume was computed by subtracting 82 mm from the initial blade-bean contact distance (X4). Multiplying this value by the shear cell dimension (46.24 cm^2), the processed bean volume was calculated (Equation 8).

$$(82mm - \text{initial bean contact}(mm))(46.24cm^2)(0.1cm/mm) = \text{processed bean vol}$$

Equation 8. Equation for Calculation of Processed Bean Volume

The apparent bean density was also computed (Equation 9). A constant weight of 100 grams processed beans was placed in the C-15 standard shear compression cell. This constant weight (100 g) was divided by the bean volume to yield apparent processed bean density.

$$\frac{\text{sheared processed bean wt (100 g)}}{\text{processed bean vol (cc)}} = \begin{matrix}\text{processed bean}\\ \text{apparent density}\end{matrix}$$

Equation 9. Equation for Calculation of Processed Bean Apparent Density

Statistical Analysis

The "Statistical Package for the Social Sciences" computer programs were used on the Michigan State University CYBER 750 computer for data computation and statistical analyses.

Two-way analysis of variance was determined by using the subprogram ANOVA. Mean squares were reported after rounding and significant probability levels of P <0.05 (*), P <0.01 (**), and P <0.001 (***) were indicated. Coefficient of Variation (CV%) which expresses the standard deviation as a percent of the mean was calculated (Little and Hills, 1972).

Tukey mean separations were used for single classification analyses by the subprogram ONEWAY. These were used to compare selected variety and treatment differences. The mean values were presented such that treatments which were significantly different (P <0.05) were indicated with like letters.

Summary of data calculations are presented in Table 1.

Table 1. Summary Computations for Dry, Soaked and Processed Beans

Dry Bean Handling

Calculation of 100 grams of dry bean solids

$$\frac{\text{solids required (g)}}{\text{solids at given moisture}}$$

Soaking

$$\text{Hydration Ratio} = \frac{\text{soaked bean weight (g)}}{\text{initial bean weight (g)}}$$

$$\text{Soaked Bean Moisture} = \frac{\text{soaked bean wt (g)} - \text{initial bean wt (g)}}{\text{soaked bean wt (g)}} \times 100$$

Processing

$$\text{Drained Weight Ratio} = \frac{\text{washed bean drained wt (g)}}{\text{soaked bean fill wt (g)}}$$

$$\text{Processed Bean Moisture} = 100\% - \text{dry bean residue}$$

$$\text{Processed Bean Volume} = (82\text{mm} - \text{initial bean contact(mm)})(46.24\text{cm}^2)(0.1\text{cm/mm})$$

$$\text{Processed Bean Apparent Density} = \frac{\text{100 g sheared processed beans}}{\text{processed bean vol (cc)}}$$

EXPERIMENTAL

The Effect of Initial Bean Moisture Content and Variety on Thermal Processing Quality

Abstract

The effect of initial moisture content on Fleetwood, Seafarer, Nep-2 and Sanfernando was investigated. All beans were adjusted to an initial moisture content of 8%, 10%, 12%, 14%, 16%, and 18%, in triplicate. One hundred grams of dry bean solids were then thermally processed at 115.6°C/45 minutes. Cans were opened and evaluated for the following quality parameters: drained weight, clumps, splits, color, texture and total solids. The results indicated initial moisture content had no significant effect on any quality parameters tested. The differences observed were primarily varietal. It was observed, however, that Nep-2 and Sanfernando slightly increased in firmness as the moisture content was raised above 16%. There was no significant difference below 16% moisture. It was also found that all bean varieties became darker after processing and Sanfernando was found to be the firmest bean.

Introduction

A major drawback to utilization of dry beans (*Phaseolus vulgaris* L.) is the initial moisture content. Beans stored at too low or too high of a moisture content have been reported to develop the so called "hardshell" phenomenon. A condition whereby beans fail to imbibe water upon soaking. Another problem is to compare canned bean quality attributes among bean types that are processed under different moisture contents. These different moisture beans may imbibe differential amounts of water during soaking and canning. These differences in water uptake may cause large variation in final product quality.

The objective of this study was to process four common bean varieties under eight initial moisture contents and to measure the moisture content, color, texture and subjective bean appearance during and after thermal processing. Two white navy pea beans were utilized: Fleetwood and Seafarer. Both varieties are annually grown in Michigan and are commercially canned. Sanfernando is a black variety from South America. It is an upright archytype which allows for more plants per row and increase in seed yields per plant. It also has a developed root system which aids in drought resistance. Due to the presence of tannins in the pigmented seedcoat, it has also been reported to have pest resistance. Nep-2 is a white seedcoated mutant of Sanfernando, developed as a suitable white bean type, desirable to American diets.

Methods and Materials

Dry Bean Handling. The varieties used were Fleetwood, Seafarer, Nep-2 and Sanfernando. Fleetwood and Seafarer are navy beans and were obtained from the Michigan Foundation Seed Association. Nep-2 and Sanfernando were white and black seeded isolines, respectively, and were obtained from the USDA Quality Nursery. Objective color measurements of dry and processed beans were determined using a

Hunter Lab Color Difference Meter. Beans were placed in an optically pure glass dish and coordinate values (L, $+a_L$, and $+b_L$) were recorded.

The initial moisture content of all samples was measured with a Motomco moisture meter. After moisture measurement, 100 grams of bean solids were filled into 4x6 inch nylon mesh bags. Beans were then placed into a humidified chamber and equilibrated to the proper moisture content. Humidified samples were then placed in a plastic zip-lock bag to ensure no environmental moisture loss or gain until processing.

Soaking and Blanching. All samples were soaked for 30 minutes at 29.3°C in 100 ppm calcium water. Samples were then transferred to a steam jacketed kettle and blanched for 30 minutes at 87.9°C in 100 ppm calcium water. Beans were removed from the hot soak cycle and cooled at 10°C for one minute. Cooled beans were removed from the cooling water and drained on perforated screens.

Can Filling, Brining and Exhausting. Blanched beans were rapidly filled into coded 303x406 cans. Beans and cans were weighed to the nearest 0.1 gram and were then transferred to an exhaust box conveyor. The cans were hand filled with heated brine (0.31% sucrose, 0.25% sodium chloride) and exhausted for four minutes.

Sealing and Thermal Processing. Exhausted cans were hermetically sealed and transferred to a still retort. Beans were thermally processed at 115.6°C/45 minutes to ensure commercial sterility. Dried, processed bean cans were stored for two weeks prior to quality evaluation to ensure proper bean-brine equilibration.

Washed Drained Weight. The contents of the can were poured onto a U.S. Standard No. 8 screen. The screen and contents were immersed in 21.1°C water and allowed to drain for two minutes. The screen was then transferred to a tared bottom plate and weighed on a counter balance over-under scale.

Visual Examination. Beans were visually judged by hedonic five point scale for clumping and splitting (1 = none, 5 = excessive) during the drained weight procedure. Each can received a subjective visual score.

Processed Texture and Total Solids. Beans were evaluated for texture using an Allo-Kramer Shear Press. A sample size of 100 grams of processed beans was placed in the cell and sheared. A 3,000 pound transducer and No. C-15 standard shear compression cell were used. The bean residue from the Kramer shear press was used for determination of total solids. One hundred grams of shear residue were weighed into a tared aluminum pan and dried to a constant weight at 80°C. The dried samples were weighed and calculation of percent total solids was performed.

Results and Discussion

The means for dry and processed color are presented in Table 2. Analyses of variance for all color data are summarized in Table 3.

The mean squares for dry and processed color in Table 3 show no significant difference for bean color among the various initial bean moisture contents. As was expected, a significant color difference was observed between varieties for both dry and processed beans.

Table 2. Surface Color Analysis[1] of Dry and Processed Beans Evaluated at the MSU Legume Quality Laboratory: Seafarer, Fleetwood, Nep-2 and Sanfernando Were Processed at Eight Initial Moisture Conditions

Variety	Initial Moisture	Hunter Lab Color Coordinates: Dry Bean L	a_L	b_L	Processed Bean L	a_L	b_L
Seafarer	8	61.2a	1.7a	10.5a	45.9a	-0.3ab	13.9a
	10	61.2a	1.7a	10.5a	46.0a	-0.2ab	14.1a
	12	61.2a	1.7a	10.5a	46.0a	-0.1b	14.2a
	14	61.2a	1.7a	10.5a	46.5ab	-0.4ab	14.0a
	16	61.2a	1.7a	10.5a	46.6ab	-0.2a	14.1a
	18	61.2a	1.7a	10.5a	47.7b	-0.7ab	13.8a
Fleetwood	8	63.0a	1.3a	10.1a	46.2a	0.7b	14.8a
	10	63.0a	1.3a	10.1a	47.6ab	0.2ab	14.9a
	12	63.0a	1.3a	10.1a	47.7b	0.2ab	14.6a
	14	63.0a	1.3a	10.1a	47.9ab	-0.1a	14.7a
	16	63.0a	1.3a	10.1a	47.6ab	0.4ab	14.7a
	18	63.0a	1.3a	10.1a	47.9b	0.1ab	14.7a
Nep-2	8	59.7a	7.7a	13.7a	48.8a	0.1a	15.2a
	10	59.7a	7.7a	13.7a	47.7a	0.1a	15.0a
	12	59.7a	7.7a	13.7a	49.2ab	-0.2a	15.1a
	14	59.7a	7.7a	13.7a	50.6b	-0.2a	15.3a
	16	59.7a	7.7a	13.7a	49.1ab	0.1a	15.4a
	18	59.7a	7.7a	13.7a	49.2ab	-0.3a	15.4a
Sanfernando	8	16.0a	-0.8a	-5.1a	13.7a	-15.3a	2.0a
	10	16.0a	-0.8a	-5.1a	13.4a	-15.7a	1.9a
	12	16.0a	-0.8a	-5.1a	13.6a	-15.4a	2.0a
	14	16.0a	-0.8a	-5.1a	13.5a	-15.6a	1.9a
	16	16.0a	-0.8a	-5.1a	13.5a	-15.3a	2.1a
	18	16.0a	-0.8a	-5.1a	13.4a	-15.6a	2.0a

[1]Mean values 100 g dry or processed beans, n=3 cans per treatment; Tukey mean separations, like letters within each variety indicate no significant difference (P<0.05)

Table 3. Analysis of Variance of Surface Color of Dry and Processed Beans for Fleetwood, Seafarer, Nep-2 and Sanfernando. Beans Were Processed at Eight Initial Moisture Contents and Evaluated for Various Bean Quality Characteristics

Source of Variation	df	Hunter Lab Color Coordinates					
		Dry Bean			Processed Bean		
		L	a_L	b_L	L	a_L	b_L
		Mean Squares					
Main Effects	8	3759.50***	89.28***	449.28***	1868.18***	541.63**	272.31***
Moisture	5	5.83	0.0	1.42	2.99	131.49	0.01
Variety	3	10015.61***	238.09***	1195.70***	4976.83***	1225.19***	726.14***
Two-Way							
Moisture X Variety	15	5.83	0.0	1.46	7.13	158.12	0.04
Residual	48	0.01	0.01	1.45	4.72	14.34	0.04
CV (%)		0.20	4.0	16.0	5.5	10.0	1.74

Table 2 shows no significant difference in dry bean Hunter Lab color coordinates between initial moisture contents within each variety. These data also indicate that beans become more dark (decrease L), more green (decrease a_L) and more yellow (increase b_L) during processing. This may be attributed to seedcoat pigment loss to the soak water and brine and to non-enzymatic browning reactions during thermal processing.

The means for bean moisture and mass ratio indexes are presented in Table 4. Analyses of variance for these parameters are summarized in Table 5. Mean values for all bean moisture levels are represented in Figure 4.

It was observed that the initial bean moisture (Table 5) had no significant effect on soaked bean moisture and hydration ratios. The data also indicate no significant difference among varieties for these hydration parameters. These mean values are presented in Table 4.

The means for dry, soaked and processed canned bean quality traits are presented in Table 6. Analyses of variance for these parameters are summarized in Table 7. Mean values for all bean weights are presented in Figure 5.

The mean squares for the drained weight (Table 7) and drained weight ratio (Table 5) showed no significant difference in the experimental main effects. This indicates that the initial moisture content for the four varieties tested does not affect processed bean drained weight. It was observed in Tables 5 and 7 that the final processed bean moisture and total solids were affected by the initial moisture content. The means for each variety are presented in Tables 4 and 6. These data indicate that Seafarer was the only variety statistically affected by the initial moisture content. However, differences among

Table 4. Moisture Measurement[1] of Dry, Soaked and Canned Beans Evaluated at the MSU Legume Quality Laboratory: Seafarer, Fleetwood, Nep-2 and Sanfernando Were Processed at Eight Initial Moisture Conditions

Variety	Initial Moisture	Bean Moisture (%) Initial	Soaked	Processed	Mass Ratio Indexes[2] Hydration	Drained Wt
Seafarer	8	8.3a	46.1a	69.9ab	1.86a	1.41ab
	10	9.8b	45.7a	69.5ab	1.84a	1.44b
	12	12.1c	44.0a	69.0ab	1.79a	1.44b
	14	13.9d	45.4a	70.9a	1.83a	1.40ab
	16	16.2e	44.2a	68.7b	1.79a	1.38ab
	18	18.0f	44.4a	70.3ab	1.80a	1.35a
Fleetwood	8	8.1a	44.2a	68.9a	1.80a	1.54a
	10	10.4b	44.8a	69.7a	1.85a	1.27a
	12	12.6c	44.9a	70.4a	1.82a	1.45a
	14	14.2d	44.8a	69.9a	1.81a	1.45a
	16	15.8e	43.9a	70.7a	1.79a	1.47a
	18	18.2f	42.8a	69.5a	1.75a	1.43a
Nep-2	8	8.1a	48.5a	70.4a	1.94a	1.43a
	10	10.0b	46.5a	68.0b	1.87a	1.53a
	12	12.2c	46.8a	71.1a	1.88a	1.43a
	14	13.9d	42.9a	71.4a	1.60a	1.73a
	16	15.6e	44.9a	70.6a	1.81a	1.38a
	18	17.6f	44.1a	70.7a	1.79a	1.37a
Sanfernando	8	8.1a	44.2a	68.7a	1.79a	1.44a
	10	10.0b	43.8a	69.2a	1.78a	1.46a
	12	11.7c	45.2a	68.7a	1.83a	1.37a
	14	14.2d	44.5a	68.9a	1.80a	1.34a
	16	15.9e	44.6a	68.6a	1.80a	1.35a
	18	18.3f	44.1a	69.9a	1.79a	1.34a

[1]Mean values 100 g bean solids per can, n = 3 cans per treatment; Tukey mean separations, like letters within each variety indicate no significant difference ($P<0.05$)

[2]Hydration ratio = soaked beans (g)/initial dry beans (g); drained weight ratio = drained canned beans (g)/soaked beans (g)

Table 5. Analysis of Variance of Dry, Soaked and Canned Moisture and Texture Measurements for Fleetwood, Seafarer, Nep-2 and Sanfernando. Beans Were Processed at Eight Initial Moisture Contents and Evaluated for Various Bean Quality Characteristics

Source of Variation	df	Bean Moisture (%)			Mass Ratio Indexes		Texture
		Initial	Soaked	Processed	Hydration	Drained Weight	Shear Resistance
				Mean Squares			
Main Effects	8	97.83***	33.73	3.75***	0.07	0.02	1387.00***
Moisture	5	156.30***	46.04	2.51**	0.08	0.02	103.16***
Variety	3	0.38	13.23	5.82***	0.04	0.03	3526.73***
Two-Way							
Moisture X Variety	15	0.30	36.94	2.28***	0.07	0.03	32.87
Residual	48	0.17	35.30	0.60	0.06	0.03	19.57
CV (%)		3.14	13.26	0.10	13.38	12.19	9.36

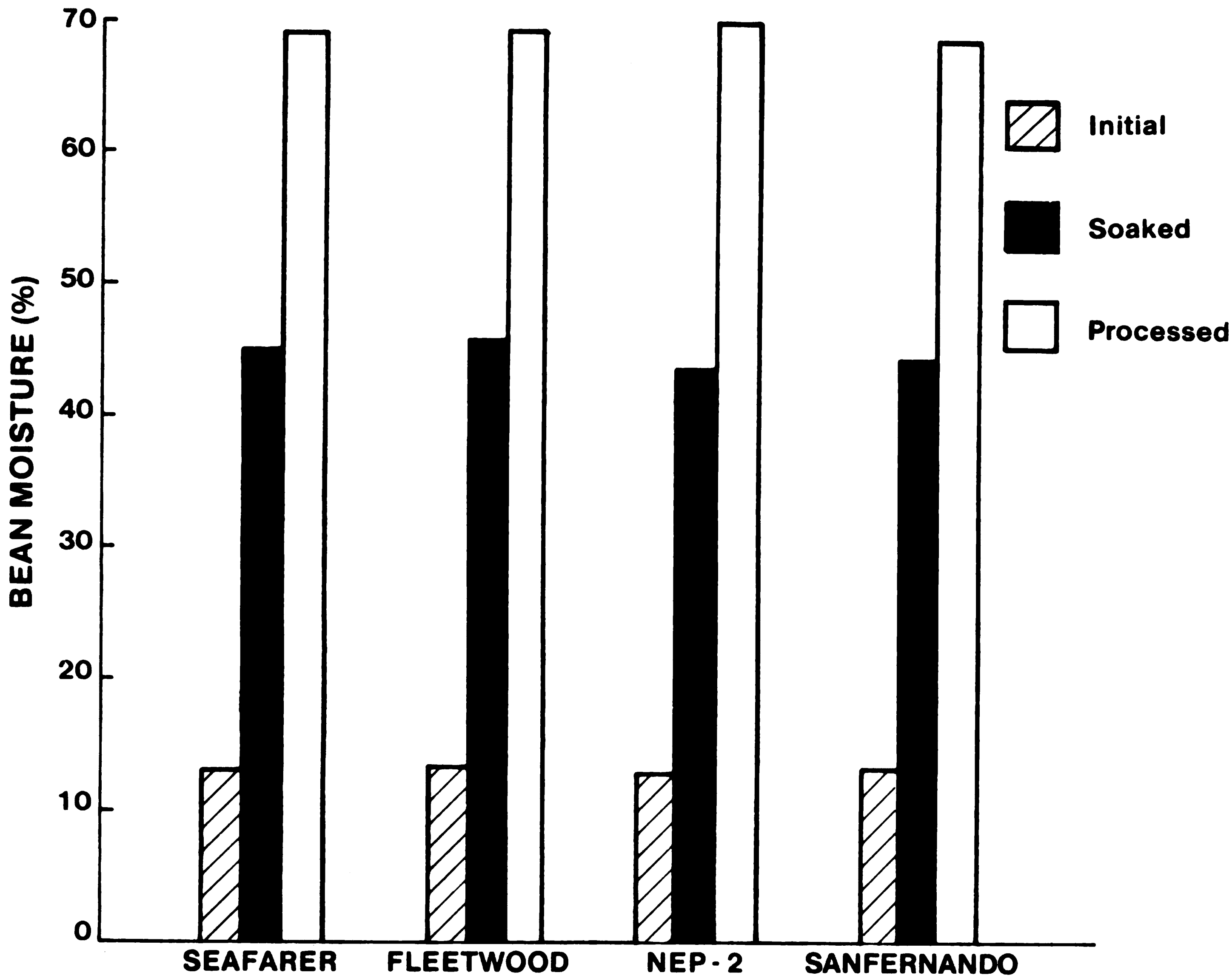

Figure 4. Mean Values for Initial, Soaked and Processed Bean Moisture for Seafarer, Fleetwood, Nep-2 and Sanfernando

Table 6. Quality Characteristics[1] of Dry, Soaked and Canned Beans Evaluated at the MSU Legume Quality Laboratory: Seafarer, Fleetwood, Nep-2 and Sanfernando Were Processed at Eight Initial Moisture Conditions

Variety	Initial Moisture	Bean Weight (g) Initial	Bean Weight (g) Soaked	Bean Weight (g) Drained	Processed Beans: % Total Solids	Processed Beans: Visual[2] Clumps	Processed Beans: Visual[2] Splits	Processed Beans: Shear Resistance (kg/100g)
Seafarer	8	109.1a	202.5a	285.9a	30.0ab	1.0a	1.0a	45.4a
	10	110.9b	204.2a	293.5a	30.5ab	1.0a	1.0a	45.6a
	12	113.7c	203.6a	294.1a	30.9ab	1.0a	1.0a	47.4a
	14	116.1d	212.5ab	298.2a	28.8a	1.0a	1.0a	47.4a
	16	119.3e	214.1ab	295.3a	31.7b	1.0a	1.0a	47.2a
	18	121.9f	219.4b	295.9a	29.7ab	1.0a	1.0a	45.4a
Fleetwood	8	108.8a	195.3a	300.8a	31.1a	1.7b	1.7b	33.6a
	10	111.6b	206.8a	309.1a	30.3a	1.0a	1.7a	35.4a
	12	114.5c	208.1a	300.9a	29.6a	1.0a	1.0a	37.7a
	14	116.5d	211.1a	305.1a	30.1a	1.0a	1.0a	33.8a
	16	118.8e	212.1a	311.9a	29.3a	1.0a	1.3a	35.2a
	18	122.3f	213.8a	305.5a	30.5a	1.0a	1.3a	37.9a
Nep-2	8	108.9a	211.7a	301.8a	29.6a	1.7a	1.0a	32.9a
	10	111.1b	207.5a	317.5a	32.0b	1.0a	1.7a	36.7ab
	12	113.8c	213.8a	304.9a	28.9a	1.7a	1.0a	34.9ab
	14	116.1d	196.0a	299.3a	28.6a	1.0a	1.0a	39.9ab
	16	118.6e	215.1a	297.7a	29.4a	1.0a	1.0a	47.9b
	18	121.4f	217.1b	298.2a	29.3a	1.0a	1.0a	47.2b

Table 6 (cont'd.).

Variety	Initial Moisture	Bean Weight (g)			Processed Beans			
		Initial	Soaked	Drained	% Total Solids	Visual[2] Clumps	Visual[2] Splits	Shear Resistance (kg/100g)
Sanfernando	8	108.8a	197.3a	283.6a	31.3a	2.3a	2.7a	61.5a
	10	111.1a	197.8a	288.3a	30.8a	3.0a	3.0a	63.5ab
	12	113.2a	206.7ab	282.4a	31.3a	1.7a	3.0a	68.3ab
	14	116.6a	210.0bc	280.8a	31.1a	2.0a	3.0a	65.6ab
	16	118.9a	214.4bc	288.8a	31.4a	2.0a	3.0a	74.8b
	18	122.4a	218.7c	293.5a	30.1a	1.3a	3.0a	69.4ab

[1]Mean values 100 g bean solids per can, n = 3 cans per treatment; Tukey mean separations, like letters within each variety indicate no significant difference ($P<0.05$)

[2]Subjective visual examination for canned bean characteristics, 5 point scale (1 = none, 5 = excessive)

Table 7. Analysis of Variance of Quality Characteristics of Dry, Soaked, and Canned Fleetwood, Seafarer, Nep-2 and Sanfernando. Beans Were Processed at Eight Initial Moisture Contents and Evaluated for Various Bean Quality Characteristics

		Dry and Processed Hunter Lab Color Coordinates					
		Bean Weight (g)				Visual	
Variation	df	Initial	Soaked	Drained	Dried	Clumps	Splits
				Mean Squares			
Main Effects	8	173.12***	651.73	607.44**	3.75	1.88***	4.19***
Moisture	5	276.55***	704.18	117.12	2.51**	0.51	0.16
Variety	3	0.73	564.42	1424.63***	5.82***	4.16***	10.91***
Two-Way							
Moisture X Variety	15	0.50	858.05	77.30	2.28***	0.35	0.43
Residual	48	0.29	797.96	123.61	0.60	0.29	0.42
CV (%)		0.47	13.30	3.74	2.56	39.89	14.49

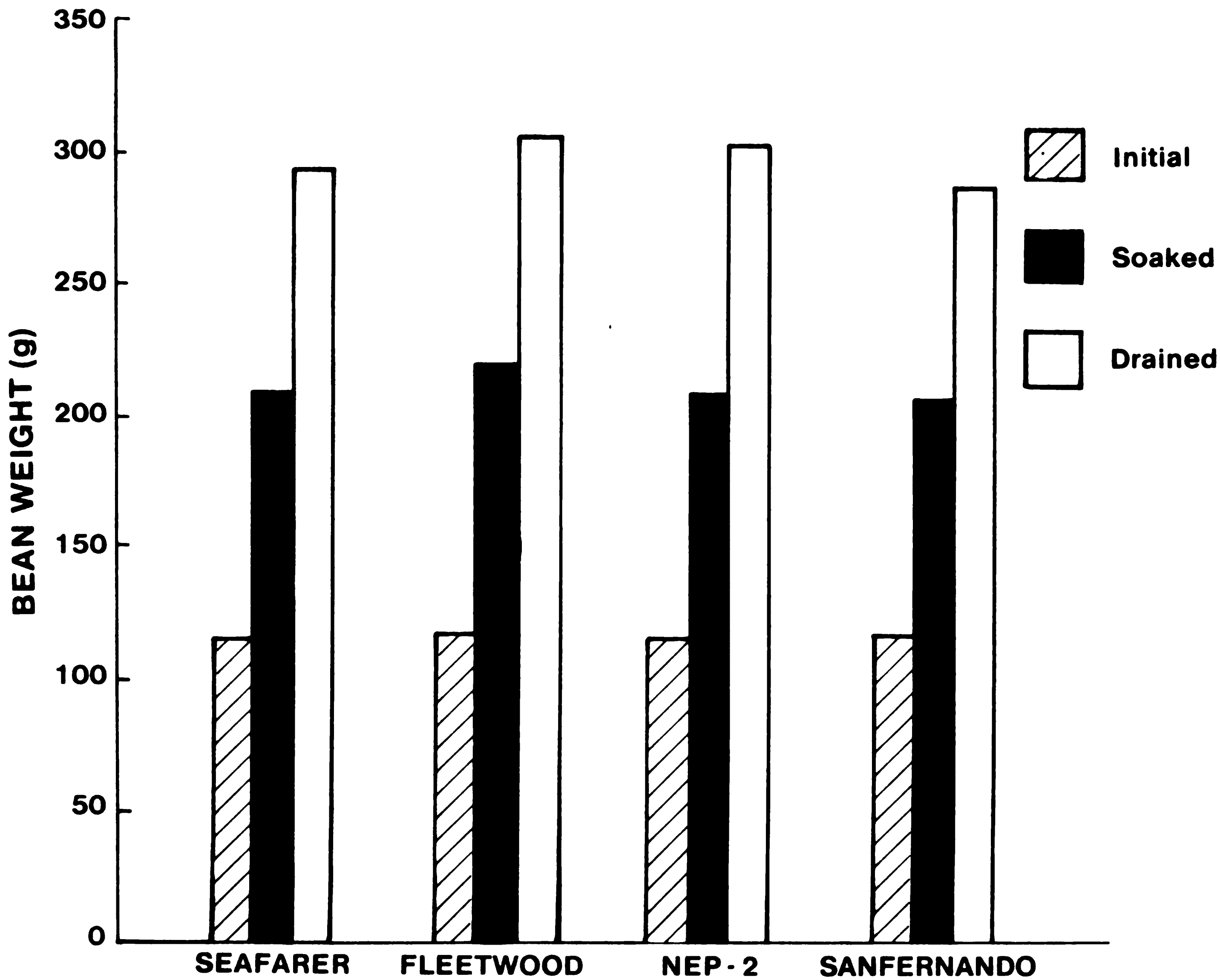

Figure 5. Mean Values for Initial, Soaked and Processed Bean Weights for Seafarer, Fleetwood, Nep-2 and Sanfernando

the initial moisture levels did not demonstrate a trend and were of limited magnitude for Seafarer.

Table 7 shows a significant difference in subjective visual examination of clumps and splits among varieties. No significant differences were observed among initial moisture contents. These data clearly indicate that certain varieties have a greater tendency to split and clump than others. Table 6 represents the Tukey mean separations for clumping and splitting. During thermal processing, beans further hydrate, swell and many breakdown or split. This splitting may cause leaching of starch from the exposed cotyledon which may be suspended in the canning medium (brine or sauce). This leached starch can gelatinize during heating and cause canned bean adhesion and clumping. It was observed that Sanfernando clumped more than the other three bean types. Bean splitting was minimal in Seafarer, Fleetwood and Nep-2. Sanfernando showed the most splitting and clumping among bean types.

The analysis of variance for texture is presented in Table 5. A significant difference for both initial moisture content and variety was observed. No significant moisture-varietal interaction was observed. Observation of shear resistance values (Table 6) indicates no significant difference in bean texture for Seafarer and Fleetwood at any moisture level. Both Nep-2 and Sanfernando showed a firming effect as initial moisture levels increased from 16% to 18% moisture. Mean values for texture and typical Kramer curve types are presented in Figure 6. Fleetwood was observed to be the softest bean with a shear resistance of 35.6 kg/100g. Fleetwood was followed in firmness by Nep-2 (39.9 kg/100 g) and Seafarer

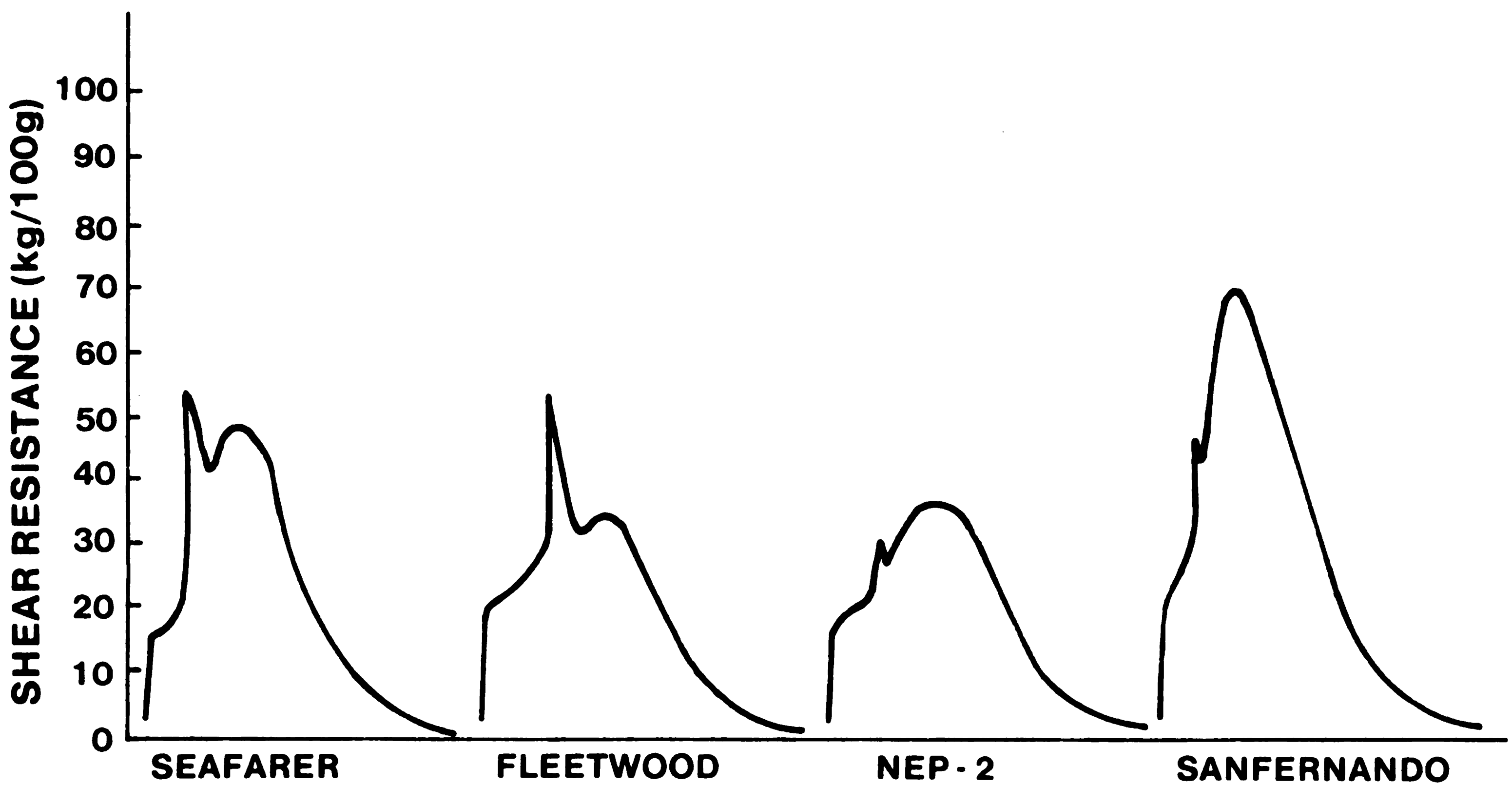

Figure 6. Typical Kramer Processed Bean Texture Curves Characterizing Mean Values for the Compression Peaks and Shear Peaks for Seafarer, Fleetwood, Nep-2 and Sanfernando

(46.4 kg/100 g). Sanfernando was observed to be the firmest bean with an average shear value of 67.2 kg/100 g.

Summary and Conclusion

Processing bean initial moisture contents ranging from 8% to 18% had no effect on soak water uptake, drained weight or objective color. In general, all varieties became darker with processing. Clumping and splitting in processed beans were found to be a varietal effect and not due to moisture content. Sanfernando exhibited the most visual bean breakdown during canning. Both Nep-2 and Sanfernando showed a firming effect as the initial moisture contents were elevated (16% to 18%). Sanfernando was the firmest bean evaluated with an average shear resistance of 67.2 kg/100 g. Nep-2 (39.9 kg/100 g) and Seafarer (46.4 kg/100 g) were of intermediate firmness. Fleetwood was the softest bean with an average shear resistance of 35.6 kg/100 g.

The Effect of Thermal Processing on Edible Beans Produced for the National Bean Nutritional Value and Food Quality Nurseries

Abstract

This study includes 27 strains representing seven of the 11 major commercial dry bean classes grown in the U.S. These classes were divided into two nurseries: National Dry Bean Quality Nursery - I (small seeded varieties) and National Dry Bean Quality Nursery - II (large seeded varieties). All cultivars were prepared and thermally processed. Results indicate the less pigmented seeds (white, pinto) became darker with processing. Heavily pigmented beans (blacks) became lighter as a result of canning. Definite cultivar differences in texture were observed. Among the small seeded varieties, Aurora was the firmest, Bunsi and JAMAPA were the softest. Data from the large seeded nursery indicate several firm pinto cultivars (Colorado 3342, U.I. 111 and Colorado 3465) and a Great Northern (Valley). Gloria Pink (Sutter's Pink) and NW 410 (pinto) were among the softest strains tested.

Introduction

Beans are consumed as a speciality food in several industrial countries, including the U.S., Western Europe, South Africa and Australia. In lesser developed countries of Central and South America, beans are a staple food which provide a major source of protein in diets of low income families.

Seed from the two production nurseries (small and large seeded) were processed from the National Bean Nutritional Value and Food Quality Nurseries, W-150 Regional Project. The small seeded nurseries were comprised of four major commercial classes of beans commonly grown in the U.S. These were the whites (small and navy), blacks (black turtle soup), brown (P 766) and pinto (PROTOP-P1). Its counterpart, the large seeded nursery also had three commercial classes: Pinto, Great Northern, and Sutter's Pink, and an undefined class, Colorado 3465. Beans produced in both nurseries were processed and analyzed as separate studies.

Quality Nursery - I (small seeded types) contained 16 entries X two replicates (plots) X two cans/replicate for a total of 64 cans. The large seeded Nursery - II had 11 entries X four replicates (plots) X two cans/replicate for a total of 88 cans. In both cases replications and cans were simultaneously used for replicates.

The objectives of this study were to screen and establish baseline thermal processing data for all commonly grown classes of dry beans. The effectsof bean strain on color, soaked weight, drained weight and textural parameters were also investigated.

Methods and Materials

Dry Bean Handling. Dry beans were grown in field plots at the Saginaw Valley Bean and Sugar Beet Research Farm, near Saginaw, MI. Objective color measurements of dry and processed beans were determined using a Hunter Lab Color and Color Difference Meter. Beans were placed in an optically pure glass dish and coordinate values (L, $+a_L$, $+b_L$) were recorded.

The initial moisture content of all samples was measured with a Motomco moisture meter. After moisture measurement, 100 grams of bean solids were filled into 4x6 inch nylon mesh bags. Samples were then placed in a plastic zip-lock bag to ensure no environmental moisture loss or gain until processing.

Soaking and Blanching. All samples were soaked for 30 minutes at 29.3°C in 100 ppm calcium water. Samples were then transferred to a steam jacketed kettle and blanched for 30 minutes at 87.9°C in 100 ppm calcium water. Beans were removed from the hot soak cycle and cooled at 10°C for one minute. Cooled beans were removed from the cooling water and drained on perforated screens.

Can Filling and Exhausting. Blanched beans were rapidly filled into coded 303x406 cans. Beans and cans were weighed to the nearest 0.1 gram and were then transferred to an exhaust box conveyor. The cans were hand filled with heated brine (0.31% sucrose, 0.25% sodium chloride) and exhausted for four minutes.

Sealing and Thermal Processing. Exhausted cans were hermetically sealed and transferred to a still retort. Beans were thermally processed at 115.6°C/45 minutes to ensure commercial sterility. Dried processed cans were stored for two weeks prior to quality evaluation to ensure proper bean-brine equilibration.

Washed Drained Weight. The contents of the can were poured onto a U.S. Standard No. 8 screen. The screen and contents were immersed in 21.1°C water and allowed to drain for two minutes. The screen was then transferred to a tared bottom plate and weighed on a counter balance over-under scale.

Visual Examination. Beans were visually judged using hedonic scales for clumping (1-5) and splitting (1-5) during the drained weight procedure. Each can of processed beans received a subjective visual score (hedonic scale: 1 = none, 5 = excessive).

Processed Texture and Total Solids. Beans were evaluated for texture using an Allo-Kramer Shear Press. A sample size of 100 g of processed beans was placed in the cell and sheared. A 3,000 pound transducer and No. C-15 standard shear compression cell were used. The residue from the Kramer shear press was for determination of total solids. One hundred grams of shear residue were weighed into a tared aluminum pan and dried to constant weight of 80°C. The dried samples were weighed and calculation of percent total solids was performed.

Results and Discussion

Quality Nursery - I (Small Seed Type). The means for dry and processed bean color are presented in Table 8. Analyses of variance for all color data are summarized in Table 9.

The analyses of variance for dry and processed color in Table 9 showed significant differences among strains for all color coordinates. There was no significant color difference for dry and processed beans among replicates. A significant strain-replicate interaction was observed for the processed color L and a_L coordinates. It was also observed after processing, the color coordinate L decreased, a_L increased and b_L increased for most strains. These data indicate that the beans became darker after canning. The black bean types 8217-VIII-32, ICA-PIJAO and JAMAPA increased in L value indicating

Table 8. Surface Color Analysis[1] of Dry and Processed Beans Evaluated at the MSU Legume Quality Laboratory: 1982 National Dry Bean Quality Nursery-I (Small Seeded). Beans Were Processed at 115.6°C/45 minutes in a Still Retort

Entry/Pedigree (Commercial Class)	Hunter Lab Color Coordinates					
	Dry Bean			Processed Bean		
	L	a_L	b_L	L	a_L	b_L
White						
800242 (small)	60.9g	3.0h	11.9j	51.4de	4.8bcde	15.2ij
Seafarer (navy)	65.4k	2.4ef	9.0g	50.6d	4.7bcde	14.3h
Sanilac (navy)	64.4j	2.4ef	9.1g	51.4de	5.0bcde	14.6hi
8217-111-24 (undefined)	66.91	2.1e	10.8i	51.9e	5.2bcde	16.5k
Nep-2 (navy)	59.6f	2.8gh	11.9j	52.3e	4.6bc	15.3ij
Bunsi (navy)	62.6h	2.2e	10.0h	52.5e	4.9bcde	15.5j
Aurora (small)	63.7i	2.6fg	11.0i	51.3de	5.4cde	15.4j
Black						
Black Turtle Soup (BTS)	17.2c	1.5d	-0.6a	16.6b	5.6e	2.0bc
MSU-61380 (BTS)	16.4ab	1.2cd	-0.6a	15.1a	4.4b	1.9abc
8217-VIII-32 (BTS)	16.1a	1.0bc	-0.4ab	17.7b	5.5de	3.0de
Jalpataqua-72 (BTS)	16.8bc	0.8ab	-0.2bc	14.1a	3.4a	1.2a
Sanfernando (BTS)	16.9bc	0.7ab	-0.0cd	14.8a	4.3ab	1.4ab
ICA-PIJAO (BTS)	16.4ab	1.0bc	-0.0cd	17.2b	4.7bcd	2.4cd
JAMAPA (BTS)	17.4c	0.6a	0.2d	17.4b	5.2bcde	3.2e
Brown						
P 766 (undefined)	23.2d	6.4i	5.6f	20.4c	8.6g	5.2f
Mottle						
PROTOP-P1 (pinto)	26.6e	2.1e	4.6e	20.9c	7.7f	6.5g

[1]Mean values 100 g dry or processed beans of 2 cans/plot x 2 plots (n = 4); Tukey mean separations, like letters within each column indicate no significant difference (P<0.05)

Table 9. Analysis of Variance of Surface Color of Dry and Processed Beans for the 1982 National Dry Bean Quality Nursery - I (Small Seeded)

Source of Variation	df	Hunter Lab Color Coordinates: Dry Bean L	Dry Bean a_L	Dry Bean b_L	Processed Bean L	Processed Bean a_L	Processed Bean b_L
		Mean Squares					
Main Effects	16	2014.57***	7.62***	103.88***	1182.50***	6.09***	155.53***
Strain	15	20148.86***	8.13***	110.81***	1261.32***	6.49***	165.89***
Replicate	1	0.23	0.04	0.02	0.11	0.10	0.08
Two-Way							
Strain X Replicate	15	0.18	0.51	0.05	0.38*	0.22*	0.08
Residual	32	0.01	0.01	0.01	0.19	0.09	0.08
CV (%)		0.26	4.90	1.95	0.58	5.70	3.38

that these bean types became slightly lighter in color after canning. This may be caused by pigment loss from the seedcoat to the soak water and brine.

The means for bean moistures and mass ratio indexes are presented in Table 10. The analyses of variance for these traits are summarized in Table 11.

The mean squares for initial and soaked bean moistures indicated a significant difference among strains. There was a significant difference for initial moistures within replicates. This was due to differential field harvest moisture and drying before canning. The hydration ratios also indicate a significant difference among strains. In general, the white bean types and pinto imbibed more water than did the blacks or brown bean types. This may be caused by a more pigmented seedcoat which inhibits water uptake.

The means for dry, soaked and processed canned bean quality characteristics are presented in Table 12. Analyses of variance for these traits are summarized in Table 13.

A significant difference in drained weight among strains is presented in Table 13. The mean values are summarized in Table 12. It was found that Aurora, a small white, had the highest drained weight and MSU-61380, a black type, had the lowest drained weight. It was also observed that there were no significant differences for percent total solids among all strains (Table 12), indicating no differential leaching of solids from the bean to the brine.

Table 12 reports the mean values for clumps and splits. Table 13 gives the mean squares for these attributes. No significant differences were observed among strains for clumping. However, significant differences did exist among strains for bean splitting,

Table 10. Moisture Measurements[1] of Dry, Soaked and Canned Beans Evaluated at the MSU Legume Quality Laboratory: 1982 National Dry Bean Quality Nursery - I (Small Seeded). Beans Were Processed at 115.6°C/45 minutes in a Still Retort

Entry/Pedigree (Comm. Class)	Bean Moisture (%)			Mass Ratio Indexes[2]	
	Initial	Soaked	Processed	Hydration	Drained Wt
White					
800242 (small)	12.3abc	47.6ef	69.5a	1.91dec	1.46abc
Seafarer (navy)	12.0abc	48.0ef	69.2a	1.92e	1.46abc
Sanilac (navy)	13.3bc	49.2ef	69.8a	1.97e	1.41a
8217-111-24 (undefined)	13.8bc	47.1ef	70.0a	1.89de	1.51bcde
Nep-2 (navy)	11.9abc	48.8f	67.8a	1.95e	1.41ab
Bunsi (navy)	11.7ab	46.9def	69.9a	1.88cde	1.58efg
Aurora (small)	13.5bc	45.2bcde	68.9a	1.83bcd	1.61f
Black					
Black Turtle Soup (BTS)	12.3abc	41.9a	69.5a	1.72a	1.63g
MSU-61380 (BTS)	13.5bc	44.2abcd	68.4a	1.79abc	1.47abcd
8217-VIII-32 (BTS)	14.2c	42.2a	68.7a	1.73a	1.56defg
Jalpataqua-72 (BTS)	12.1abc	43.8abc	70.0a	1.78ab	1.59efg
Sanfernando (BTS)	10.8a	47.1ef	69.0a	1.89de	1.48abcd
ICA-PIJAO (BTS)	13.0abc	44.2abcd	68.8a	1.79abc	1.62fg
JAMAPA (BTS)	12.3abc	45.4cde	69.6a	1.83bcd	1.58efg
Brown					
P 766 (undefined)	12.4abc	42.5ab	69.1a	1.74ab	1.56defg
Mottle					
PROTOP-P1 (pinto)	11.5ab	48.7f	68.3a	1.95e	1.53cdef

[1]Mean values 100 g bean solids per can, of 2 cans per plot x 2 plots (n = 4); Tukey mean separations, like letters within each column indicate no significant difference (P<0.05)

[2]Hydration ratio = soaked beans (g)/initial dry beans (g); drained wt ratio = drained canned beans (g)/soaked beans (g)

Table 11. Analysis of Variance of Dry, Soaked and Canned Moisture and Texture Measurements for the 1982 National Dry Bean Quality Nursery - I (Small Seeded)

Source of Variation	df	Bean Moisture (%)			Mass Ratio Indexes		Texture
		Initial	Soaked	Processed	Hydration	Drained Weight	Shear Resistance
				Mean Squares			
Main Effects	16	4.36***	22.61***	1.65**	0.03***	0.02***	736.50***
Strain	15	3.48***	24.02***	1.75**	0.03***	0.02***	780.48***
Replicate	1	17.62***	1.53	0.23	0.00	0.00	76.74**
Two-Way							
Strain X Replicate	15	1.68***	2.58***	1.00	0.00***	0.00*	28.12**
Residual	32	0.01	0.55	2.71	0.01	0.01	8.93
CV (%)		0.01	1.62	3.92	5.41	6.53	5.70

Table 12. Quality Characteristics[1] of Dry, Soaked and Canned Beans Evaluated at the MSU Legume Quality Laboratory: 1982 National Dry Bean Quality Nursery - I (Small Seeded). Beans Were Processed at 115.6°C/45 minutes in a Still Retort

Entry/Pedigree (Commercial Class)	Bean Weight (g)				Visual[2]		Shear Resistance (kg/100g)
	Initial	Soaked	Processed	Dried	Clumps	Splits	
White							
800242 (small)	114.1abcd	217.5fgh	317.2abc	30.5a	1.0a	1.0a	51.9cde
Seafarer (navy)	113.7abcd	218.9ghi	319.0bc	30.8a	1.0a	3.0c	44.9bc
Sanilac (navy)	115.3abcd	227.0i	319.0bc	30.2a	1.0a	2.8bc	48.8cd
8217-11-24 (undefined)	116.0cd	219.2ghi	330.5cde	30.0a	1.0a	2.5bc	60.7ef
Nep-2 (navy)	113.5abc	221.8h	312.8ab	30.3a	1.0a	1.0a	62.6f
Bunsi (navy)	113.3abc	213.3efgh	336.7de	30.1a	1.0a	1.8abc	37.1ab
Aurora (small)	115.7bcd	211.3defg	340.3e	31.1a	1.0a	2.3abc	95.6g
Black							
Black Turtle Soup (BTS)	114.0abcd	196.4a	319.0bc	30.5a	1.5a	1.8abc	49.5cd
MSU-61380 (BTS)	115.7bcd	207.4bcde	303.9a	30.6a	1.0a	2.8bc	57.2def
8217-61380 (BTS)	116.6ab	201.8abc	314.6ab	31.3a	1.0a	1.5ab	50.4cd
Jalpataqua-72 (BTS)	113.8abcd	202.4abcd	322.6bcd	30.0a	1.0a	2.8bc	55.3def
Sanfernando (BTS)	112.6a	212.9efgh	314.5ab	31.1a	1.5a	1.8abc	52.4cdef
ICA-PIJAO (BTS)	115.0abcd	206.1bcde	334.1de	31.3a	1.0a	2.0abc	42.4bc
JAMAPA (BTS)	114.0abcd	208.8cdef	330.5cde	30.4a	1.0a	2.8bc	32.0a

Table 12 (cont'd.)

Entry/Pedigree (Commercial Class)	Bean Weight (g)				Visual[2]		Shear Resistance (kg/100g)
	Initial	Soaked	Processed	Dried	Clumps	Splits	
Brown							
P 766 (undefined)	114.2abcd	198.8ab	310.2ab	30.9a	1.0a	3.0c	49.3cd
Mottle							
PROTOP-P1 (pinto)	113.0b	220.3ghi	335.8de	31.7a	1.0a	1.0a	48.8cd

[1]Mean values 100 g bean solids per can, 2 cans per plot x 2 plots (n = 4); Tukey mean separations, like letters within each column indicate no significant difference ($P<0.05$)

[2]Subjective visual examination for canned bean characteristics, 5 point scale (1 = none, 5 = excessive)

Table 13. Analysis of Variance of Quality Characteristics of Dry, Soaked and Canned Beans for the 1982 National Dry Bean Quality Nursery - I (Small Seeded)

Source of Variation	df	Bean Weight (g)				Visual	
		Initial	Soaked	Drained	Dried	Clumps	Splits
				Mean Squares			
Main Effects	16	6.79***	300.90***	437.61***	1.65***	0.16***	2.00***
Strain	15	5.41***	319.59***	464.22***	1.75	0.16	2.09***
Replicate	1	27.56***	20.48	38.46	0.23	0.63	0.56
Two-Way							
Strain X Replicate	15	2.50	23.45**	36.79	1.00	0.63	0.16
Residual	32	0.01	8.17	32.05	2.71	0.06	0.34
CV (%)		0.79	1.35	1.75	4.56	22.47	27.89

Table 13. Seafarer and P 766 showed the most degree of bean breakdown and splitting during processing. PROTOP-P1 and 800242 showed the least amount of splitting.

The mean values for texture are presented in Table 12. The range was 32.0 to 95.6 kg/100 g and Aurora, which had the highest drained weight, also had the highest shear resistance. Bunsi (37.1 kg/100 g) and JAMAPA (32,0 kg/100 g) were the softest beans. Mean squares for shear resistance are presented in Table 11. These data indicate a significant difference among strains as well as replicates. There was also a significant strain-replicate interaction which makes it difficult to interpret the main effects.

Quality Nursery - II (Large Seed Type). The means for dry and processed color are presented in Table 14. Analyses of variance for these traits are summarized in Table 15,

Significant differences for dry color coordinates L, a_L and b_L among strains were observed. These data indicate a significant difference for the a_L (red) coordinate among bean plots. Significant differences were shown among breeding lines and strains for L and b_L coordinates. No significant difference in L was observed for replicates and no significant interactions were observed. Mean values for surface color are summarized in Table 14. These data indicate that during processing the beans became darker. This is depicted by a decreased L (increased blackness), a decreased a_L (increased L, green) and a decrease in b_L (increased yellow) for all bean types. This bean darkening was due to pigment loss to the soak water and brine as well as due to non-enzymatic browning reactions which occur from thermal processing.

Table 14. Surface Color Analysis[1] of Dry and Processed Beans Evaluated at the MSU Legume Quality Laboratory: 1982 National Dry Bean Quality Nursery - II (Large Seeded). Beans Were Processed at 115.6°C/45 minutes in a Still Retort

Entry/Pedigree (Comm. Class)	Hunter Lab Color Coordinates					
	Dry Bean			Processed Bean		
	L	a_L	b_L	L	a_L	b_L
Pinto						
U.I. 114 (pinto)	42.1a	11.9ac	11.2bc	28.7c	2.6bcd	11.7a
U.I. 111 (pinto)	42.2a	12.7bc	11.1bc	29.1c	2.5bcd	11.9a
Colo. 3342 (pinto)	42.2a	12.4ac	11.1bc	29.2cd	3.0cd	11.8a
Colo. 3644 (pinto)	42.3a	12.5bc	11.2bc	28.1c	2.3bc	11.5a
NW 590 (pinto)	42.5a	12.7bc	10.6a	30.5e	2.8bcd	12.2a
NW 410 (pinto)	42.8a	12.2ac	11.3c	28.9c	3.4de	11.8a
Great Northern						
790112 (Gr.No.)	60.7b	24.5c	10.5a	46.7f	0.6a	16.2a
Valley (Gr. No.)	65.5b	7.4a	11.2bc	46.6f	0.6a	16.1a
Sutter's Pink						
Gloria (pink)	40.5a	11.9ac	11.6d	24.9a	2.6bcd	19.2a
Undefined						
Colo. 3465 (undef.)	40.9a	10.1ac	16.4e	30.4de	4.2e	12.9a

[1]Mean values 100 g dry or processed beans, n = 2 cans/lot x 4 plots (n = 8); Tukey mean separations, like letters within each column indicate no significant difference ($P<0.05$)

Table 15. Analysis of Variance of Surface Color of Dry and Processed Beans for the 1982 National Dry Bean Quality Nursery - II (Large Seeded)

Source of Variation	df	Hunter Lab Color Coordinates					
		Dry Bean			Processed Bean		
		L	a_L	b_L	L	a_L	b_L
				Mean Squares			
Main Effects	13	450.41***	153.72***	16.39***	344.90***	7.46***	59.71
Strain	10	578.23***	142.28***	21.31***	448.27***	9.50***	55.63
Replicate	3	24.33	191.83	0.00	0.32	0.68	73.31
Two-Way Strain X Replicate	30	27.11	178.37	0.05	0.69	0.36	70.57
Residual	44	0.01	0.01	0.01	0.44	0.36	71.81
CV (%)		0.22	0.78	0.87	2.08	24.79	63.57

The means for bean moistures and mass ratio indexes are presented in Table 16. Analyses of variance for these traits are summarized in Table 17.

These data indicate that significant differences exist among entries for soaked bean moisture and calculated hydration ratios. The mean values for these parameters are presented in Table 16. This data showed no significant difference among Pinto, Sutter's Pink, or Colorado 3465 bean types. Great Northern appears to imbibe significantly less water than other bean types. These beans also had a higher initial moisture content than the other strains. These differences are also reflected in the hydration ratios. However, these low soak moistures exhibited by the Great Northerns during the soak cycle did not affect the drained weight.

The means for dry, soaked and processed canned beans are presented in Table 18. Analyses of variance for these traits are summarized in Table 19.

Observation of Table 18 indicated no meaningful difference in drained weight among strains. Thus, it appears that the Great Northerns take up enough water after canning to compensate for the initial low soak moisture levels.

Visual examination of processed beans indicates a significant difference among strains for clumps and splits. No significant difference was observed between bean plots. Observation of the visual data in Table 18 indicates that the Great Northern types (790112 and Valley) clumped less than the other entries. These data also indicate significant differences among strains for splits. The pinto type Colorado 3644 split less than all other strains,

Table 16. Moisture Measurements[1] of Dry, Soaked and Canned Beans Evaluated at the MSU Legume Quality Laboratory: 1982 National Dry Bean Quality Nursery - II (Large Seeded). Beans Were Processed at 115.6°C/45 minutes in a Still Retort

Entry/Pedigree (Comm. Class)	Bean Moisture (%)			Mass Ratio Indexes[2]	
	Initial	Soaked	Processed	Hydration	Drained Wt
Pinto					
U.I. 114 (pinto)	14.2b	45.7b	73.4b	1.84b	1.29ab
U.I. 111 (pinto)	13.7ab	46.8b	73.2ab	1.88b	1.29ab
Colo. 3342 (pinto)	13.7ab	45.1b	72.9ab	1.82b	1.29ab
Colo. 3644 (pinto)	14.1ab	47.2b	73.4b	1.90b	1.24a
Colo. 3591 (pinto)	12.3a	46.9b	72.9ab	1.88b	1.26ab
NW 590 (pinto	15.4bc	44.8b	73.3b	1.82b	1.30ab
NW 410 (pinto)	15.2bc	46.4b	73.4b	1.87b	1.34b
Great Northern					
790112 (Gr. No.)	16.2cd	37.0a	72.4a	1.59a	1.49c
Valley (Gr. No.)	17.7d	33.4a	72.4a	1.55a	1.48c
Sutter's Pink					
Gloria (pink)	15.1bc	45.1b	72.7ab	1.82b	1.33ab
Undefined					
Colo. 3465 (undefined)	15.3bc	45.9b	72.8ab	1.85b	1.27ab

[1]Mean values 100 g bean solids per can, n = 2 cans/lot x 4 plots (n = 8); Tukey mean separations, like letters within each column indicate no significant difference ($P<0.05$)

[2]Hydration ratio = soaked beans (g)/initial dry beans (g); drained weight ratio = drained canned beans (g)/soaked beans (g)

Table 17. Analysis of Variance of Dry, Soaked and Canned Moisture and Texture Measurements for the 1982 National Dry Bean Quality Nursery - II (Large Seeded)

Source of Variation	df	Bean Moisture (%)			Mass Ratio Indexes		Texture
		Initial	Soaked	Processed	Hydration	Drained Weight	Shear Resistance
				Mean Squares			
Main Effects	13	14.49***	102.06***	1.03**	0.09***	0.04***	112.46***
Strain	10	16.34***	132.34***	1.29***	0.11***	0.06***	143.66***
Replicate	3	8.30	1.14	0.16	0.00	0.00	8.44*
Two-Way							
Strain X Replicate	30	2.14	3.21	0.29	0.01	0.01	11.53***
Residual	44	0.10	2.69	0.32	0.01	0.01	2.91
CV (%)		0.68	3.71	0.77	17.57	7.52	3.22

Table 18. Quality Characteristics[1] of Dry, Soaked and Canned Beans Evaluated at the MSU Legume Quality Laboratory: 1982 National Dry Bean Quality Nursery - II (Large Seeded). Beans Were Processed at 115.6°C/45 minutes in a Still Retort

Entry/Pedigree (Comm. Class)	Bean Weight (g)			Processed Beans			
				% Total Solids	Visual[2]		Shear Resistance (kg/100g)
	Initial	Soaked	Drained		Clumps	Splits	
Pinto							
U.I. 114 (pinto)	116.4ab	214.8b	276.0a	26.6a	2.3cd	2.1ab	49.9ab
U.I. 111 (pinto)	115.9ab	218.0b	281.8ab	26.8ab	2.1bcd	2.1ab	56.6de
Colo. 3342 (pinto)	115.8ab	211.3b	273.4a	27.1ab	2.0abcd	2.0ab	56.9de
Colo. 3644 (pinto)	116.4ab	220.7b	274.3a	26.6a	2.3cd	1.5a	57.7de
Colo. 3591 (pinto)	114.8a	216.3b	272.1a	27.1ab	2.0abcd	2.0ab	53.8bcd
NW 590 (pinto)	118.1bc	214.4b	278.7ab	26.7a	1.9abcd	3.5d	49.8ab
NW 410 (pinto)	116.7ab	217.6b	290.6b	26.5a	2.5d	2.0ab	47.2a
Great Northern							
790112 (Gr. No.)	119.3cd	189.6a	282.7ab	27.6b	1.4a	2.9bcd	51.5bc
Valley (Gr. No.)	121.5d	188.0a	278.7ab	27.7ab	1.5ab	3.1cd	54.7cde

Table 18 (cont'd.)

Entry/Pedigree (Comm. Class)	Bean Weight (g)			Processed Beans			
	Initial	Soaked	Drained	% Total Solids	Visual[2] Clumps	Visual[2] Splits	Shear Resistance (kg/100g)
Sutter's Pink							
Gloria (pink)	117.8bc	214.5b	276.2ab	27.3ab	1.8abc	2.5bc	46.4a
Undefined							
Colo. 3465 (undefined)	118.0bc	218.3b	284.5a	27.2ab	2.4cd	2.0ab	58.1e

[1]Mean values 100 g bean solids per can, n = 2 cans/lot x 4 plots (n = 8); Tukey mean separations, like letters within each column indicate no significant difference ($P<0.05$)

[2]Subjective visual examination for canned bean characteristics, 5 point scale (1 = none, 5 = excessive)

Table 19. Analysis of Variance of Quality Characteristics of Dry, Soaked and Canned Beans for the 1982 National Dry Bean Quality Nursery - II (Large Seeded)

Source of Variation	df	Bean Weight (g)				Visual	
		Initial	Soaked	Drained	Dried	Clumps	Splits
				Mean Squares			
Main Effects	13	23.62***	799.45***	196.48*	1.03**	0.80***	2.22***
Strain	10	28.08***	1033.20***	244.73**	1.28***	1.00***	2.83***
Replicate	3	8.76***	20.31	35.64	0.16	0.12	0.19
Two-Way							
Strain X Replicate	30	4.89***	38.21	43.92	0.29	0.22	0.50*
Residual	44	0.01	35.03	81.30	0.32	0.16	0.28
CV (%)		0.08	2.80	3.23	2.09	20.00	22.61

whereas pinto NW 590 split the most. The other bean types were generally similar with moderate levels of split beans.

Analysis of strains for texture is summarized in Table 17. Mean values are presented in Table 16. These data indicate a significant difference in shear resistance among strains and replicates. Observation of the two-way analysis of variance indicated a significant strain-replicate interaction. Observation of the mean values indicated the pinto strains of U.I. 111, Colorado 3465 to be the firmest beans. Gloria, NW 410, Colorado 3591 and U.I. 114 were the softest strains. The remaining strains were of intermediate firmness.

Summary and Conclusion

The small seeded nursery data indicated beans of various varieties exhibit differential canning characteristics. Most bean types became darker with processing; however, some strains of blacks became lighter with processing. Generally, the navy and pinto types had a higher moisture content after soaking than the black and brown types. Aurora (small white, 95.6 kg/100 g) was the firmest bean and 8217-111-24 (undefined white, 60.7 kg/100 g), Nep-2 (white navy, 62.6 kg/100 g) and JAMAPA (black turtle soup, 32.0 kg/100 g) were the softest beans tested.

Data from the large seeded nursery clearly indicated all bean types became darker with thermal processing. Valley and 790112, two Great Northerns, had the lowest hydration ratios, indicating these two strains imbibed less water during the soak cycle than the other bean varieties. Gloria (Sutter's Pink, 46.4 kg/100 g) and NW 410 (pinto, 47.2 kg/100 g) had the lowest shear resistance. Colorado

3342 (pinto, 56.9 kg/100 g) and Valley (Great Northern, 54.7 kg/100 g) were the firmest beans tested.

The Effect of Variety, Production Location and Thermal Processing Method on Quality Attributes of Processed Beans

Abstract

The effect of thermal processing on various varieties of navy beans was investigated. Similar cultivars grown in three different locations were investigated. Beans were also thermally processed by a still retort and an agitating retort. Results clearly indicate beans processed in an agitating retort yielded a more firm bean. The data also indicate a definite cultivar and variety-location difference among beans. Fleetwood possessed the softest texture of all varieties at all locations. North Dakota produced beans of soft and intermediate texture. Beans from Michigan and Canada were found to contain varieties of soft, intermediate and firm texture. Canadian varieties were more firm than Michigan and North Dakota varieties.

Introduction

In recent years processors have expressed concern about the textural quality of navy beans grown in different regions of North America. A study was conducted to compare white navy beans from Michigan, North Dakota and Canada. Two varieties were common to all locations: Fleetwood and Seafarer. The other samples represented a varietal pool to compare varietal-location differences as well as any interactions.

Beans from all locations were processed and evaluated by two methods. Process I employed an agitating retort operating for 7 minutes/122°C, 14 minutes/130°C, 7 minutes/190°C, and 7 minutes/35°C. Process II utilized a still retort operated at 45 minutes/115.6°C and 15 minutes/35°C. Comparison of textural and visual appearance was made for all beans processed.

The experiment consisted of 11 variety-locations X 2 processing methods replicated six times (n = 6 cans). The objective of this study was to compare navy bean varieties produced with and among geographic locations. This experiment was designed as a demonstration to observe variability. Material processed was obtained from known sources without replication of growing locations. A secondary objective was to compare and contrast different processing methods.

Methods and Materials

Dry Bean Handling. Dry beans comprised of varieties Fleetwood, Seafarer, Sanilac, Neptune and Swan Valley were obtained from Michigan Foundation Seed Association. Bean samples of Fleetwood, Seafarer and Upland were obtained from North Dakota. The varieties of Fleetwood, Seafarer and Kentwood were obtained from Ontario, Canada. Objective color measurements of dry and processed beans were determined using a pure glass dish and coordinate values (L, $+a_L$, $+b_L$) were recorded.

The initial moisture content of all samples was measured with a Motomco moisture meter. After moisture measurement, 100 grams of bean solids were filled into 4x6 inch nylon mesh bags. Samples were then placed in plastic zip-lock bags to ensure no environmental moisture loss or gain until processing.

Soaking and Blanching. All samples were soaked for 30 minutes at 29.3°C in 100 ppm calcium water. Samples were then transferred to a steam jacketed kettle and blanched for 30 minutes at 87.9°C in 100 ppm calcium water. Beans were removed from the hot soak cycle and cooled at 10°C for one minute. Cooled beans were removed from the cooling water and drained on perforated screens.

Can Filling, Brining and Exhausting. Blanched beans were rapidly filled into coded 303x406 cans. Beans and cans were weighed to the nearest 0.1 gram and were then transferred to the exhaust box conveyor. The cans were hand filled with heated brine (0.31% sucrose, 0.25% sodium chloride) and exhausted for four minutes.

Sealing and Thermal Processing. Exhausted cans were hermetically sealed and transferred to a retort for thermal processing. Beans were processed by two methods. Method I utilized an agitating retort in which all samples were axially rotated at 19 rpms. Cans were processed for 7 minutes/122°C, 14 minutes/130°C, 7 minutes/190°C, and 7 minutes/35°C. Beans sterilized by Method II were thermally processed at 115.6°C/45 minutes in a still retort and 15 minutes at 35°C. Dried processed cans were stored for two weeks prior to quality evaluation to ensure proper bean-brine equilibration.

Washed Drained Weight. The contents of the can were poured onto a U.S. Standard No. 8 screen. The screen and contents were immersed in 21.1°C water and allowed to drain for two minutes. The screen was then transferred to a tared bottom plate and weighed on a counter balance over-under scale.

Visual Examination. Beans were visually judged by five point hedonic scales for clumping and splitting (1 = none, 5 = excessive) during the drained weight procedure. Each can received a subjective visual score.

Processed Texture and Total Solids. Beans were evaluated for texture using an Instron. A 200 gram sample was placed in a Kramer C-15 standard shear compression cell and sheared. A 500 kg load cell was used with a head speed 200mm/minute, a gauge of 7.5 cm and a return of 9.7 cm. The residue from the Instron was used for determination of total solids. One hundred grams of shear residue were weighed into a tared aluminum pan and dried to a constant weight at 80°C. The dried samples were weighed and calculation of percent total solids was performed.

Results and Discussion

The means for dry and processed color are presented in Tables 20, 21 and 22. Analyses of variance for these parameters are summarized in Tables 23 and 24.

The mean squares for dry and processed colors are presented in Tables 23 and 24. The data indicate significant differences among varieties and locations for all color coordinates. It was observed in Tables 20 and 21 that the two Michigan varieties, Neptune and Swan Valley, had a significant lower L coordinate than the other varieties. These data clearly indicate a darker seedcoat existed for Neptune and Swan Valley than the seedcoats of the other varieties tested. The data also indicate that after thermal processing a general bean darkening occurred. Tables 20 and 21

Table 20. Surface Color Analysis[1] of Dry and Processed Beans Evaluated at the MSU Legume Quality Laboratory: Beans from 11 Variety-Locations Were Processed in an Agitating Retort for 7 minutes/35°C, 14 minutes/130°C, 7 minutes/190°C and 7 minutes/35°C. Cans Were Axially Rotated at 19 rpms

Location/ Variety	Hunter Lab Color Coordinates					
	Dry Bean			Processed Bean		
	L	a_L	b_L	L	a_L	b_L
Michigan						
Fleetwood	63.0	1.3	10.2	49.5bcd	5.9cde	16.3cde
Neptune	55.9	2.4	13.0	49.9cd	4.2a	15.7ab
Sanilac	60.5	1.8	9.7	50.1d	5.8cd	16.5de
Seafarer	61.2	1.7	11.0	49.9cd	6.2de	16.6e
Swan Valley	56.1	2.3	13.0	49.4bc	5.1b	15.6a
North Dakota						
Fleetwood	62.7	1.4	8.9	48.6a	6.0cde	16.1bc
Seafarer	61.9	1.8	10.3	51.1e	6.3e	16.4cde
Upland	62.6	1.7	9.2	51.1e	6.2de	16.3cd
Canada						
Fleetwood	61.2	2.1	11.9	50.1cd	6.0cde	16.4cde
Kentwood	59.4	2.1	12.4	49.5bcd	5.2b	16.7e
Seafarer	61.6	1.5	10.3	49.0ab	5.7c	16.3cde

[1]Mean values 100 g dry or processed beans, n = 6 cans per location-variety; Tukey mean separations, like letters within each column indicate no significant difference ($P<0.05$)

Table 21. Surface Color Analysis[1] of Dry and Processed Beans Evaluated at the MSU Legume Quality Laboratory: Beans from 11 Variety-Locations Were Processed in a Still Retort at 115.6°C/45 minutes

Location/ Variety	Hunter Lab Color Coordinates					
	Dry Bean			Processed Bean		
	L	a_L	b_L	L	a_L	b_L
Michigan						
Fleetwood	63.0	1.3	10.2	52.1abc	5.5cd	15.8de
Neptune	55.9	2.4	13.0	52.3b	3.5a	14.7a
Sanilac	60.5	1.8	9.7	53.4cde	5.7cd	15.7cd
Seafarer	61.2	1.7	11.0	53.7e	5.7cd	16.1e
Swan Valley	56.1	2.3	13.0	52.6cd	3.8a	14.7a
North Dakota						
Fleetwood	62.7	1.4	8.9	51.5ab	5.5bc	15.5bcd
Seafarer	61.9	1.8	10.3	52.5c	6.2e	15.6bcd
Upland	62.6	1.7	9.2	52.8cd	5.9de	15.3b
Canada						
Fleetwood	61.2	2.1	11.9	51.6ab	6.1e	15.4bc
Kentwood	59.4	2.1	12.4	52.1abc	5.2b	15.8de
Seafarer	61.6	1.5	10.3	51.4a	5.7cd	15.4bc

[1]Mean values 100 g dry or processed beans, n = 6 cans per location-variety; Tukey mean separations, like letters within each column indicate no significant difference (P<0.05)

Table 22. Surface Color Analysis[1] of Dry and Processed Beans Evaluated at the MSU Legume Quality Laboratory: Fleetwood and Seafarer from Michigan, North Dakota and Canada Were Thermally Processed in an Agitating Retort and in a Still Retort

Process Method	Hunter Lab Color Coordinates					
	Dry Bean			Processed Bean		
Variety/Location	L	a_L	b_L	L	a_L	b_L
<u>Agitating</u>						
Fleetwood						
Michigan	63.0a	1.3a	10.2a	49.9b	5.9a	16.3a
North Dakota	62.7a	1.4a	8.9a	49.0a	5.9a	16.1a
Canada	61.2a	2.1a	11.9a	49.5ab	6.0a	22.0a
Seafarer						
Michigan	61.2a	1.7a	11.0a	50.3a	6.2a	16.8b
North Dakota	61.9a	1.8a	10.3a	50.5a	6.3a	16.4a
Canada	61.6a	1.5a	10.3a	48.6b	5.8b	16.3a
<u>Still</u>						
Fleetwood						
Michigan	63.0a	1.3a	10.2a	52.1b	5.5a	15.8b
North Dakota	62.7a	1.4a	8.9a	51.5a	5.4a	15.5a
Canada	61.2a	2.1a	11.9a	51.6ab	6.1b	15.4a
Seafarer						
Michigan	61.2a	1.7a	11.0a	53.7c	5.8a	16.1c
North Dakota	61.9a	1.8a	10.3a	52.5b	6.1b	15.6b
Canada	61.6a	1.5a	10.3a	51.4a	5.7a	15.4a

[1]Mean values 100 g dry or processed beans, n = 6; Tukey mean separations, like letters within each column indicate no significant difference ($P<0.05$)

Table 23. Analysis of Variance of Surface Color of Dry and Processed Beans for Fleetwood and Seafarer from Michigan, North Dakota and Canada Processed with an Agitating Retort

Source of Variation	df	Hunter Lab Color Coordinates					
		Dry Bean			Processed Bean		
		L	a_L	b_L	L	a_L	b_L
		Mean Squares					
Main Effects	3	6.80***	0.35***	9.59***	5.40**	0.39***	58.94
Variety	1	9.68***	0.08***	0.98***	1.92**	0.54***	50.59
State	2	5.36***	0.49***	13.91***	7.14**	0.31***	63.12
Two-Way							
Variety X State	2	7.28***	2.32***	14.95***	8.41**	0.53***	73.25
Residual	66	0.01	0.01	0.01	6.61	0.48	67.56
CV (%)		0.16	6.33	0.97	5.19	11.74	45.21

Table 24. Analysis of Variance of Surface Color of Dry and Processed Beans for Fleetwood and Seafarer from Michigan, North Dakota and Canada Processed with a Still Retort

Source of Variation	df	Hunter Lab Color Coordinates					
		Dry Bean			Processed Bean		
		L	a_L	b_L	L	a_L	b_L
		Mean Squares					
Main Effects	3	3.40***	4.79***	0.18***	5.85***	0.19**	0.74**
Variety	1	4.84***	0.49***	0.04***	5.80***	0.23**	0.76**
State	2	6.95***	6.95***	0.24***	5.89***	0.18**	1.08**
Two-Way							
Variety X State	2	3.64***	7.47***	1.15***	2.35***	1.00**	0.08**
Residual	66	0.01	0.01	0.57	0.12	0.27	0.14
CV (%)		0.17	5.52	0.12	1.59	1.38	1.30

indicate a decrease in L value, an increase in a_L, and an increase in b_L coordinates for all methods. These data indicate that all varieties became darker after thermal processing. It was also observed that thermally processed Neptune and Swan Valley darkened to a point where they were not significantly different from the other varieties. Thus, dry beans which are significantly darker from a standard white bean may not necessarily be significantly darker from that standard after thermal processing. These data also indicate that for processed color Canadian varieties had a significantly lower L value than Michigan or North Dakota, indicating a darker bean.

The mean values for bean moisture and mass ratio indexes are presented in Tables 25, 26 and 27. The analyses of variance for these parameters are summarized in Tables 28 and 29. Mean values of bean moistures for all variety-locations are presented in Figure 7.

The data indicate significant differences among varieties and states for initial and soaked bean moistures (Tables 25 and 26). For all methods utilized, Canadian Seafarer had the lowest soaked bean moisture and hydration ratio among all varieties. The data indicate Fleetwood and Seafarer from Canada imbibed significantly less water during the soak process than beans from Michigan and North Dakota (Table 27).

The mean values for quality characteristics of dry, soaked and processed canned beans are presented in Tables 30, 31 and 32. Analyses of variance for these parameters are summarized in Tables 33 and 34. Mean values of bean weights for all variety-locations are presented in Figure 8.

The mean squares for drained weight and total solids are represented in Tables 33 and 34. These data indicate significant

Table 25. Moisture Measurements[1] of Dry, Soaked and Canned Beans Evaluated at the MSU Legume Quality Laboratory: Beans from 11 Variety-Locations Were Processed in an Agitating Retort for 7 minutes/122°C, 14 minutes/130°C, 7 minutes/190°C, and 7 minutes/35°C. Cans Were Axially Rotated at 19 rpms

Location/ Variety	Bean Moisture (%)			Mass Ratio Indexes[2]	
	Initial	Soaked	Processed	Hydration	Drained Wt
Michigan					
Fleetwood	11.4	47.6e	68.5ab	1.91f	1.37abc
Neptune	12.7	42.3b	69.8defg	1.73b	1.42c
Sanilac	11.7	46.4d	68.8bc	1.87e	1.34a
Seafarer	11.4	44.1c	68.9bcd	1.79cd	1.41bc
Swan Valley	11.8	47.5e	70.0efg	1.91f	1.35ab
North Dakota					
Fleetwood	15.7	44.4c	70.6g	1.80d	1.36abc
Seafarer	20.0	43.9c	70.4fg	1.78cd	1.37abc
Upland	13.3	46.0d	69.1bcde	1.85e	1.36abc
Canada					
Fleetwood	21.6	43.5c	69.6cdef	1.77cd	1.35a
Kentwood	17.9	43.3bc	67.8a	1.76bc	1.32a
Seafarer	20.6	38.1a	68.2ab	1.62a	1.37abc

[1]Mean values 100 g bean solids per can, n = 6 cans per location-variety; Tukey mean separations, like letters within each column indicate no significant difference ($P<0.05$)

[2]Hydration ratio = soaked beans (g)/initial dry beans (g); drained weight ratio = drained canned beans (g)/soaked beans (g)

Table 26. Moisture Measurements[1] of Dry, Soaked and Canned Beans Evaluated at the MSU Legume Quality Laboratory: Beans from 11 Variety-Locations Were Processed in a Still Retort at 115.6°C/45 minutes

Location/ Variety	Bean Moisture (%)			Mass Ratio Indexes[2]	
	Initial	Soaked	Processed	Hydration	Drained Wt
Michigan					
Fleetwood	11.4	48.5fg	70.9	1.94f	1.44bc
Neptune	12.7	47.2de	71.3cd	1.90de	1.40ab
Sanilac	11.7	49.3g	71.3cd	1.97g	1.39ab
Seafarer	11.4	48.5f	70.7bcd	1.94f	1.40ab
Swan Valley	11.8	47.5e	70.5bcd	1.90e	1.40ab
North Dakota					
Fleetwood	15.8	43.7a	71.5d	1.78a	1.51d
Seafarer	20.0	44.7b	70.8cd	1.81b	1.44bc
Upland	13.3	46.5d	70.9cd	1.87d	1.45c
Canada					
Fleetwood	21.6	45.1bc	70.4bc	1.82bc	1.37a
Kentwood	17.9	45.6c	69.0a	1.84c	1.36a

[1]Mean values 100 g bean solids per can, n = 6 cans per location-variety; Tukey mean separations, like letters within each column indicate no significant differences ($P<0.05$)

[2]Hydration ratio = soaked beans (g)/ initial dry beans (g); drained weight ratio = drained canned beans (g)/soaked beans (g)

Table 27. Moisture Measurements[1] of Dry, Soaked and Canned Beans Evaluated by the MSU Legume Quality Laboratory: Fleetwood and Seafarer from Michigan, North Dakota and Canada Were Thermally Processed in an Agitating Retort and in a Still Retort

Process Method	Bean Moisture (%)			Mass Ratio Indexes[2]	
Variety/Location	Initial	Soaked	Processed	Hydration	Drained Wt
Agitating					
Fleetwood					
Michigan	11.4a	47.6b	69.4a	1.92c	1.38a
North Dakota	15.7b	44.4a	70.4b	1.81b	1.36a
Canada	21.6c	43.5a	69.1a	1.74a	1.36a
Seafarer					
Michigan	11.4a	44.1b	68.9b	1.84c	1.38b
North Dakota	20.0b	43.9b	70.2c	1.78b	1.37ab
Canada	20.6b	38.1a	68.1a	1.64a	1.34a
Still					
Fleetwood					
Michigan	11.4a	48.5c	70.9b	1.94c	1.44b
North Dakota	15.7b	43.7a	71.5c	1.78a	1.51a
Canada	21.6c	45.1b	70.4a	1.82b	1.37a
Seafarer					
Michigan	11/4a	48.5c	70.7a	1.94c	1.40ab
North Dakota	20.0b	44.7b	70.8a	1.81b	1.44b
Canada	20.6b	43.1a	69.8a	1.76a	1.35a

[1]Mean values 100 g bean solids per can, n = 3 cans per lot; Tukey mean separations, like letters within each column indicate no significant differences ($P<0.05$)

[2]Hydration ratio = soaked beans (g)/initial dry beans (g); drained weight ratio = drained canned beans (g)/soaked beans (g)

Table 28. Analysis of Variance of Dry, Soaked and Canned Moisture and Texture Measurements for Fleetwood and Seafarer from Michigan, North Dakota and Canada Processed with an Agitating Retort

Source of Variation	df	Bean Moisture (%)			Mass Ratio Indexes		Texture
		Initial	Soaked	Processed	Hydration	Drained Wt	Shear Resistance
				Mean Squares			
Main Effects	3	187.4**	426.58**	14.28***	0.17***	0.01**	4213.42***
Variety	1	210.3**	311.68***	5.78***	0.09***	0.00**	9338.89***
State	2	194.3**	198.61***	18.54***	0.21***	0.01**	1650.68***
Two-Way							
Variety X State	2	311.65*	115.30***	0.01***	0.01***	0.01**	1168.43***
Residual	66	20.30	17.31	0.34	0.10	0.01	19.09
CV (%)		0.08	1.60	1.89	1.75	10.25	14.50

Table 29. Analysis of Variance of Dry, Soaked and Canned Moisture and Texture Measurements for Fleetwood and Seafarer from Michigan, North Dakota and Canada Processed with a Still Retort

Source of Variation	df	Bean Moisture (%)			Mass Ratio Indexes		Texture
		Initial	Soaked	Processed	Hydration	Drained Wt	Shear Resistance
Main Effect	3	245.95***	118.63**	3.09***	0.61***	0.03**	2264.57***
Variety	1	210.36***	102.31**	2.40***	0.01***	0.17**	2601.00***
State	2	298.63***	186.54**	3.44***	0.09***	0.04**	2096.36***
Two-Way							
Variety X State	2	126.51***	306.41**	0.12***	0.01***	0.02**	865.08**
Residual	66	6.58	7.26	6.37	0.01	0.01	28.77
CV (%)		0.65	0.98	3.62	1.58	1.65	10.23

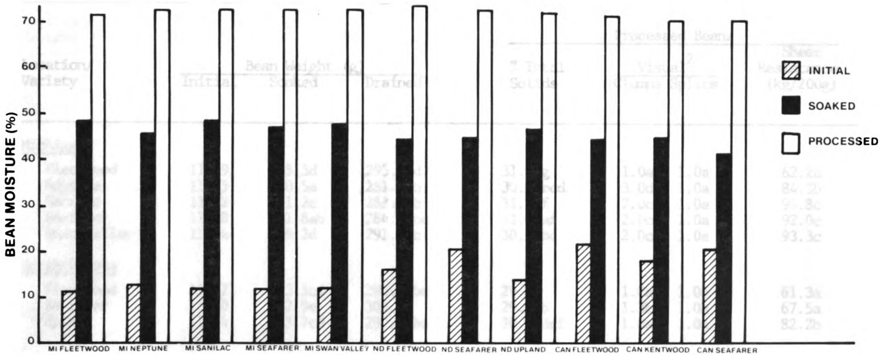

Figure 7. Mean Values for Initial, Soaked and Processed Navy Bean Moistures for Various Variety-Locations

Table 30. Quality Characteristics[1] of Dry, Soaked and Canned Beans Evaluated at the MSU Legume Quality Laboratory: Beans from 11 Variety-Locations Were Processed in an Agitating Retort for 7 minutes/122°C, 14 minutes/130°C, 7 minutes/190°C, and 7 minutes/35°C. Cans Were Axially Rotated at 19 rpms

Location/ Variety	Bean Weight (g)			Processed Beans			
	Initial	Soaked	Drained	% Total Solids	Visual[2] Clumps	Visual[2] Splits	Shear Resistance (kg/200g)
Michigan							
Fleetwood	112.9	215.5d	295.3cd	31.5fg	1.0a	1.0a	62.2a
Neptune	114.5	198.5a	281.3ab	30.2abcd	3.0d	1.0a	84.3b
Sanilac	113.2	211.2c	283.6ab	31.3ef	2.0c	1.0a	94.8c
Seafarer	112.8	201.8ab	284.8abc	31.3def	2.0c	1.0a	92.0c
Swan Valley	113.4	216.2d	291.3bc	30.1abc	2.0c	1.0a	93.3c
North Dakota							
Fleetwood	118.7	213.3cd	290.6abc	29.5a	1.0a	1.0a	61.3a
Seafarer	125.0	222.9e	305.5d	29.6ab	1.3b	1.0a	67.5a
Upland	115.4	213.7cd	290.7abc	30.9cdef	1.0a	1.0a	82.2b
Canada							
Fleetwood	127.6	225.7e	303.7d	30.5bcde	1.0a	1.0a	65.8a
Kentwood	121.8	214.9c	283.6abc	32.2g	1.0a	1.0a	98.7c
Seafarer	126.0	203.6bd	278.9a	31.7fg	1.0a	1.0a	96.5c

[1]Mean values 100 g bean solids per can, n = 6 cans per location-variety. Tukey mean separations, like letters within each column indicate no significant difference ($P<0.05$)

[2]Subjective visual examination for canned bean characteristics, 5 point scale (1 = none, 5 = excessive)

Table 31. Quality Characteristics[1] of Dry, Soaked and Canned Beans Evaluated at the MSU Legume Quality Laboratory: Beans from 11 Variety-Locations Were Processed in a Still Retort at 115.6°C/45 min

Location/ Variety	Bean Weight (g)			Processed Beans			
	Initial	Soaked	Drained	% Total Solids	Visual[2] Clumps	Visual[2] Splits	Shear Resistance (kg/200g)
Michigan							
Fleetwood	112.9	219.3cd	315.4cde	29.1ab	1.0a	2.0a	56.7abc
Neptune	114.5	217.0bc	303.6ab	28.7ab	2.0b	2.5b	80.3fgh
Sanilac	113.2	223.1ef	310.1abcd	28.7ab	1.2a	3.0c	63.8bcd
Seafarer	112.8	219.0cd	306.0abc	29.3abc	1.0a	2.0a	86.8gh
Swan Valley	113.4	215.9b	301.3a	29.5abc	2.0b	1.8a	77.6efg
North Dakota							
Fleetwood	118.7	210.8a	318.4de	28.5a	1.2a	2.0a	53.8ab
Seafarer	125.0	226.2f	325.3e	29.2ab	1.0a	3.0c	51.7a
Upland	115.4	215.8b	313.7bcd	29.2ab	1.0a	3.0c	71.1def
Canada							
Fleetwood	127.6	232.2g	317.2cde	29.6bc	1.0a	3.0c	66.7cde
Kentwood	121.8	223.8ef	303.6ab	31.0d	1.0a	2.2ab	90.3h
Seafarer	126.0	221.6de	299.0a	30.2cd	1.0a	2.0a	89.7h

[1] Mean values 100 g bean solids per can, n = 6 cans per location-variety; Tukey mean separations, like letters within each column indicate no significant difference ($P<0.05$)

[2] Subjective visual examination for canned bean characteristics, 5 point scale (1 = none, 5 = excessive)

Table 32. Quality Characteristics[1] of Dry, Soaked and Canned Beans Evaluated at the MSU Legume Quality Laboratory: Fleetwood and Seafarer from Michigan, North Dakota and Canada Were Thermally Processed in an Agitating Retort and in a Still Retort

Process Method Variety/Location	Bean Weight (g) Initial	Soaked	Drained	Processed Beans: % Total Solids	Visual[2] Clumps	Splits	Shear Resistance (kg/200g)
Agitating							
Fleetwood							
Michigan	112.9a	216.2a	297.9b	30.6b	1.0a	1.0a	62.8a
North Dakota	118.7b	214.6a	290.9a	29.6a	1.0a	1.0a	61.3a
Canada	127.6c	222.4b	301.6b	30.9b	1.0a	1.0a	64.2a
Seafarer							
Michigan	112.8a	207.3a	286.8b	31.0a	1.0a	1.0a	93.3b
North Dakota	125.0b	222.7b	305.1c	29.7b	1.0a	1.0a	67.9a
Canada	126.0b	206.5a	276.2a	31.9c	1.0a	1.0a	95.3b
Still							
Fleetwood							
Michigan	112.9a	210.8a	315.4a	29.1b	1.0a	2.0a	56.7a
North Dakota	118.7b	219.3b	318.4a	28.5c	1.2a	2.0a	53.8a
Canada	127.6c	232.2c	317.2a	29.6a	1.0a	3.0a	66.7b

Table 32 (cont'd.)

Process Method Variety/Location	Bean Weight (g)			Processed Beans			
				% Total Solids	Visual[2]		Shear Resistance (kg/200g)
	Initial	Soaked	Drained		Clumps	Splits	
Seafarer							
Michigan	112.8a	219.0a	306.0a	29.3a	1.0a	2.0a	86.8a
North Dakota	125.0b	226.2c	325.5b	29.2a	1.0a	3.0a	51.7b
Canada	126.0b	221.6b	298.6a	30.2a	1.0a	2.0a	89.7a

[1]Mean values 100 g bean solids per can, n = 3 cans per lot; Tukey mean separations, like letters within each column indicate no significant difference ($P<0.05$)

[2]Subjective visual examination for canned bean characteristics, 5 point scale (1 = none, 5 = excessive)

Table 32 (cont'd.)

Process Method Variety/Location	Bean Weight (g)			Processed Beans			
				% Total	Visual[2]		Shear Resistance
	Initial	Soaked	Drained	Solids	Clumps	Splits	(kg/200g)
Seafarer							
Michigan	112.8a	219.0a	306.0a	29.3a	1.0a	2.0a	86.8a
North Dakota	125.0b	226.2c	325.5b	29.2a	1.0a	3.0a	51.7b
Canada	126.0b	221.6b	298.6a	30.2a	1.0a	2.0a	89.7a

[1]Mean values 100 g bean solids per can, n = 3 cans per lot; Tukey mean separations, like letters within each column indicate no significant difference ($P<0.05$)

[2]Subjective visual examination for canned bean characteristics, 5 point scale (1 = none, 5 = excessive)

Table 33. Analysis of Variance of Quality Characteristics of Dry, Soaked and Canned Beans for Fleetwood and Seafarer from Michigan, North Dakota and Canada Processed with an Agitating Retort

Source of Variation	df	Bean Weight (g)				Visual	
		Initial	Soaked	Drained	Dried	Clumps	Splits
		Mean Squares					
Main Effect	3	11.93***	385.76***	675.03***	14.28***	0.56**	0.0
Variety	1	10.98***	569.53**	1001.09***	5.78***	0.89**	0.0
State	2	6.54***	293.87***	511.99***	18.53***	0.39**	0.0
Two-Way							
Variety X State	2	13.37***	913.00**	2410.29***	1.18***	0.39**	0.0
Residual	66	3.68	12.02	36.58	0.34	0.49	0.0
CV (%)		0.65	1.05	0.82	5.43	7.19	12.56

Table 34. Analysis of Variance of Quality Characteristics of Dry, Soaked and Canned Beans for Fleetwood and Seafarer from Michigan, North Dakota and Canada Processed with a Still Retort

Source of Variation	df	Bean Weight (g)				Visual	
		Initial	Soaked	Drained	Dried	Clumps	Splits
				Mean Squares			
Main Effects	3	216.41***	181.26***	574.49***	3.09***	0.28**	0.67
Variety	1	210.32***	19.80***	422.46***	2.40***	0.28**	0.00
State	2	113.46***	261.99***	650.51***	3.44***	0.28**	1.00
Two-Way							
Variety X State	2	313.25***	515.59***	498.05***	0.12***	0.28**	3.00
Residual	66	3.26	2.25	40.83	0.36	0.28	0.01
CV (%)		1.52	0.67	2.0	1.75	4.99	4.29

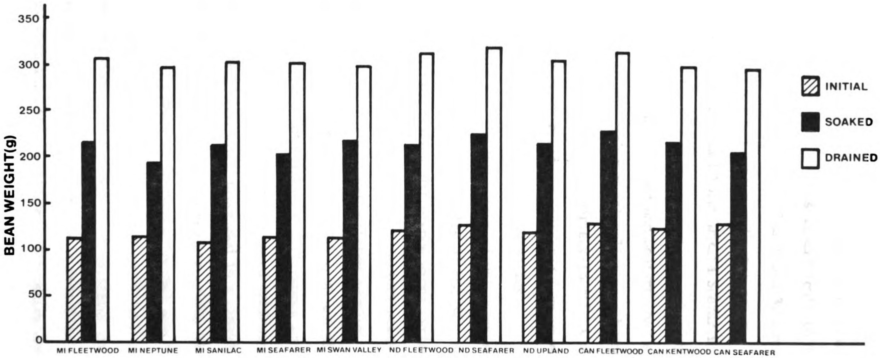

Figure 8. Mean Values for Initial, Soaked and Processed Navy Bean Weights for Various Variety-Locations

differences among varieties and states for drained weight and total solids; however, a significant variety-state interaction existed for these two parameters. This makes it difficult to interpret the variety and location effects. Tables 30 and 31 summarize the Tukey mean values for drained weight and total solids. Generally, Fleetwood from all locations and North Dakota Seafarer had significantly high drained weights than beans of the other variety-locations tested. Canadian Kentwood and Seafarer had significantly lower drained weights and higher total solids than beans of the other variety-locations. These two variety-locations also had a lower processed bean moisture which indicated less water absorption, decreased weight and an increase in total solids.

The mean squares for the subjective visual examination for clumps and splits are presented in Tables 33 and 34. Analysis of variance indicated a significant difference among varieties and states for both processes. A significant variety-state interaction was also observed for both still and agitated samples. The data for clumps and splits are summarized in Table 30 and 31 for all variety-locations. These data indicate differences among processing methods for splits. Beans which were agitated exhibited less splitting and clumping than types processed in a conventional still retort. This could be due to the reduced processing time required during agitation as a result of increased thermal penetration offered through convection heating. These process conditions caused less bean breakdown and decreased the degree of splitting and clumping.

The analysis of variance for texture is presented in Tables 28 and 29. These data indicate significant differences among varieties and states for both processes. A significant variety-state interaction was also observed. The means for these texture data are summarized in Tables 30 and 31. Beans which were agitated were generally more firm than nonagitated beans. These data indicate that less bean softening occurred when agitation was employed which also assists explanation of the splitting and clumping differences observed between the two processes. The data for all variety-locations (Tables 30 and 31) also indicated that Fleetwood from all locations and North Dakota Seafarer were the softest beans. Michigan Neptune and North Dakota Upland were intermediate in firmness. The firmest beans were obtained from variety-locations Michigan (Sanilac, Seafarer and Swan Valley) and Canada (Kentwood and Seafarer). No firm beans were obtained from the North Dakota grown varieties.

Summary and Conclusion

All bean types became darker after thermal processing regardless of process method utilized. Both Neptune and Swan Valley were significantly darker than the other variety-locations before processing; however, after thermal processing, no significant difference in color was found among all beans.

Fleetwood varieties were significantly softer (51.7 to 66.7 kg/200 g) than the other varieties tested and this phenomenon occurred at all locations. Beans from Canada were generally firmer than those from Michigan or North Dakota.

Visual appearance and texture characteristics of beans which were processed with agitation were more desirable than beans processed in a still retort. These beans were firmer and displayed less clumping and splitting than their still retorted counterparts.

The Effect of Soak Treatment and Processing on Texture of Five Commercial Classes of Beans

Abstract

The effects of five bean classes (navy, black turtle soup, cranberry, pinto and kidney) and various soak and process conditions on canned bean quality were studied. Beans were soaked in 100 ppm calcium water for 1) 12 hours/25°C, 2) 30 minutes/25°C plus 30 minutes/87.8°C, and 3) under 'no soak' conditions (dry pack). The samples were also thermally processed in a still retort under two schedules: 115.6°C/45 minutes and 121°C/30 minutes. The experiment was replicated three times. The data indicated that beans soaked for 12 hours/25°C were significantly softer than those soaked for 30 minutes/25°C plus 30 minutes/87.8°C or the dry pack beans. Cranberry beans were found to be the firmest bean processed regardless of treatment. Results also indicated that beans processed at 121°C/30 minutes had a higher lethal rate (F_o = 28.2) and firmer texture than those cans processed at 115.6°C/45 minutes (F_o = 11.3). Texture curve analysis indicated that navy beans have a higher shear length and are the most dense beans on a 100 gram basis; however, these beans had the lowest, and cranberries, the highest, compression peaks.

Introduction

Frequently industry implements a 12-16 hour ambient soak before thermal processing of beans. This method employs the use of a large amount of water which generates tons of high BOD effluent. This procedure generates large waste loads and is energy intensive. Such water use can also be expensive and labor intensive. Alternatively, high temperature-short time bean soaking or blanching may be employed. More efficient procedures for dry bean soaking and canning are needed in the industry.

During evaluation of beans, objective texture measurements are used with a Kramer Shear Press. This produces various curve types which are specific for each bean class. In the past, these curve types have been analyzed for maximum peak height as an index for quality. The higher the peak height the firmer the bean. Because of these different curve types, an equation was generated to produce new parameters relevant to texture, which could assist the processor in quality assessments.

The objective of this study was to process five bean classes under three soak conditions and two process schedules and to evaluate bean quality. The investigation of the various Kramer texture curve types using an equation derived to express textural components of the bean was conducted.

Methods and Materials

Dry Bean Handling. Dry beans were obtained from the Michigan Foundation Seed Association. The classes and varieties were navy (Fleetwood), black turtle soup (T-39), cranberry (Michigan Improved), pinto (Oletha) and kidney (Montcalm). Objective color measurements of dry and processed beans were determined using a Hunter Lab Color and Color Difference Meter. Beans were placed in an optically pure glass dish and coordinate values (L, a_L, b_L) were recorded.

The initial moisture content of all samples was measured with a Motomco moisture meter. After moisture measurement, 100 grams of bean solids were filled into 4x6 inch nylon mesh bags. Samples were then placed in plastic zip-lock bags to ensure no environmental moisture loss or gain until processing.

Soaking and Blanching. Samples were soaked for 12 hours/25°C, 30 minutes/25°C plus 30 minutes/87.8°C, and not soaked (dry pack). All soaked samples were placed in 100 ppm calcium water. Beans were removed from the soak cycle and drained on perforated screens.

Can Filling, Brining, and Exhausting. Beans were rapidly filled into coded 303x406 cans. Beans and cans were weighed to the nearest 0.1 gram and were then transferred to an exhaust box conveyor. The cans were hand filled with heated brine (0.31% sucrose, 0.25% sodium chloride) and exhausted for four minutes.

Sealing and Thermal Processing. Exhausted cans were hermetically sealed and transferred to a still retort. Beans were thermally processed at 115.6°C/45 minutes or at 121°C/30 minutes to ensure commercial sterility. Beans were processed with a thermocouple in the geometric can center for heat penetration data collection. These data were collected and stored every 30 seconds in a HP-85 computer. This enabled calculation of the lethal rate following the process. Dried processed cans were removed from the retort and stored for two weeks prior to quality evaluation to ensure proper bean-brine equilibration.

Washed Drained Weight. The contents of the can were poured onto a U.S. Standard No.8 screen. The screen and contents were immersed in 21.1°C water and allowed to drain for two minutes. The screen was then transferred to a tared bottom plate and weighed on a counter balance over-under scale.

Visual Examination. Beans were visually judged by five point hedonic scales for clumping and splitting (1 = none, 5 = excessive) during the drained weight procedure. Each can received a subjective visual score.

Processed Texture and Total Solids. Beans were evaluated for texture using an Allo-Kramer Shear Press. A sample size of 100 grams of processed beans was placed in the cell and sheared. A 3,000 pound transducer and No. C-15 standard shear compression cell were used. The residue from the Kramer Shear Press was used for determination of total solids. One hundred grams of shear residue were weighed into a tared aluminum pan and dried to a constant weight at 80°C. The dried samples were weighed and calculation of percent total solids was performed.

Texture Curve Analysis. The curve produced from the Kramer Shear Press was further analyzed to yield new parameters. Specific curve points were entered into Equation 7 which calculated three new parameters specific for each curve type.

Results and Discussion

Bean Soaking and Processing. The means for dry and processed color are presented in Tables 35 and 36. Analyses of variance of

Table 35. Surface Color Analysis[1] of Dry and Processed Beans Evaluated at the MSU Legume Quality Laboratory: Beans Were Processed at 115.6°C/45 minutes in a Still Retort. All Beans Were Pre-Soaked: 1) 12 hours/25°C, 2) 30 minutes/25°C plus 30 minutes/87.8°C, and 3) Not Soaked (Dry Pack)

Type/ Soak Treatment	Hunter Lab Color Coordinates: Dry Bean L	Dry Bean a_L	Dry Bean b_L	Processed Bean L	Processed Bean a_L	Processed Bean b_L
Navy						
12 hr	60.8a	3.2a	7.6a	49.6b	0.7a	16.2a
30/30	60.8a	3.2a	7.6a	49.1b	0.4a	16.9c
Dry	60.8a	3.2a	7.6a	46.9a	3.8a	16.6b
Black Turtle Soup						
12 hr	16.8a	0.7a	16.1a	18.1a	4.4a	3.1a
30/30	16.8a	0.7a	16.1a	18.2a	4.6b	3.3b
Dry	16.8a	0.7a	16.1a	13.4b	2.6c	1.5c
Cranberry						
12 hr	32.1a	7.2a	3.9a	29.7b	8.3a	12.2b
30/30	32.1a	7.2a	3.9a	26.0a	9.4b	11.7b
Dry	32.1a	7.2a	3.9a	24.9a	7.9a	10.9a
Pinto						
12 hr	37.1a	4.0a	5.6a	32.2a	7.3a	13.5b
30/30	37.1a	4.0a	5.6a	27.2b	9.0b	13.0ab
Dry	37.1a	4.0a	5.6a	26.9b	7.9a	11.9a
Kidney						
12 hr	22.9a	10.8a	6.9a	16.5b	11.0b	2.7a
30/30	22.9a	10.8a	6.9a	14.6a	9.8b	2.4a
Dry	22.9a	10.8a	6.9a	14.8a	8.2a	2.4a

[1]Mean values 100 g dry or processed beans, n = 3 cans per treatment; Tukey mean separation, like letters within each bean class indicate no significant difference ($P<0.05$)

Table 36. Surface Color Analysis[1] of Dry and Processed Beans Evaluated at the MSU Legume Quality Laboratory: Beans Were Processed at 121°C/30 minutes in a Still Retort. All Beans Were Pre-soaked, 1) 12 hours/25°C, 2) 30 minutes/25°C plus 30 minutes/87.8°C, and 3) Not Soaked (Dry Pack)

Type/ Soak Treatment	Hunter Lab Color Coordinates					
	Dry Bean			Processed Bean		
	L	a_L	b_L	L	a_L	b_L
Navy						
12 hr	60.8a	3.2a	7.6a	47.5a	0.9b	15.8a
30/30	60.8a	3.2a	7.6a	48.5b	0.3a	16.4b
Dry	60.8a	3.2a	7.6a	44.9c	1.0b	14.7c
Black Turtle Soup						
12 hr	16.8a	0.7a	16.1a	17.7a	4.4a	3.1a
30/30	16.8a	0.7a	16.1a	17.8a	4.2a	2.2a
Dry	16.8a	0.7a	16.1a	14.9b	1.3b	5.9b
Cranberry						
12 hr	32.1a	7.2a	3.9a	29.3a	7.7ab	11.8a
30/30	32.1a	7.2a	3.9a	26.9b	8.0b	7.4a
Dry	32.1a	7.2a	3.9a	25.9b	7.1a	5.8a
Pinto						
12 hr	37.1a	4.0a	5.0a	29.9b	7.3a	8.5a
30/30	37.1a	4.0a	5.0a	27.3ab	8.2b	10.7a
Dry	37.1a	4.0a	5.0a	25.9a	7.4ab	5.2a
Kidney						
12 hr	22.9a	10.8a	6.9a	17.7b	8.9b	2.8a
30/30	22.9a	10.8a	6.9a	16.8ab	7.5ab	1.4b
Dry	22.9a	10.8a	6.9a	14.9a	6.8a	10.3c

[1]Mean values 100 g dry or processed beans, n = 3 cans per treatment; Tukey mean separations, like letters within each bean class indicate no significant difference ($P<0.05$)

these parameters are summarized in Table 37.

The mean squares for dry and processed color indicate a significant difference among bean classes for all coordinates. No significant difference for dry color was observed among process or soak treatments. Mean values in Table 35 and 36 show the color differences among classes. Navy beans had relatively high L values (60.8) whereas black turtle soup had a low L value (16.8). These data also indicated that cranberry (32.1) and pinto (37.1) had a similar L coordinate but that cranberry had a higher a_L value, indicating that cranberry (7.2) was more red in color than pinto (4.0). Color coordinates for kidney show a lower L coordinate (22.9) and a higher a_L value (10.8) than either cranberry or pinto. These data indicate a darker, more red seedcoat. Observation of processed color data showed all classes became darker (decreased L) with processing (Tables 35 and 36). The mean squares in Table 37 indicate a significant difference among classes, processes and soaks. However, there was no difference in the L coordinate between process schedules. The dry pack (no soak) navy and black beans were significantly darker (decrease L coordinate) for both processes than the other soak treatments. Since these beans were not soaked, there was no pigment leaching into the soak water and more bean pigment retention was possible; furthermore, the absence of soak water did not affect surface washing prior to filling. Although a statistically significant difference existed for a_L and b_L coordinates, this difference was judged not to be of meaningful magnitude.

The mean values for bean moisture and mass ratio indexes are presented in Tables 38 and 39. The analyses of variance for these parameters are summarized in Table 40. Mean values for all bean

Table 37. Analysis of Variance of Surface Color of Dry and Processed Beans for Various Bean Types Thermally Processed at 115.6°C/45 minutes and 121°C/30 minutes. Beans Were Pre-soaked: 1) 12 hours/25°C, 2) 30 minutes/25°C plus 30 minutes/87.8°C, and 3) Not Soaked (Dry Pack)

Source of Variation	df	Hunter Lab Color Coordinates					
		Dry Bean			Processed Bean		
		L	a_L	b_L	L	a_L	b_L
		Mean Squares					
Main Effects	7	2958.41**	156.98**	226.39***	1729.47***	117.63***	301.58***
Class	4	5177.21**	274.72**	396.09***	2981.75***	197.99***	519.99***
Process	1	0.00	0.00	0.00	0.37	21.22***	27.22**
Soak	2	0.00	0.00	0.00	89.45***	5.14**	1.94
Two-Way							
Class X Process	4	0.00	0.00	0.13***	5.83***	1.59	38.14***
Class X Soak	8	0.00	0.00	0.13***	6.04***	6.90***	18.28***
Process X Soak	2	0.00	0.00	0.13*	2.89*	1.35	4.58
Three-Way							
Class X Process X Soak	8	0.00	0.00	0.13***	1.15	1.05	15.39***
Residual	60	0.01	0.01	0.30	0.61	1.08	2.48
CV (%)		0.29	1.93	6.79	2.87	17.67	18.14

Table 38. Moisture Measurements[1] of Dry, Soaked and Canned Beans Evaluated at the MSU Legume Quality Laboratory. Beans Were Processed at 115.6°C/45 minutes in a Still Retort. All Beans Were Pre-soaked: 1)12 hours/25°C, 2)30 minutes/25°C plus 30 minutes/87.8°C, and 3)Not Soaked (Dry Pack)

Type/	Bean Moisture (%)			Mass Ratio Indexes[2]		Lethality
Soak Treatment	Initial	Soaked	Processed	Hydration	Drained Wt	F_o
Navy						
12 hr	9.6a	51.2c	69.5a	2.05a	1.60a	10.99a
30/30	9.6a	48.7b	66.5a	1.95b	1.89b	11.35a
Dry	9.6a	0.0a	67.9a	1.00c	3.92c	11.44a
Black Turtle Soup						
12 hr	11.6a	52.8a	69.9a	2.07a	1.72a	11.23a
30/30	11.6a	48.3b	67.9a	1.93b	1.93b	11.69b
Dry	11.6a	0.0c	67.5a	1.00c	3.12c	10.81a
Cranberry						
12 hr	13.8a	46.6a	65.9a	1.87a	1.39a	11.22a
30/30	13.8a	42.3b	64.9a	1.73b	1.87b	11.45a
Dry	13.8a	0.0c	63.9a	1.00a	2.56c	10.55a
Pinto						
12 hr	15.8a	47.7a	67.5a	1.91a	1.68a	11.74a
30/30	15.8a	45.0b	67.2a	1.81b	1.56a	11.80a
Dry	15.8a	0.0c	65.2b	1.00c	3.11b	11.30a

Table 38 (cont'd.)

Type/ Soak Treatment	Bean Moisture (%)			Mass Ratio Indexes[2]		Lethality
	Initial	Soaked	Processed	Hydration	Drained Wt	F_o
Kidney						
12 hr	14.6a	50.6a	68.2b	2.02a	1.56a	11.69a
30/30	14.6a	46.8b	67.9b	1.88b	1.68a	11.74a
Dry	14.6a	0.0c	65.9a	1.00c	3.35b	10.76b

[1]Mean values 100 g bean solids per can, n = 3 cans per treatment; Tukey mean separations, like letters within each bean class indicate no significant difference ($P<0.05$)

[2]Hydration ratio = soaked beans (g)/initial dry beans (g); drained weight ratio = drained canned beans (g)/soaked beans (g)

Table 39. Moisture Measurements[1] of Dry, Soaked and Canned Beans Evaluated at the MSU Legume Quality Laboratory. Beans Were Processed at 121°C/30 minutes in a Still Retort. All Beans Were Pre-soaked: 1)12 hours/25°C, 2)30 minutes/25°C plus 30minutes/87.8°C and 3)Not Soaked (Dry Pack)

Type/	Bean Moisture (%)			Mass Ratio Indexes[2]		Lethality
Soak Treatment	Initial	Soaked	Processed	Hydration	Drained Wt	F_o
Navy						
12 hr	9.6a	51.5a	69.2a	2.09a	1.58a	27.93a
30/30	9.6a	49.7b	69.9a	1.99b	1.64a	28.84a
Dry	9.6a	0.0c	65.2b	1.00c	3.10b	30.34a
Black Turtle Soup						
12 hr	11.6a	51.6a	70.2a	2.06a	1.58a	27.47a
30/30	11.6a	50.1b	69.9a	2.00b	1.54a	28.58a
Dry	11.6a	0.0c	66.5b	1.00c	2.93b	26.36a
Cranberry						
12 hr	13.8a	47.1a	66.5a	1.89a	1.47a	27.87a
30/30	13.8a	45.9b	66.2a	1.84b	1.41a	28.91a
Dry	13.8a	0.0c	62.9b	1.0c	2.54b	25.70a
Pinto						
12 hr	15.8a	47.9a	68.5a	1.92a	1.50a	28.81a
30/30	15.8a	47.5a	67.2a	1.90a	1.46a	29.11a
Dry	15.8a	0.0b	62.9b	1.00b	2.53b	26.34a

Table 39 (cont'd.)

Type/ Soak Treatment	Bean Moisture (%)			Mass Ratio Indexes[2]		Lethality
	Initial	Soaked	Processed	Hydration	Drained Wt	F_o
Kidney						
12 hr	14.6a	51.0a	68.9a	2.04a	1.42a	29.72a
30/30	14.6a	48.2b	68.2a	1.93a	1.45a	29.94a
Dry	14.6a	0.0c	65.2b	1.00c	2.69b	27.47b

[1]Mean values 100 g bean solids per can, n = 3 cans per treatment; Tukey mean separations, like letters within each bean class indicate no significant difference ($P<0.05$)

[2]Hydration ratio = soaked beans (g)/initial dry beans (g); drained weight ratio = drained canned beans (g)/soaked beans (g)

Table 40. Analysis of Variance of Dry, Soaked and Canned Moisture, Texture and Lethality Measurements for Various Bean Types Thermally Processed at 115.6°C/45 minutes and 121°C/30 minutes. Beans Were Pre-soaked: 1)12 hours/25°C, 2)30 minutes/25°C plus 30 minutes/87.8°C and 3) Not Soaked (Dry Pack)

Source of Variation	df	Bean Moisture (%)			Mass Ratio Indexes		Texture	Lethality
		Initial	Soaked	Processed	Hydration	Drained Wt	Shear Resistance	F_o
				Mean Squares				
Main Effects	7	63.1***	6764.92***	43.19***	2.62***	6.03***	5710.05***	615.85**
Class	4	110.48***	38.98***	36.26***	0.54***	0.45***	7850.35***	2.25*
Process	1	0.0	15.61***	0.28	0.02***	1.66***	2675.45**	4286.35***
Soak	2	0.0	23591.44***	78.53***	9.04***	19.35***	2946.76***	7.81*
Two-Way								
Class X Process	4	0.0	0.44**	0.53	0.0*	0.04**	71.81	1.62
Class X Soak	8	0.0	10.30***	0.69	0.14***	0.20***	820.44***	2.02
Process X Soak	2	0.0	8.94***	16.84***	0.01***	0.26***	2398.69***	1.87

Table 40 (cont'd.)

Source of Variation	df	Bean Moisture (%)			Mass Ratio Indexes		Texture	Lethality
		Initial	Soaked	Processed	Hydration	Drained Wt	Shear Resistance	F_o
Residual	60	0.01	0.09	0.82	0.0	0.0	291.7	0.41
CV (%)		0.77	0.93	1.35	6.13	4.85	27.56	3.23

moistures are presented in Figure 9.

These data indicated a significant difference among classes for initial moisture content. A significant difference was also observed among classes, process and soaks for soaked bean moisture. Significant two-way and three-way interactions also existed for soaked moisture content. Also a significant difference among the three treatments existed for the hydration ratio. The mean values are presented in Tables 38 and 39. These data clearly indicate that the beans imbibed more water during the 12 hour (long term) soak than during the 30 minute/25°C plus 30 minutes/87.8°C treatment. This difference was also observed in the hydration ratios where all values for the long term soak were approximately 2.0. This value indicates that dry beans doubled their weight during the 12 hour soak cycle. Short time soaking resulted in a hydration ratio of approximately 1.8. The dry pack beans had a hydration ratio of 1.0 since they were not soaked prior to filling.

The means for dry, soaked and processed canned bean quality are summarized in Tables 41 and 42. Analyses of variance of these parameters are summarized in Table 43. Mean values for all bean weights are presented in Figure 10.

The analyses of variance for drained weight and the subjective visual examination are presented in Table 43. The Tukey mean separations are presented in Tables 41 and 42. The mean squares indicate a significant difference in drained weight among classes, processes and soak treatments. Significant two-way and three-way interactions also occurred which make interpretation of the main effects for drained weight difficult. The mean values show no significant difference among soak treatments for cranberry and

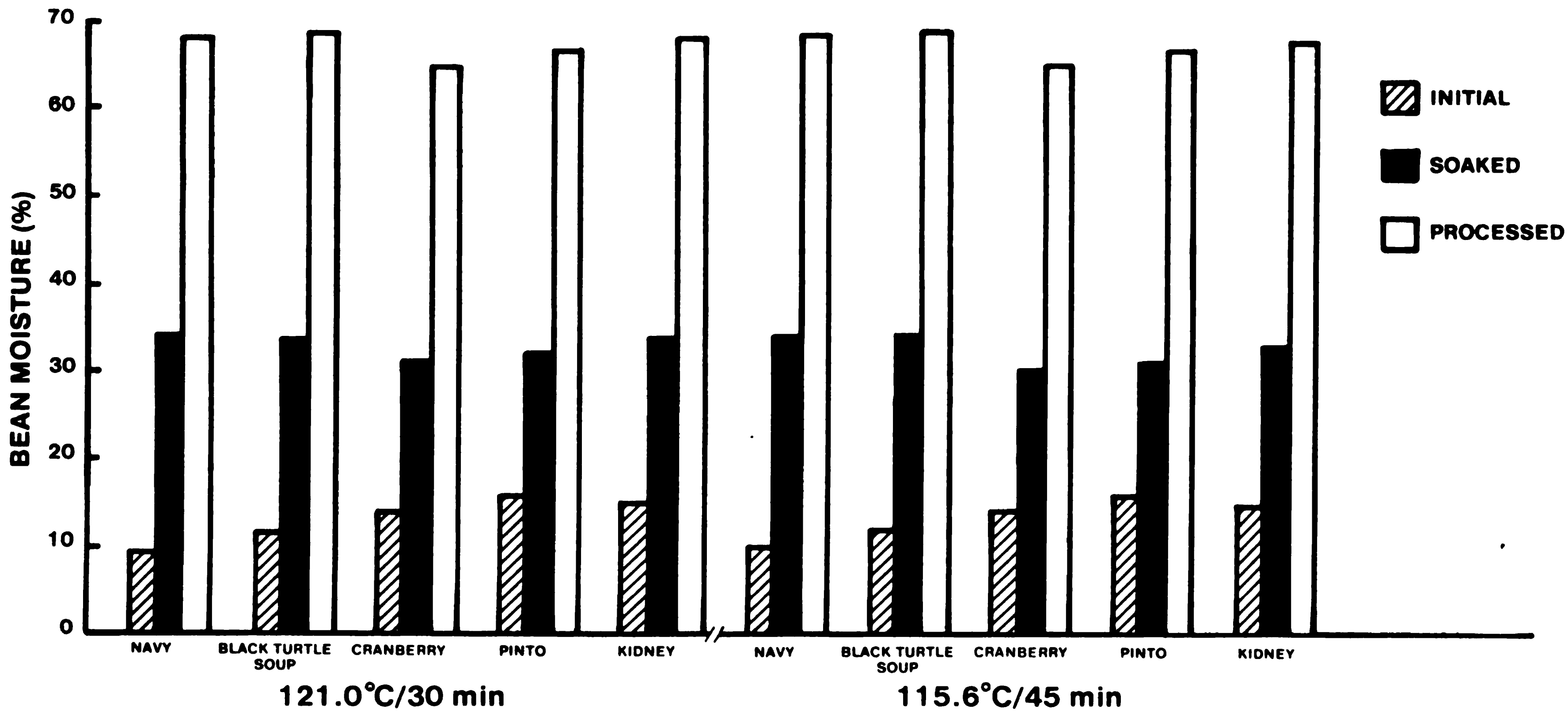

Figure 9. Mean Values for Initial, Soaked and Processed Moisture of Navy, Black Turtle Soup, Cranberry, Pinto and Kidney Beans Processed at 115.6°C/45 minutes or 121°C/30 minutes in a Still Retort

Table 41. Quality Characteristics[1] of Dry, Soaked and Canned Beans Evaluated at the MSU Legume Quality Laboratory. Beans Were Processed at 115.6°C/45 minutes in a Still Retort. All beans Were Pre-soaked: 1)12 hours/25°C, 2)30 minutes/25°C plus 30 minutes/87.8°C and 3)Not Soaked (Dry Pack)

Type/ Soak Treatment	Bean Weight (g)			Processed Beans			Shear Resistance (kg/100g)
				% Total	Visual[2]		
	Initial	Soaked	Drained	Solids	Clumps	Splits	
Navy							
12 hr	110.6a	226.7a	362.5a	30.5a	1.3a	1.7a	34.0a
30/30	110.6a	215.7b	407.6b	32.1a	1.0a	3.0b	32.2b
Dry	110.6a	110.6c	433.6b	33.5a	1.0a	2.0a	41.7c
Black Turtle Soup							
12 hr	113.2a	234.7a	403.9a	30.1a	1.7a	3.0a	32.7a
30/30	113.2a	219.0b	422.9b	32.1a	2.7a	3.0a	47.2b
Dry	113.2a	113.2c	353.2c	32.5a	1.3a	2.7a	57.6b
Cranberry							
12 hr	115.9a	217.0a	301.3a	34.1a	2.0a	1.0a	93.3a
30/30	115.9a	201.0b	375.7a	35.1a	2.0a	1.0a	93.3a
Dry	115.9a	115.9c	296.5a	36.1a	1.7a	1.0a	101.2b
Pinto							
12 hr	118.2a	226.3a	379.3b	32.5a	2.3b	2.0a	42.1a
30/30	118.2a	215.0b	334.3a	32.8a	2.7b	1.7a	57.2b
Dry	118.2a	118.2c	367.4ab	34.8b	1.0a	2.7a	70.7c

Table 41 (cont'd.)

Type/ Soak Treatment	Bean Weight (g)			Processed Beans			Shear Resistance (kg/100g)
	Initial	Soaked	Drained	% Total Solids	Visual[2] Clumps	Visual[2] Splits	
Kidney							
12 hr	117.0a	236.3a	368.2a	31.8a	1.7a	2.0a	42.2a
30/30	117.0a	219.8b	368.6a	32.1a	1.3a	1.7a	53.1b
Dry	117.0a	117.0c	392.2a	34.1b	1.7a	3.0b	63.5c

[1]Mean values 100 g bean solids per can, n = 3 cans per treatment; Tukey mean separations, like letters within each bean class indicate no significant difference ($P<0.05$)

[2]Subjective visual examination for canned bean characteristics, five point scale (1 = none, 5 = excessive)

Table 42. Quality Characteristics[1] of Dry, Soaked and Canned Beans Evaluated at the MSU Legume Quality Laboratory. Beans Were Processed at 121°C/30 minutes in a Still Retort. All Beans Were Presoaked: 1)12 hours/25°C, 2)30 minutes/25°C plus 30 minutes/87.8°C and 3)Not Soaked (Dry Pack)

				Processed Beans			
Type/	Bean Weight (g)			% Total	Visual[2]		Shear Resistance
Soak Treatment	Initial	Soaked	Drained	Solids	Clumps	Splits	(kg/100g)
Navy							
12 hr	110.6a	232.0a	366.3a	30.8a	1.0a	2.0b	38.6a
30/30	110.6a	220.0b	361.5a	30.1a	1.0a	1.7ab	31.8a
Dry	110.6a	110.6c	342.5a	34.8b	1.0a	1.0a	52.0b
Black Turtle Soup							
12 hr	113.2a	233.8a	368.6a	29.8a	2.0a	3.0a	44.0a
30/30	113.2a	227.6b	349.7b	30.1a	3.0b	2.0a	48.5a
Dry	113.2a	113.2c	332.1c	33.5b	1.0c	2.3ab	70.3b
Cranberry							
12 hr	115.9a	219.2a	323.8a	33.5a	1.0a	1.0a	107.9a
30/30	115.9a	214.2b	302.5b	33.8a	2.7b	1.0a	111.1a
Dry	115.9a	115.9c	295.3b	37.1b	1.0a	1.7a	127.0b
Pinto							
12 hr	118.2a	226.8a	340.2a	31.5a	2.0a	2.3a	64.8a
30/30	118.2a	225.0a	329.6a	32.8a	2.3a	1.0a	68.9a
Dry	118.2a	118.2b	298.9b	37.1b	2.0a	2.3a	104.3b

Table 42 (cont'd.)

Type/ Soak Treatment	Bean Weight (g)			Processed Beans			
				% Total Solids	Visual[2]		Shear Resistance (kg/100g)
	Initial	Soaked	Drained		Clumps	Splits	
Kidney							
12 hr	117.0a	239.0a	339.2b	31.1a	1.7a	1.7a	44.5a
30/30	117.0a	226.0b	328.5ab	31.8a	2.0a	2.0a	58.5b
Dry	117.0a	117.0c	314.2a	34.8b	1.3a	2.7a	73.5c

[1]Mean Values 100 g bean solids per can, n = 3 cans per treatment; Tukey mean separations, like letters within each bean class indicate no significant difference ($P<0.05$)

[2]Subjective visual examination for canned bean characteristics, five point scale (1 = none, 5 = excessive)

Table 43. Analysis of Variance of Quality Characteristics of Dry, Soaked and Canned Beans for Various Bean Types Thermally Processed at 115.6°C/45 minutes and 121°C/30 minutes. Beans Were Pre-soaked: 1)12 hours/25°C, 2)30 minutes/25°C plus 30 minutes/87.8°C and 3)Not Soaked (Dry Pack)

Source of Variation	df	Bean Weight (g)				Visual	
		Initial	Soaked	Drained	Dried	Clumps	Splits
				Mean Squares			
Main Effects	7	96.81***	34305.33***	11817.36***	43.20***	2.82***	3.69***
Class	4	169.42***	377.49***	11397.73***	36.26***	2.73***	5.71***
Process	1	0.0	268.67***	33033.64***	0.28	0.01	1.34*
Two-Way							
Class X Process	4	0.0	4.68*	696.42	0.53	0.18***	0.51*
Class X Soak	8	0.0	131.14***	1778.53***	0.69	0.08	1.28***
Process X Soak	2	0.0	144.77***	2975.89***	16.84***	0.54***	0.68*

Table 43 (cont'd.)

Source of Variation	df	Bean Weight (g)				Visual	
		Initial	Soaked	Drained	Dried	Clumps	Splits
Three-Way							
Class X Process X Soak	8	0.00	10.08***	1932.66***	1.89*	0.54**	0.43*
Residual	60	0.00	1.76	303.72	0.82	0.16	0.20
CV (%)		0.08	0.70	4.95	2.74	23.80	22.70

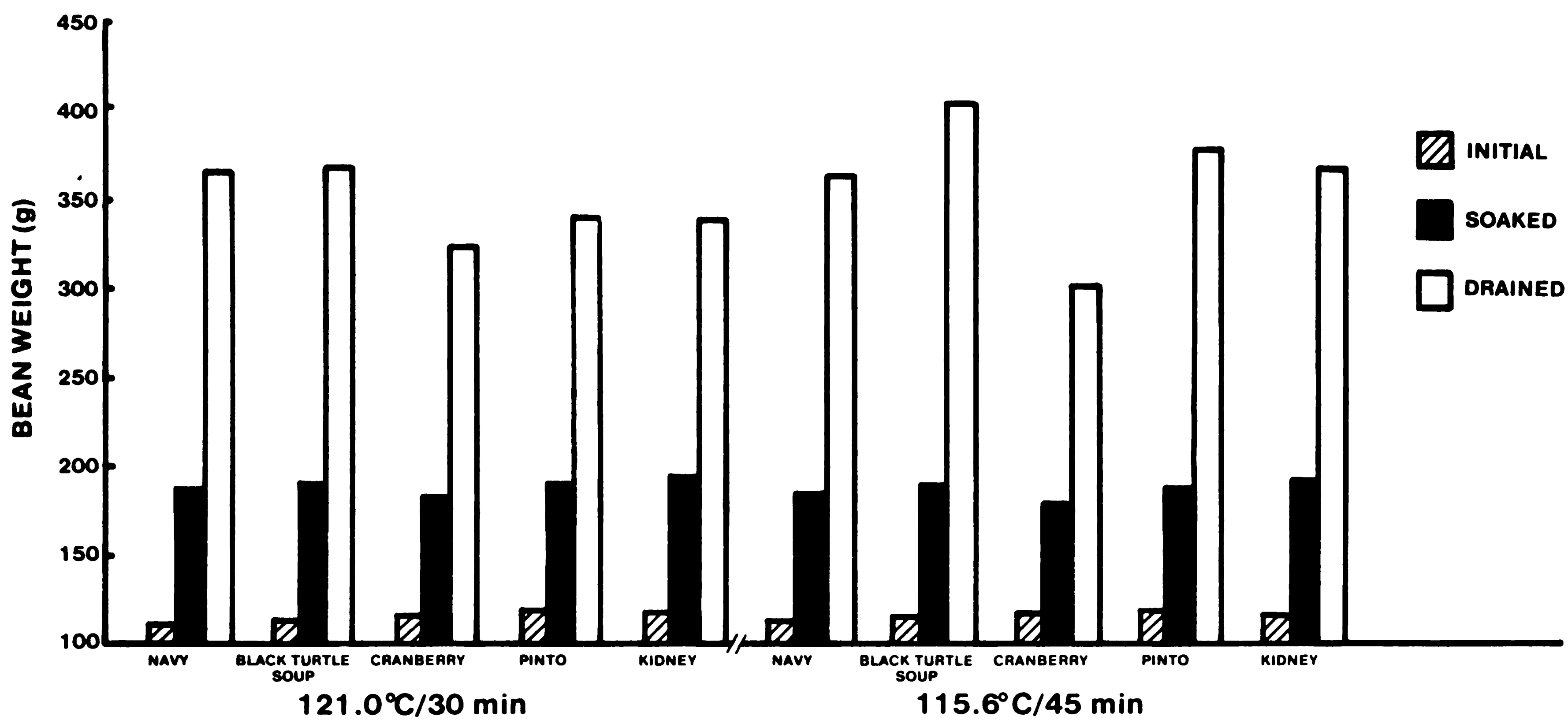

Figure 10. Mean Values for Initial, Soaked and Processed Weights of Navy, Black Turtle Soup, Cranberry, Pinto and Kidney Beans Processed at 115.6°C/45 minutes or 121°C/30 minutes in a Still Retort

kidney beans processed at 115.6°C/45 minutes or for navy beans processed at 121°C/30 minutes. Black turtle soup beans showed a significant drained weight difference among all soaks and processes. No significant drained weight trend was observed among the other classes. Observation of the subjective visual examination showed no meaningful difference for either processes in clumps or splits among soak treatments. Table 43 indicates a significant difference in class, process and soak; however, the two-way and three-way interactions make it difficlt to interpret the main effects.

The analyses of variance for the processed bean moisture and total solids are presented in Table 40 and 43. Significant differences were observed among classes and soaks. No significant difference occurred between processes. Significant process X soak and class X process X soak interactions were observed for total solids and processed bean moisture. Generally for the two processes, the cranberry and pinto beans had the highest total solids, kidney was intermediate, followed by navy and black turtle soup with the lowest total solids.

Significant differences among classes, processes and soaks for shear resistance were observed (Table 40). Significant two-way class X soak and process X soak interactions were also detected. Beans processed at 121°C/30 minutes were firmer than beans processed at 115.6°C/45 minutes (Tables 41 and 42). It was also found that the dry pack beans were significantly firmer than the 12 hour soak or 30 minute/25°C plus 30 minutes/87.8°C soaked beans. These beans also had a lower processed moisture (Tables 38 and 39), indicating they had a lower capacity for water uptake. It was found for both processes that navy and black turtle soup beans were the softest

(Figure 11). These were followed in increasing firmness by the kidney and pinto beans. Cranberry beans were observed to be the firmest bean in both processes.

The analysis of variance for lethality is presented in Table 40. Significant differences were observed for bean classes, processes and soak methods. The Tukey mean separations for the data are summarized in Table 38 and 39. These data indicate no meaningful difference among bean classes for lethality. The dry pack kidney in both processes were significantly different from the other two soak treatments. They both had a lower F_o value indicating less thermal processing. The beans processed at 121°C/30 minutes (15 psi) received significantly more effective process lethality ($F_o = 28.2$) than beans processed at 115.6°C/45 minutes (10 psi, $F_o = 11.3$). This does not mean that the lower temperature process beans were not safe, because a commercially sterile process must have an F_o equal to 2.45.

Texture Curve Analysis. The means for direct texture curve analysis parameters for the 115.6°C/45 minute process are presented in Table 44. Analyses of variance for these parameters are summarized in Table 45.

The mean squares for the compression components are presented in Table 45. These data indicate a significant difference among classes and soak treatments for peak height. A significant two-way class X soak interaction was also observed. The compression peak is the measurement of the Kramer shear curve peak height represented by coordinate (Y3) in Figure 2. This value is an objective measurement of processed bean firmness. The data indicated a difference among classes and soaks in texture. It was observed that the cranberry

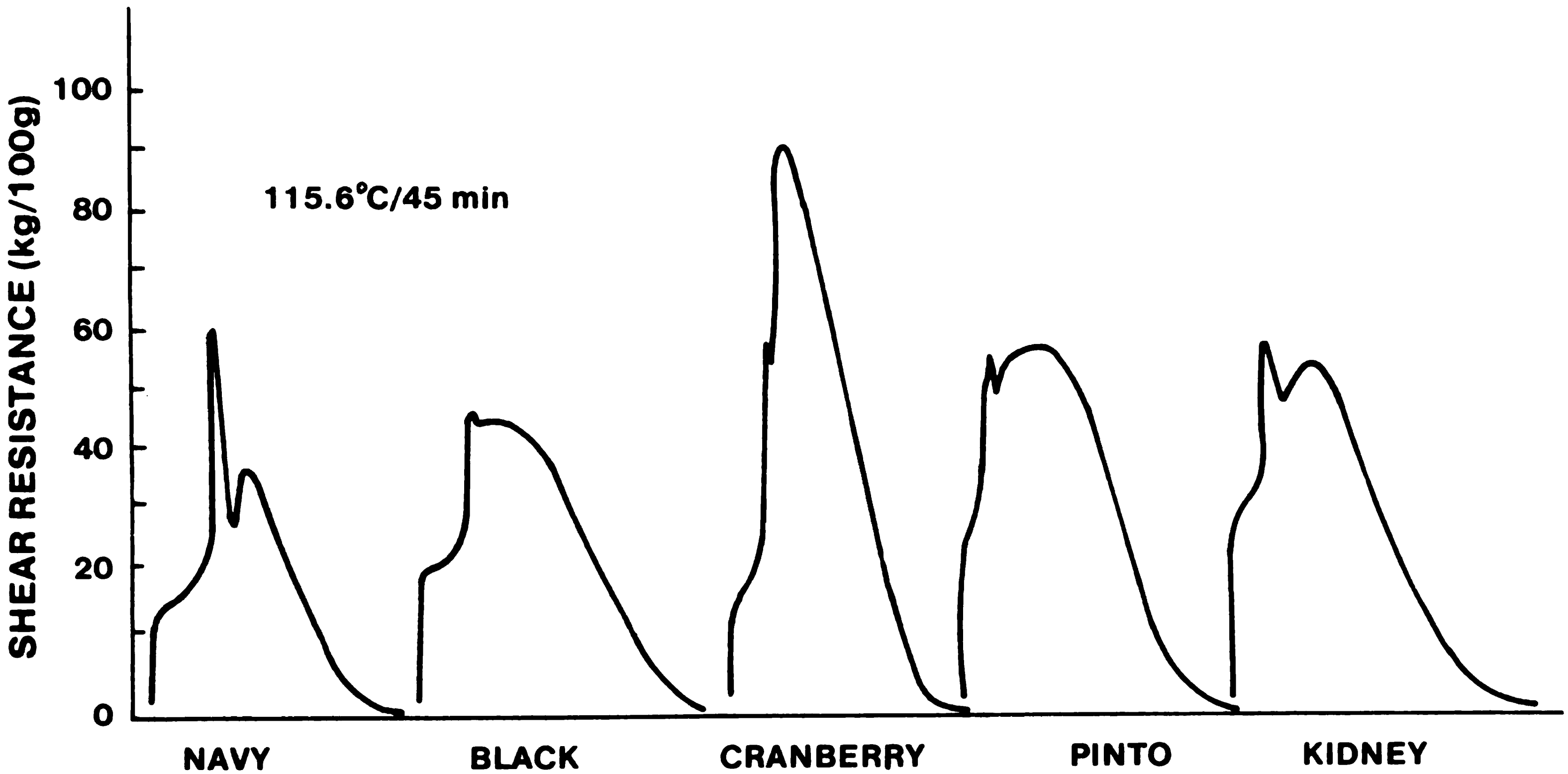

Figure 11. Typical Kramer Texture Curves Characterizing Mean Values of the Compression Peak and Shear Peak for Navy, Black Turtle Soup, Cranberry, Pinto and Kidney Beans Processed at 115.6°C/45 minutes or 121°C/30 minutes in a Still Retort

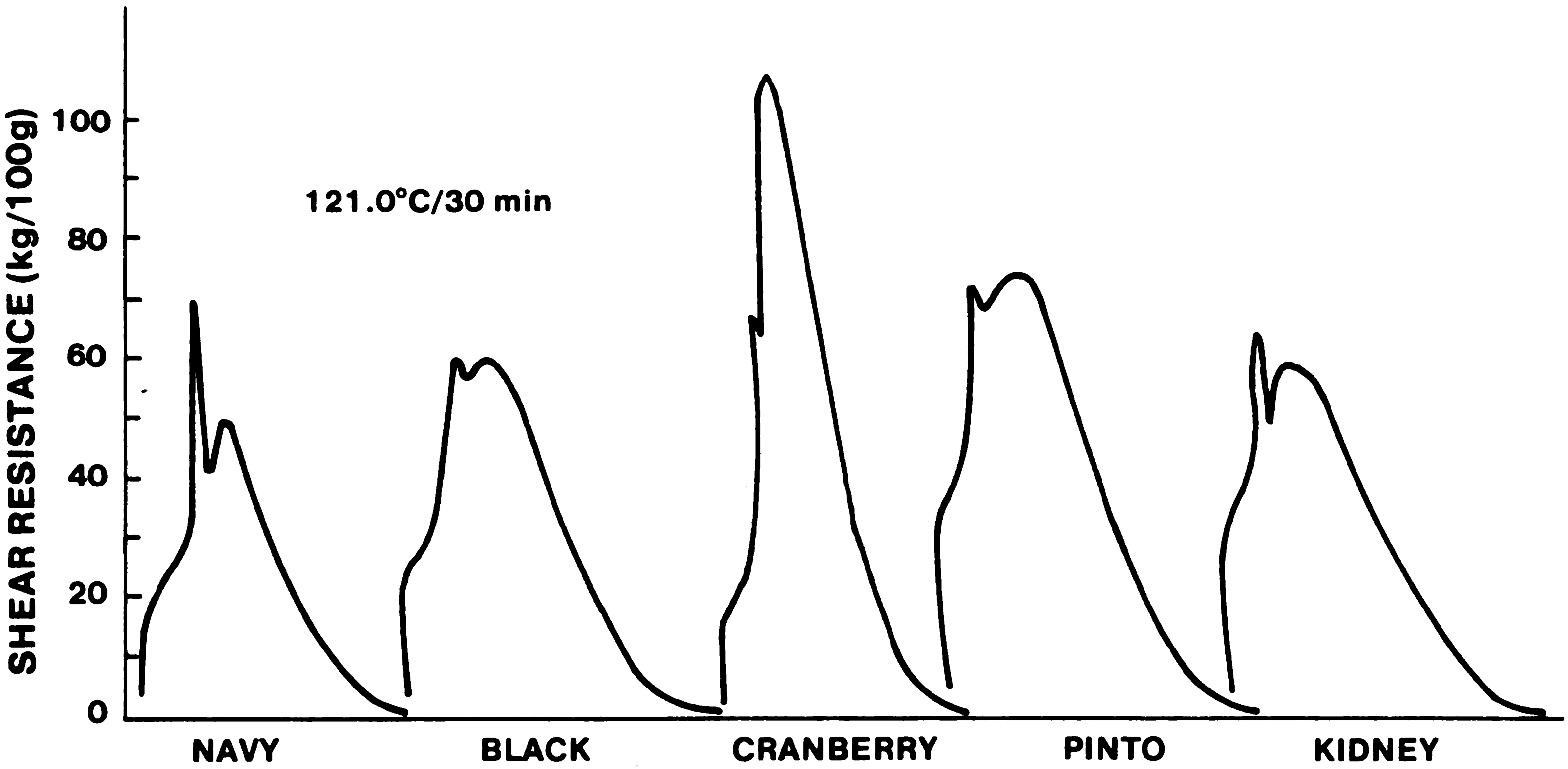

Figure 11 (cont'd.)

Table 44. Direct Texture Curve Analysis Parameters of Canned Beans Evaluated at the MSU Legume Quality Laboratory. Beans Were Thermally Processed at 115.6°C/45 minutes. Beans Were Pre-soaked: 1)12 hours/25°C, 2)30 minutes/25°C plus 30 minutes/87.8°C and 3)Not Soaked (Dry Pack)

Type/	Compression Component		Shear Component			
Soak Treatment	Peak	Peak Time	Minimum	Minimum Time	Peak	Peak Time
Navy						
12 hr	22.3ab	53.0a	20.7ab	56.3a	42.3a	58.7a
30/30	20.7a	53.3a	18.0a	56.8a	32.0b	58.7a
Dry	28.3b	54.0a	24.7b	57.1a	35.7b	58.8a
Black Turtle Soup						
12 hr	20.5a	52.5a	18.0a	57.0a	20.0a	58.5a
30/30	31.0b	53.0a	25.0b	57.3a	28.0b	59.0a
Dry	37.0c	52.5a	28.0b	57.0a	29.0b	58.5a
Cranberry						
12 hr	76.0a	51.7a	39.8a	56.7a	40.3a	58.0a
30/30	74.3a	52.8a	38.0a	57.8b	38.5a	58.8a
Dry	98.3b	54.2a	37.3a	57.9b	37.0a	58.1a
Pinto						
12 hr	26.7a	52.0a	21.3a	57.3a	26.0a	58.8a
30/30	37.7b	52.2a	30.3b	56.3a	38.0b	59.0a
Dry	51.3c	52.3a	28.3b	57.4a	28.8a	58.7a

Table 44 (cont'd.)

Type/ Soak Treatment	Compression Component		Shear Component			
	Peak	Peak Time	Minimum	Minimum Time	Peak	Peak Time
Kidney						
12 hr	31.7a	53.2a	28.2a	56.2a	36.0a	58.7a
30/30	36.7b	52.7a	32.0a	56.5a	38.7a	58.8a
Dry	43.0c	53.3a	30.8a	57.5a	31.4a	58.8a

[1]Mean values 100 g bean solids per can, n = 3 cans per lot; Tukey mean separations, like letters within each bean class indicate no significant difference ($P<0.05$)

Table 45. Analysis of Variance of Compression and Shear Components for Various Bean Types Thermally Processed at 115.6°C/45 minutes. Beans Were Pre-soaked:1)12 hours/25°C, 2)30 minutes/25°C plus 30 minutes/87.8°C and 3)Not Soaked (Dry Pack)

Source of Variation	df	Compression Component		Shear Component			
		Peak	Peak Time	Minimum	Minimum Time	Peak	Peak Time
				Mean Squares			
Main Effects	6	3634.08***	73.68	291.97***	1.13***	179.44***	0.40
Class	4	4933.00***	80.98	402.13***	0.78**	255.66***	0.38
Soak	2	1036.24***	59.09	71.65***	1.84***	27.01	0.43
Two-Way							
Class X Soak	8	76.18***	67.63	31.18**	0.69**	73.65***	0.17
Residual	30	8.72	58.93	7.72	0.20	9.72	0.25
CV (%)		6.96	14.90	9.89	0.78	9.33	0.85

beans were the firmest and that the navy beans were the softest among all classes. These data also indicate that the dry pack (no soak) treatment yielded the firmest beans for all bean classes. The peak time is represented as coordinate (X3) in Figure 2. It is the time from initial contact of shear blades with beans (X4, Figure 2) until the compression peak occurs. No significant difference among classes or bean soak treatments was observed for peak time.

The mean squares for the shear components are summarized in Table 45. A significant difference for shear peak was observed for classes and soak treatments. A significant two-way class X soak interaction also occurred. The shear peak is point Y1 in Figure 2. The mean values for shear components are represented in Table 44. It was observed that navy, cranberry and kidney had similar shear peak heights. The shear peak time is represented by coordinate X1 in Figure 2. These values are the time from initial contact of shear blades with beans until the shear peak occurs. No significant difference was observed among classes or soaks (Table 45).

The analyses of variance for the shear minimum and shear maximum time are summarized in Table 45. A significant difference among classes and soaks was observed for both parameters. The mean values for these data are presented in Table 44. The shear minimum and shear maximum time are represented as point X2 and Y2, respectively in Figure 2. The shear minimum is the height of the mathematical minimum point between the compression peak and shear peak. The shear minimum time is the time in which the shear minimum peak height occurred. The shear minimum in black turtle soup and pinto beans showed a significant difference among soak treatments.

The shear minimum was significantly larger for the dry pack soak than for the 12 hour/25°C soak. It was also observed that the shear minimum for cranberry beans was larger than for the other bean classes. This was due to the fact that cranberry was the firmest bean which caused a large compression peak which in turn resulted in a large shear minimum value. A significant difference in shear minimum time was observed for the 30 minute/25°C plus 30 minutes/ 87.8°C and dry pack cranberry beans. However, this difference was so small it was judged to be of no practical meaning.

The mean values for methematically derived parameters are summarized in Tables 46 and 47. Analyses of variance for these parameters are presented in Tables 48 and 49.

The analyses of variance for the inflection point, shear acceleration and compression curvature are presented in Table 46. These calculated parameters are found in Figure 3. The inflection point is the point of directional change of the curve from the initial contact of shear blades with the beans and the compression peak. No significant differences in the inflection point were observed among classes or soak treatments.

The compression curvature and shear acceleration are a measure of the sharpness of the curve as it passes through the compression peak and shear minimum (Figure 6). Computationally, these values were determined by computing the radius of the circles which are the best fit tangents to the curves at these points. The analyses of variance for these two parameters, expressing rate of directional change, indicate a significant difference among bean classes and soak treatments. A significant class X soak interaction was also observed. The mean values for these parameters are summarized in

Table 46. Derived Texture Curve Analysis Parameters of Canned Beans Evaluated at the MSU Legume Quality Laboratory. Beans Were Thermally Processed at 115.6°C/45 minutes. Beans Were Pre-soaked: 1) 12 hours/25°C, 2) 30 minutes/25°C plus 30 minutes/87.8°C and 3) Not Soaked (Dry Pack)

Type/ Soak Treatment	Inflection Point	Shear Acceleration	Compression Curvature	Peak Difference	Shear Length
Navy					
12 hr	45.7a	3.79a	3.69a	20.0a	21.7a
30/30	47.9a	0.17b	0.53b	11.3b	14.0b
Dry	46.8a	0.20b	0.48b	7.4c	11.0b
Black Turtle Soup					
12 hr	43.0a	2.81a	7.53a	0.5a	2.0a
30/30	42.7a	1.73b	6.21a	3.0b	3.0a
Dry	41.3a	0.08c	1.05b	-8.0c	1.0a
Cranberry					
12 hr	39.9a	0.04a	0.13a	-35.7a	0.5a
30/30	45.7a	0.03a	0.08a	-35.8a	0.5a
Dry	44.3a	0.02a	0.15a	-40.4a	-0.3b
Pinto					
12 hr	43.9a	1.35a	3.74a	-0.7a	4.6a
30/30	44.2a	1.37a	4.18a	0.3b	7.6b
Dry	47.0a	0.07b	0.43b	-22.2c	0.5c

Table 46 (cont'd.)

Type/ Soak Treatment	Inflection Point	Shear Acceleration	Compression Curvature	Peak Difference	Shear Length
Kidney					
12 hr	40.7a	0.50a	1.00a	4.3a	7.7a
30/30	45.3a	0.35a	1.11a	1.0b	6.7a
Dry	46.5a	0.19a	0.55a	-11.6c	0.6b

[1]Mean values 100 g bean solids per can, n = 3 cans per lot; Tukey mean separations, like letters within each bean class indicate no significant difference ($P<0.05$)

Table 47. Bean Weight Indexes of Dry and Canned Beans Evaluated at the MSU Legume Quality Laboratory. Beans Were Thermally Processed at 115.6°C/45 minutes. Beans Were Pre-soaked: 1) 12 hours/25°C, 2) 30 minutes/25°C plus 30 minutes/87.8°C and 3)Not Soaked (Dry Pack)

Type/ Soak Treatment	Seed Weight/100 Seeds (g) Dry	Seed Weight/100 Seeds (g) Processed	Processed Bean Volume (cc)	Processed Bean Density (g/cc)
Navy				
12 hr	14.5	45.2	248.2a	0.40
30/30	14.5	40.0	231.2a	0.43
Dry	14.5	32.5	262.0a	0.38
Black Turtle Soup				
12 hr	22.3	52.5	234.3a	0.42
30/30	22.3	45.0	248.2a	0.40
Dry	22.3	40.0	248.2a	0.40
Cranberry				
12 hr	57.0	115.3	271.3a	0.36
30/30	57.0	105.4	257.4a	0.39
Dry	57.0	99.8	269.7a	0.37
Pinto				
12 hr	40.0	100.2	245.1a	0.41
30/30	40.0	95.0	249.7ab	0.40
Dry	40.0	83.5	268.2b	0.37
Kidney				
12 hr	63.0	174.0	265.11a	0.37
30/30	63.0	150.2	263.6a	0.38
Dry	63.0	137.5	261.3a	0.38

[1]Mean values 100 g bean solids, n = 3 cans per lot; Tukey mean separations, like letters within each bean class indicate no significant difference ($P<0.05$)

Table 48. Analysis of Variance of the Inflection Points, Shear Acceleration and Compression Curvature for Various Bean Types

Source of Variation	df	Inflection Point	Shear Acceleration	Compression Curvature
			Mean Squares	
Main Effect	6	27.70	178.99***	174.26***
Class	4	25.68	166.15***	1748.20***
Soak	2	31.73	204.66***	1731.50***
Two-Way				
Class X Soak	8	9.64	140.86***	1424.40***
Residual	30	20.12	0.49	2.72
CV (%)		10.19	27.13	21.36

Table 49. Analysis of Peak Difference, Shear Length and Bean Volume for Various Bean Types

Source of Variation	df	Peak Difference	Shear Length	Bean Volume
			Mean Squares	
Main Effects	6	3100.78***	252.59***	773.25**
Class	4	4048.46***	331.54***	870.82**
Soak	2	1205.44***	94.67***	578.13*
Two-Way				
Class X Soak	8	83.11***	20.63***	240.78
Residual	30	7.99	1.00	173.55
CV (%)		31.4	18.9	5.17

Table 46. A significant soak treatment difference was observed for navy, black turtle soup and cranberry. The compression curvature decreased among the three soak treatments. This indicated that texture curves become more peaked shaped and less rounded among soak treatments due to an increase in processed bean firmness. The data in Table 46 indicated that the compression peak increased from 12 hour/25°C soak to the dry pack. Thus, as beans became firmer, the degree of roundness or compression curvature decreased. It was also observed that 12 hour/25°C soak black turtle soup had the highest compression curvature or curve roundness among all classes. The shear acceleration showed a similar trend. It decreased in area in navy, black turtle soup and pinto beans among soak treatments. This means that the area between the compression peak and shear peak decreases as the beans become more firm. It was observed that the 12 hour/25°C navy beans had the largest shear acceleration among classes.

The mean squares for the peak difference and shear length are presented in Table 49. Both parameters indicated a significant difference among classes and soaks. A significant process X soak interaction also occurred. The peak difference is defined in Table 50. It is the difference between the shear peak and the compression peak. The mean values are presented in Table 46. A significant difference in peak difference among all soak treatments was observed for the navy, black turtle soup, pinto and kidney beans. No significant difference was observed for the cranberry. A significant difference in peak differences was also observed among bean classes. The navy clearly showed a large shear peak indicated by a positive peak difference. The data for cranberry beans indicated a negative peak difference indicative of a small shear peak relative to a large compression peak. The shear peak size was determined by the shear length parameter. This shear length is defined in Table 50 to be the difference in the shear peak and shear minimum. The data in Table 46 indicated that navy beans had the largest shear length and cranberry, the smallest.

Table 50. Calculations of Various Texture Curve Analysis Parameters

Peak Differences = Shear Peak - Compression Peak

Shear Length = Shear Peak - Shear Minimum

The analysis of variance for bean volume is presented in Table 49. Significant differences among classes and soaks were observed. The bean volume was calculated according to Equation 8. The parameter of blade contact time represented by point X4 in Figure 2 was measured from the curve. This was the point where the shear blades made initial contact with the beans. Since the beans were taking up a given volume in the cell (X4), the bean volume could be computed by difference from the known cell volume. The bean volume was then computed according to Equation 8. The mean values for bean volume are summarized in Table 47. No significant difference was observed among soak treatments except for pinto beans. It was also found that the larger beans occupied greater volume of the cell than did the small beans of equal weight. Dry and processed seed weight per 100 grams of beans is summarized in

Table 47. These data indicate that the navy and black beans are small seeded, and cranberry, pinto and kidney beans are large seeded. Values for bean volumes showed that the kidneys had a greater bean volume than did the navy or the black turtle soup beans.

A constant bean weight of 100 grams was placed in the compression cell. Since the volume had been computed, the apparent density could be calculated by dividing the 100 grams of bean mass by the bean volume (Equation 9). These values are summarized in Table 47. Observation of the data indicated that navy and black beans were more dense than the cranberry, pinto or kidney beans. Since the large beans take up a greater cell volume and are less dense, it can be concluded that larger less dense bean types have more air spaces between beans than do smaller more dense beans.

Summary and Conclusion

Beans soaked for 12 hours/25°C had a higher percent soak moisture than did beans soaked for 30 minutes/25°C plus 30 minutes/ 87.8°C. The dry packed (no soak) beans were significantly darker than beans obtained from the other two soak treatments. No significant difference among lethal rates was observed for soak treatments and classes.

All cans processed at 121°C/30 minutes were firmer and had a higher lethal rate than beans processed at 115.6°C/45 minutes, regardless of bean class or soak treatment. The 121°C/30 minutes processed beans received more heat penetration than did the beans processed at 115.6°C/45 minutes, but were firmer due to a shorter cooking time which resulted in less softening. The lethal rate increased and texture decreased as heating time increased. It was concluded that beans were not processed for 45 minutes to achieve sterility, but for textural acceptability.

Texture curve analysis yielded significant differences among classes for various parameters. Navy beans were found to have the largest length of shear among all classes. Cranberry beans were found to have the largest compression peak. It was also found that cranberry beans had the largest bean volume and navy beans, the smallest bean volume in the compression cell. The larger seeded, large volume kidney beans were also observed to be the least dense bean class in the compression cell during objective texture measurement.

SUMMARY AND CONCLUSION

The data obtained in the moisture study indicated initial moisture content had no effect on processing quality of Fleetwood, Seafarer, Nep-2 or Sanfernando. It was found that navy beans became darker while Sanfernando was lighter after processing. Sanfernando was the firmest bean and Fleetwood, the softest bean tested.

The National Dry Bean Quality Nurseries indicated differences in color, drained weight and texture for both the large and small seeded classes. Most beans became darker after processing. The small seeded Bunsi (navy, 37.1 kg/100 g) and JAMAPA (black turtle soup, 32.0 kg/100 g) had the lowest shear resistance and Aurora had the highest (95.6 kg/100 g). Data from the large seeded nursery indicated all bean types became darker with thermal processing. Great Northern beans had the lowest hydration ratios. Gloria and NW 410 had the lowest shear resistance. Colorado 3465, U.I. 111, Colorado 3342 and Valley were the firmest beans tested.

The data for the North American Variety Trial indicated Fleetwood to be the softest bean processed. Beans from Canada were found to be firmer than beans from Michigan or North Dakota. Beans which were processed with agitation had less clumping and splitting and were firmer than the nonagitated product.

The final study, the effect of soak treatment and processing on texture of five bean classes, indicated that beans soaked for 12 hours/25°C had a significantly lower shear resistance than did either the 30 minutes/25°C plus 30 minutes/87.8°C or dry pack soak treatments. Beans processed at 115.6°C/45 minutes also had a lower shear resistance than the 121°C/30 minutes samples. The 121°C/30 minute cans had a higher lethal rate than the 115.6°C/45 minute cans. The cranberry beans were the firmest among all bean classes. Texture curve analysis indicated navy beans had a higher shear length and possessed the highest apparent density. It was also observed that as beans became firmer, the peak shape was less rounded as indicated by decreased compression curvature.

APPENDIX I

Calculations for Bean Soak Water Processing Brine Formulation

<u>Soak Water Target Water Hardness</u>: $Ca^{++} = 30$ ppm

$Mg^{++} = 85$ ppm

Molecular Weight:

$CaCl_2$ 40.08 g Ca^{++} + 2(35.5 g) Cl_2 = 111.8 g

$MgCl_2$ 24.30 g Ca^{++} + 2(35.5 g) Cl_2 = 94.3 g

Empirical Formula:

$CaCl_2$

$$\% \text{ Ca} = \frac{40.08 \text{ g}}{111.80 \text{ g}} \times 100 = 36.4\%$$

$$\% Cl_2 = \frac{70.0 \text{ g}}{111.8 \text{ g}} \times 100 = 63.6\%$$

$MgCl_2$

$$\% \text{ Mg} = \frac{24.3 \text{ g}}{94.3 \text{ g}} \times 100 = 25.7\%$$

$$\% Cl_2 = \frac{70.0 \text{ g}}{94.3 \text{ g}} \times 100 = 74.2\%$$

Preparation of soak water at specified hardness (batch size 100# water = 45.4 kg deionized water)

$$\text{Ca:}\quad 30\ \text{ppm} = \frac{\text{mg}}{45.5\ \text{kg}} = \frac{1359.0\ \text{mg}}{0.364} = 3633.5\ \text{mg}\ CaCl_2$$

$$= 3.7\ \text{g}\ CaCl_2/45.5\ \text{kg water}$$

$$\text{Mg:}\quad 85\ \text{ppm} = \frac{\text{mg}}{45.5\ \text{g}} = \frac{1359.0\ \text{mg}}{0.257} = 3633.5\ \text{mg}\ CaCl_2$$

$$= 14.9\ \text{g}\ MgCl_2/45.5\ \text{kg water}$$

Formulation Summary for Soak Water:

Chemical	Amount (g) in Water	ppm Ca^{++}	ppm Mg^{++}	ppm Cl_2
$CaCl_2$	0.08 g/kg	30.0	-	52.4
$MgCl_2$	0.33 g/kg	-	85	244.1
	Total (ppm)	30.0	85	296.5

Processing Brine Ingredients and Concentrations

Target Concentrations:

- Ca^{++} 30 ppm
- Mg^{++} 85 ppm
- sucrose 1.52%
- sodium chloride 1.22%

Brine Formulation:

Chemical	Amount (g) in Water	Concentration
$CaCl_2$	0.08 g/kg	30 ppm
$MgCl_2$	0.33 g/kg	85 ppm
sucrose	15.2 g/kg	1.52%
sodium chloride	12.2 g/kg	1.22%

APPENDIX II

Computer Program for Lethal Rate Calculation

```
 10 DIM C1(7,180),S1(180),L1(7,180)
 20 CLEAR
 30 DISP "DATA FILE NAME";
 40 INPUT D1$
 50 ASSIGN# 1 TO D1$
 60 DISP "NO OF CHANNEL";
 70 INPUT A1
 80 DISP "Process TIME";
 90 INPUT A2
100 DISP "TIME INTERVAL FOR DATA COLLECTING";
110 INPUT A3
120 N1=A2/A3+1
130 FOR M1=0 TO N1-1
140 FOR M2=0 TO A1-1
150 READ# 1; C1(M2,M1)
160 DISP C1(M2,M1);
170 NEXT M2
180 READ# 1; S1(M1)
190 DISP S1(M1)
200 NEXT M1
210 ASSIGN# 1 TO *
220 F=0
230 PRINT "Lethal rate analysis"
240 PRINT "Data file:";
250 PRINT D1$
260 DISP "Channel No. for Analysis";
270 INPUT A6
280 PRINT "Channel:";
290 PRINT A6
300 DISP "Z Value(Des C)";
310 INPUT A4
320 DISP "Temp(C) for F Value";
330 INPUT A5
331 DISP "Highest Lethal Rate Value";
332 INPUT A7
340 FOR M1=0 TO N1-1
350 L1(A6,M1)=1/10^((A5-C1(A6,M1))/A4)
360 F=f+L1(A6,M1)*A3
370 NEXT M1
380 PRINT "F= ";
390 PRINT F/60;
400 PRINT "at";
```

```
410 PRINT A5;
420 PRINT "with Z of";
430 PRINT A4
431 GOSUB 470
440 DISP "DO YOU WANT TO DO OTHER ANALYSIS";
450 INPUT A1$
460 IF A1$="Y" THEN 220
461 GOTO 600
470 REM *GRAPH SUB*
471 PRINT "X axis from 0 to";
472 PRINT A2
473 PRINT "    with interval";
474 PRINT A2/20
475 PRINT "Y axis from 0 to";
476 PRINT A7
477 PRINT "    with interval";
478 PRINT A7/20
480 GCLEAR
490 SCALE 0,A2,0,A7
500 LDIR 0
510 MOVE A2/2,A7/40 @ LABEL "Time"
520 LDIR 90
530 MOVE A2/20,A7/3 @ LABEL "Lethal Rate"
540 XAXIS 0, A2/20 @ YAXIS 0,A7/20
550 MOVE 0,0
560 FOR I=0 TO N1-1
570 DRAW S1(I),L1(A6,I)
580 NEXT I
590 RETURN
600 DISP "END OF RUN"
610 END
```

APPENDIX III

APPENDIX III

Computer Program for Texture Curve Analysis

```
 60 LPRINT"EQUATION ANALYSIS OF KRAMER SHEAR CURVES"
 70 LPRINT
 80 LPRINT
 90 L PRINT
100 DIM E(3,7),A(5),R(3,4),S(3,4)
110 DIM X1(500),X2(500),X3(500),X4(500),Y1(500),Y2(500),Y3(500),Y4(500)
120 PRINT "Enter LOOP COUNT"
130 INPUT LOOP
140 PRINT "BEGIN X1 INPUT"
150 FOR I=1 TO LOOP
160 PRINT "X1,";I
170 INPUT X1(I)
180 PRINT " "
190 NEXT I
200 PRINT "BEGIN Y1 INPUT"
210 FOR I=1 TO LOOP
220 PRINT "Y1,";I
230 INPUT Y1(I)
240 PRINT " "
250 NEXT I
260 PRINT "BEGIN X2 INPUT"
270 FOR I=1 TO LOOP
280 PRINT "X@,";I
290 INPUT X2(I)
300 PRINT " "
310 NEXT I
320 PRINT "BEGIN X3 INPUT"
330 FOR I= 1 TO LOOP
340 PRINT "Y2,";I
350 INPUT Y2(I)
360 PRINT " "
370 NEXT I
380 PRINT "BEGIN X3 INPUT"
390 FOR I= 1 TO LOOP
400 PRINT "X3,"I
410 INPUT X3(I)
420 PRINT " "
430 NEXT I
440 PRINT "BEGIN Y3 INPUT"
450 FOR I= 1 TO LOOP
460 PRINT "Y3,";I
470 INPUT Y3(I)
```

```
 480 PRINT " "
 490 NEXT I
 500 PRINT "BEGIN X4 INPUT"
 510 FOR I= 1 TO LOOP
 520 PRINT "X4,";I
 530 INPUT X4(I)
 540 PRINT " "
 550 NEXT I
 560 PRINT "BEGIN Y4 INPUT"
 570 FOR I= 1 TO LOOP
 580 PRINT "Y4,";I
 590 INPUT Y4(I)
 600 PRINT " "
 610 NEXT I
 620 REM*****************************************
 630 REM*                                       *
 640 REM*                                       *
 650 REM*          BEGIN BIG LOOP               *
 660 REM*****************************************
 670 FOR L=1 TO LOOP
 680 LPRINT "X1= ";X1(L);" X2= ";X2(L);" X3= ";X3(L);" X4= ";X4(L)
 690 LPRINT "Y1= ";Y1(L);" Y2= ";Y2(L);" Y3= ";Y3(L);" Y4= ";Y4(L)
 700 FOR J=1 TO 7
 710 E(I,J)=X1(L) ^ J-X4(L) ^ J
 720 NEXT J
 730 FOR J 1 TO 7
 740 E(2,J)=X2(L) ^ J-X4(L) ^ J
 750 NEXT J
 760 FOR J=1 TO 7
 770 E(3,J)=X3(L) ^ J-X4(L) ^ J
 780 NEXT J
 790 A(1)=X2(L)*X3(L)*(X4(L) ^ 2)
 800 A(2)=-((2*(X2(L)*X3(L)*X4(L)+(X2(L)+X3(L)*(X4(L) ^2)))
 810 A(3)=X2(L)*X3(L)+(X4(L) ^ 2)+(2*X2(L)*X4(L)+@*X3(L)*X4(L)
 820 A(4)=-(X2(L)+X3(L)+2*(X4(L)))
 830 A(5)=1
 840 FOR I= 1 TO 3
 850 FOR K= 1 TO 3
 860 SUM=0
 870 FOR J=1 TO 5
 880 SUM= A(J)*E(I,J+3-K)/(J+3-K)+SUM
 890 NEXT J
 900 R(I,K)=SUM
 910 NEXT K
 920 NEXT I
 930 REM
 940 REM
 950 REM
 960 REM
 970 R(1,4)=Y1(L)
 980 R(2,4)=Y2(L)
 990 R(3,4)=Y3(L)
1000 IF ABS(R(2,1))<=ABS(R(1,1)) THEN 1060
1010 FOR CC= 1 TO 4
1020 TEMP=R(1,CC)
```

```
1030 R(1,CC)=R(2,CC)
1040 R(2,CC)=TEMP
1050 NEXT CC
1060 IF ABS(R(3,1))<=ABS(R(1,1)) THEN 1120
1070 FOR CC= 1 TO 4
1080 TEMP=R(1,CC)
1090 R(1,CC)=R(3,CC)
1100 R (3,CC)=TEMP
1110 NEXT CC
1120 T=R(2,1)/R(1,1)
1130 R(2,2)=R(2,2)-(T*R(1,2))
1140 R(2,3)=R(2,3)-(T*R(1,3))
1150 R(2,4)=R(2,4)-(T*R(1,4))
1160 R(2,1)=0
1170 REM
1180 REM
1190 U=R(3,1)/R(1,1)
1200 R(3,2)=R(3,2)-(U*R(1,2))
1210 R(3,3)=R(3,3)-(U*R(1,3))
1220 R(3,4)=R(3,4)-(U*R(1,4))
1230 R(3,1)=0
1240 T=R(3,2)/R(2,2)
1250 R(3,3)=R(3,3)-(T*R(2,3))
1260 R(3,4)=R(3,4)-(T*R(2,4))
1270 R(3,2)=0
1280 GOSUB 1740
1290 REM
1300 REM
1310 REM
1320 GAMA=R(3,4)/R(3,3)
1330 BATA=1/R(2,2)*(R(2,4)-R(2,3)*GAMA)
1340 ALFA=1/R(1,1)*(R(1,2)-(R(1,2)*BATA+R(1,3)*GAMA))
1350 REM
1360 REM
1370 REM
1380 P=X3(L)
1390 Q=X4(L)
1400 S=(P+Q)/2
1410 FOR COUNT =1 TO 10
1420 INF=(ALFA*S^2+BATA*S+GAMA)*(S-X4(L)*(2*(S-X2(L))*(S-X3(L))+(S-X4(L))
1430 INF=INF+(2*ALFA*S+BATA)*((S-X4(L)))^2*(S-X2(L))*(S-X3(L))
1440 IF INF=0 THEN 1500
1450 IF INF<0 THEN P=S
1460 IF INF>0 THEN Q=S
1470 S=(P+Q)/2
1480 NEXT COUNT
1490 LPRINT "INFLECTION POINT= ";S;
1500 S=X2(L)
1510 GOSUB 1650
1520 PRINT
1530 PRINT
1540 LPRINT "    AREA 2= ";AREA;
1550 S=X3(L)
1560 GOSUB 1650
```

```
1570 LPRINT "     AREA 3=";AREA;
1580 LPRINT
1590 LPRINT "*********************"
1600 LPRINT
1610 NEXT L
1620 PRINT
1630 PRINT
1640 STOP
1650 INF=(ALFA*S^2+BATA*S+GAMA)*(S-X4(L))*(2*(S-X2(L)*(S-X3(L))+(S-X4(L))
1660 INF=INF+(2*ALFA*S+BATA)*((S-X4(L)))^2*(S-X2(L))*(S-X3(L))
1670 AREA=3.14159*((1/INF)^2)
1680 RETURN
1690 REM
1700 REM
1710 REM
1720 REM
1730 REM
1740 FOR ZZ=1 TO 3
1750 FOR QQ=1 TO 4
1760 PRINT R(ZZ,QQ);"  ";
1770 NEXT QQ
1780 PRINT
1790 NEXT ZZ
1800 PRINT
1810 PRINT
1820 RETURN
1830 FOR ZZ=1 TO 3
1840 FOR QQ=1 TO 4
1850 PRINT S(ZZ,QQ);"  ";
1860 NEXT QQ
1870 PRINT
1880 NEXT ZZ
1890 PRINT
1900 PRINT
1910 RETURN
```

LIST OF REFERENCES

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Antunes, P.L. and Sgarbieri, V.C. 1979. Influence of time and conditions of storage on technological and nutritional properties of a dry bean (Phaseolu vulgaris) Variety Rosinha G2. J. Food Sci. 44:1703.

Ball, C.O. 1928. Mathematical solution of problems on thermal processing of canned foods. Univ. of California Pub. Health 1, No. 2.

Becke, R., Olson, A.C., Frederick, D.P., Kon, S., Gumbamn, M.R. and Wagner, J.R. 1974. Conditions for the autolysis of alpha-galactosides and phytic acid in California small white beans. J. Food Sci. 39:766.

Bedford, C.L. 1972. Bean storage and processing. Proc. of the International Dry Bean Symposium. August 22-24, Michigan State Univ., E. Lansing, MI 63.

Bourne, M.C. 1967. Size, density, and hardshell in dry beans. Food Technol. 21:335.

Bressani, R., Elias, L.G. and Navarette, D.A. 1961. Nutritive value of Central American beans. The essential amino acid content of samples of black beans, red beans, rice beans and cowpeas of Guatemala. J. Food Sci. 26:525.

Brown, A.H. and Kon, S. 1970. Observations on bean processing and a new bean product. Tenth Dry Bean Res. Conf. August 12-14, Davis, CA.

Burr, H.K., Kon, S. 1966. Factors influencing the cooking rate of stored dry beans. Eighth Dry Bean Res. Conf. August 11-13, Bellaire, MI.

Burr, H.K., Kon, S. and Morris, H.J. 1968. Cooking rates of dry beans as influenced by moisture content and temperature and time of storage. Food Technol. 22:336.

Burr, H.K. 1973. Effect of storage on cooking qualities, processing and nutritive value of beans. In: Nutritional Aspects of Common Beans and Other Legume Seeds As Animal and Human Foods. W.G. Jaffe, ed. Arch Latioamer. Nutr.

Daoud, H.N., Luh, L.S. and Miller, M.W. 1977. Effect of blanching, EDTA and $NaHSO_3$ on color and vitamin B_6 retention in canned garbanzo beans. J. Food Sci. 42:375.

Davis, R.R. 1976. Effect of blanching methods and processes on quality of canned dried beans. Food Product Dev. Sept.

Davis, R.R. and Cockrell, C.W. 1976. Effect of added calcium chloride on the quality of canned dried lima beans. Arkansas Farm Res. 25(4):14.

Dawson, H.N., Lamb, J.C., Toepfer, E.W. and Warren, H.W. 1952. Development of rapid methods of soaking and cooking dry beans. USDA Tech. Bull. 1051.

Ekpenjong, T.E. and Borchers, R.L. 1980. Effect of cooking on the chemical composition of winged beans (Psophocarpus tetragonolobus). J. Food Sci. 45:1559.

Elbert, E.M. 1961. Temperature effect on reconstitution of small white beans. Fifth Annual Dry Bean Res. Conf., USDA.

Fennema, O., Karel, M. and Lund, D.B. 1975. Principles of Food Science, Heat Processing. Chapter 3. Marcel and Dekker Inc. New York and Brussels.

Fleming, S.E. 1981. A study of relationships between flatus potential and carbohydrate distribution in legume seeds. J. Food Sci. 46:794.

Gloyer, W.O. 1928. Hardshell of beans: its production and prevention under storage conditions. Proc. Assoc. Analysis North America 20:52.

Greenwood, M.L. 1935. Pinto beans: their production and palatability. N. Mex. Agric. Expt. Sta. Bull. 231.

Hackler, L.R., LaBelle, R.L., Steinkraus, K.H. and Hand, O.B. 1964. Effect of processing on the nutritional quality of pea beans. Seventh Res. Conf. on Dry Beans. Ithaca and Geneva, NY.

Harris, H.B. 1969. Bird resistance in sorghum. Annual Corn Res. Conf. Proc. 24th. Chicago, IL. p. 113.

Hoff, J.E. and Nelson, P.E. 1965. An investigation of accelerated water-uptake in dry pea beans. Indiana Agric. Expt. Sta. Res. Progress Rpt. 211.

Hosfield, G.L. and Uebersax, M.A. 1980. Variability in physiochemical properties and nutritional components of tropical and domestic dry bean germplasm. J. Amer. Soc. Hort. Sci. 105(2):246.

Jackson, G.M. and Varriano-Marston, E. 1981. Hard-to-cook phenomenon in beans: effects of accelerated storage on water absorption and cooking time. J. Food Sci. 46:799.

Junek, J.J., Sistrunk, W.A. and Neely, M.B. 1980. Influence of processing methodology on quality attributes of canned dry beans. J. Food Sci. 45:821.

Kon, S. 1968. Pectin substances of dry beans and their possible correlation with cooking time. J. Food Sci. 33:437.

Kon, S. 1979. Effect of soaking temperature on cooking and nutritional quality of beans. J. Food Sci. 44:1328.

Kon, S., Brown, A.H., Ohanneson, J.G. and Booth, A.N. 1973. Split peeled beans: preparation and some properties. J. Food Sci. 38:496.

Lai, C.C. and Varriano-Marston, E. 1979. Studies on the characteristics of black bean starch. J. Food Sci. 44:528.

Lang, K. 1970. Influence of cooking on foodstuffs. World Rev. of Nutrition and Diets 12:266.

Lee, B.J. 1979. Effects of processing factors on the quality characteristics of soaked and processed navy beans. Michigan State Univ. Masters Thesis, East Lansing.

Little, T.M. and Hills, F.J. 1972. Some basic concepts. In Statistical Methods in Agricultural Research. Agric. Ext., U. California, Berkley, CA. p. 13.

Luh, B.S., Mahmaud, K. and Schweigert, B.S. 1978. Thiamine, riboflavin, niacin, and color retention in canned small white and garbanzo beans as affected by sulfite treatment. J. Food Sci. 43:431.

Luh, B.S., Wang, C. and Daoud, H.W. 1975. Several factors affecting color, texture and drained weight of canned dry lima beans. J. Food Sci. 40:557.

Mattson, S. 1946. The cookability of yellow peas. Acta. Agr. Suecana II 2:185.

McCurdy, A.R., Leung, H.K. and Swanson, B.G. 1980. Moisture equilibration and measurement in dry pinto beans (Phaseolus vulgaris). J. Food Sci. 45:506.

Molina, M.R., Batew, M.A., Gomez-Brenes, R.A., King, K.W. and Bressani, R. 1976. Heat treatment: a process to control the development of the hard-to-cook phenomenon in black bean (Phaseolus vulgaris). J. Food Sci. 41:661.

Molina, M.R., DeLaFuente, G., and Bressani, R. 1975. Interrelationships between storage, soaking time, cooking time, nutritive value and other characteristics of the black bean (Phaseolus vulgaris.) J. Food Sci. 40:587.

Morris, H.J. 1963. Cooking qualities of dry beans. Sixth Annual Dry Bean Conf. January 2-4, Los Angeles, CA.

Morris, H.J. and Seifert, R.M. 1964. Constituents and treatments affecting cooking of dry beans. Seventh Annual Dry Bean Res. Conf. p. 42.

Muneta, P. 1964. The cooking time of dry beans after extended storage. Food Technol. 18:130.

Neely, M. and Sistrunk, W.A. 1979. Effect of type of bean, moisture level, blanch treatment and storage time on quality attributes and nutrient content of canned dry beans. J. Food Sci. 44(2):392.

Nordstrum, C.L. and Sistrunk, W.A. 1979. Effect of type of bean, moisture level, blanch treatment and storage time on quality attributes and nutrient content of canned dry beans. J. Food Sci. 42:795.

Ott, A.C. and Ball, C.D. 1943. Some components of the seed coats of the common bean, Phaseolus vulgaris, and their relation to water retention. Arch. Biochem. 3:189.

Powers, J.J., Pratt, D.E. and Joiner, J.B. 1961. Gelation of canned peas and pinto beans as influenced by processing conditions starch and pectic content. Food Technol. 15:41.

Powrie, W.D., Adams, M.W. and Pflug, I.J. 1960. Chemical, anatomical, and histochemical studies on the navy bean seed. Agron. J. 52:163.

Quast, D.C. and daSilva, S.D. 1977. Temperature dependence of the cooking rate of dry legumes. J. Food Sci. 42:370.

Quenzer, N.M., Huffman, V.L. and Burns, E.E. 1978. Some factors affecting pinto bean quality. J. Food Sci. 43:1059.

Reddy, N.R., Balakrishnan, C.V. and Salunkhe, D.K. 1978. Phytate, phosphorus and mineral changes during germination and cooking of black gram (Phaseolus mungo) seeds. J. Food Sci. 43:540.

Reeve, R.M. 1947. Relation of histological characteristics to texture in seedcoats of peas. Food Res. 12:10.

Rockland, L.B. 1963. Chemical and physical changes associated with processing of large, dry beans. Sixth Dry Bean Res. Conf. Los Angeles,CA.

Rockland, L.B. and Jones, F.T. 1974. Scanning electron microscope studies on dry beans: effects of cooking on the cellular structure of cotyledons in dehydrated large lima beans. J. Food Sci. 39:342.

Rockland, L.B. and Metzler, A.E. 1967. Quick-cooking lima and other dry beans. Food Technol. 21:345.

Rockland, L.B., Zaragosa, E.M. and Oracca-Tetteh, R. 1979. Quick cooking winged beans (Psophocarpus tetragonolobus). J. Food Sci. 44:1004.

Rockland, L.B., Zaragosa, E.M. and Hahn, D.M. 1974. New information on the chemical, physical and biological properties of dry beans. Proc. Rept. of Bean Improvement Coop. and Natl. Dry Bean Res. Assoc. Conf. Rochester, NY.

Sathe, S.K. and Salunkhe, D.K. 1981. Functional properties of the Great Northern (Phaseolus vulgaris L.): proteins---emulsion, foaming, viscosity and gelatin properties. J. Food Sci. 46:71.

Snauwaert, F. and Markakis, P. 1976. Effect of germination of gamma irradiation on the oligosaccharides of navy bean (Phaseolus vulgaris L.). Legersmitt Wissensch Technol. 9:2, p. 93.

Snyder, E.B. 1936. Some factors affecting the cooking quality of the peas and Great Northern types of dry beans. Nebraska Agric. Expt. Sta. Res. Bull. 85.

Tabekha, M.M. and Luh, B.S. 1980. Effect of germination, cooking, and canning on phosphorus and phytate retention in dry beans. J. Food Sci. 45:406.

Uebersax, M.A. 1972. Effects of storage and processing parameters on quality attributes of processed navy beans. Masters Thesis. Michigan State Univ., East Lansing.

Umadevi Sajjan, S. and Wankhede, D.B. 1981. Carbohydrate composition of winged bean (Psophocarpus tetragonolobus). J. Food Sci. 46:601.

Varriano-Marston, E. and Deomana, E. 1979. Effects of sodium salt solutions on the chemical composition and morphology of black beans (Phaseolus vulgaris). J. Food Sci. 44:531.

Voisey, P.W. 1973. Some measurements of baked bean texture. Contribution Engineering Res. Service, 7222. Ottawa, Canada.

vonMollendroff, A.W. and Priestley, R.J. 1979. Aspects of the hard-to-cook phenomenon in dry beans. 19th Supplement to South African Food Rev.

Zaragosa, E.M., Rockland, L.B. and Guadagni, D.G. 1977. Canned refried beans prepared from quick-cooking beans. J. Food Sci. 42:921.