SENSORY DESCRIPTIVE ANALYSIS OF GUATEMALAN BLACK BEANS, AND PREDICTION OF HEDONIC RATINGS USING MULTIPLE REGRESSION AND PRINCIPAL COMPONENT STATISTICAL ANALYSIS

by

Brenda Lissette Ríos-Sierra

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BY

BRENDA LISSETTE RIOS-SIERRA

A thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF SCIENCE

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ABSTRACT

Descriptive sensory analysis was carried out to identify and quantify the characteristics of appearance, flavor and texture of 22 samples of Guatemalan black beans. A 10-member trained panel identified 10 attributes as representative of the sensory properties of the bean samples. They were, darkness of color, degree of splitting, beany flavor, beany aftertaste, bitterness, cotyledon particle size, hardness, cohesiveness, seed coat toughness and chewiness. Storage time and conditions, type of bean and growing location were identified as factors affecting the sensory characteristics of the beans.

Significant sample effects ($p<0.001$), with F-values ranging from 9.25 to 40.84 were found for all the sensory attributes evaluated. Good discrimination among the samples was obtained based on the attributes selected by the panelists. Highly significant correlations ($p<0.001$) were found between beany flavor and beany aftertaste (0.84), as well as between cotyledon particle size and hardness (0.66), cohesiveness and hardness (-0.47) and cohesiveness and particle size (-0.58). Correlations ($p<0.001$) were also found between darkness of color and hardness (0.37), darkness of color and particle size (0.33) and darkness of color and chewiness (0.26). These four characteristics (darkness of color, hardness, particle size and chewiness)

were affected by storage conditions. Five components, which accounted for 90% of the variance among the samples, were extracted by Principal Component Analysis (PCA). Component one (cotyledon texture), component two (flavor), component three (seed coat), component four (color) and component five (bitterness) accounted for 24.9%, 18.7%, 13.9%, 11.8% and 10.3% of the variance, respectively.

Overall acceptability of the samples was determined by an in-house panel of 30 untrained judges. The samples stored for long periods under suboptimal conditions were significantly less acceptable ($p<0.05$) than all the other samples. Texture played a major role in determining acceptability. Highly significant negative correlations ($p<0.001$) were found between hedonic scores and hardness (-0.88), hedonic scores and particle size (-0.93) and hedonic scores and chewiness (-0.83). Cohesiveness and hedonic scores were positively correlated (0.91). Equations to predict hedonic ratings from attribute scores were developed using stepwise multiple regression and maximum R^2 procedures. Very good predictability was possible using scores for cotyledon particle size (X_1) and for chewiness (X_2). The predictive equation derived was:

Acceptability (hedonic rating)= $10.89 - (0.17)X1 - (0.22)X2$ with an r^2 of 0.91.

The prediction of hedonic ratings based on the five factors obtained from PCA was also performed. The equation including the five factors as predictors had an r^2 of 0.88, lower than the r^2 obtained with the equation including two sensory variables (chewiness and particle size). These results indicate that it should be possible to predict consumer acceptability on the basis of a limited number of attribute scores determined by a well trained sensory panel.

SUMARIO

Análisis cuantitativo descriptivo se llevó a cabo para identificar y cuantificar las características de apariencia, sabor y textura de 22 muestras de frijol negro cultivados en Guatemala. Un grupo de 10 panelistas entrenados, identificó 10 atributos como representativos de las propiedades sensoriales de las muestras de frijol. Estos atributos identificados son: oscuridad de color, proporción de granos reventados, sabor a frijol, sabor residual a frijol, sabor amargo, tamaño de partícula del cotiledón, dureza, cohesividad, dureza de cáscara y masticabilidad. El tiempo y las condiciones de almacenamiento, el tipo de frijol y la localidad de su producción fueron factores que afectaron las características sensoriales del frijol.

Se encontró un efecto significativo de muestras ($p<0.001$), con un valor F entre 9.25 y 40.84 para todos los atributos sensoriales evaluados. Se obtuvo una discriminación adecuada entre las muestras, en base a los atributos seleccionados por los panelistas. Se encontraron correlaciones altamente significativas ($p<0.001$) entre sabor a frijol y sabor residual a frijol (0.84) asi como entre tamaño de partícula del cotiledón y dureza (0.66), entre cohesividad y dureza (-0.47), y entre cohesividadd y tamaño de partícula (-0.58). También se encontraron correlaciones ($p<0.001$) entre oscuridad del color y dureza (0.37),

oscuridad del color y tamaño de partícula (0.33), y entre oscuridad del color y masticabilidad (0.26). Estas cuatro características (oscuridad del color, dureza, tamaño de particula y masticabilidad) fueron afectadas por las condiciones de almacenamiento. Cinco componentes, que contribuyeron con un 90% de la varianza entre las muestras, fueron obtenidos usando Análisis del Componente Principal (PCA). El primer componente (textura del cotiledón), el segundo componente (sabor), el tercer componente (cáscara), el cuarto componente (color) y el quinto componente (sabor amargo) contribuyeron con 24.9%, 18.7%, 13.9%, 11.8% y 10.3% de la varianza respectivamente.

La aceptabilidad general de las muestras se determinó usando un panel interno de 30 jueces sin entrenamiento. Las muestras almacenadas por períodos largos en condiciones subóptimas fueron significativamente menos aceptadas ($p<0.05$) que las otras muestras. Las características de textura fueron muy importantes para determinar aceptabilidad de las muestras. Se encontraron correlaciones negativas, altamente significativas ($p<0.001$) entre valores hedónicos y dureza (-0.88), valores hedónicos y tamaño de partícula (-0.93) y entre valores hedónicos y masticabilidad (-0.83). Se obtuvo correlación positiva entre valores hedónicos y cohesividad (0.91).

Se obtuvieron ecuaciones para predecir valores hedónicos en base a puntajes dados a características sensoriales, usando regresión múltiple con los procedimientos de paso a paso y de R^2 máximo. Buena predicción fue posible usando puntajes dados a tamaño de partícula del cotiledón (X1) y a masticabilidad (X2). La ecuación de predicción que se obtuvo es:

Aceptabilidad (valor hedónico) = 10.89 - (0.17)X1 - (0.22)X2

con un R^2 de 0.91.

La predicción de valores hedónicos en base a 5 factores obtenidos usando PCA también se llevo a cabo. La ecuación teniendo los 5 factores como predictores tiene un R^2 de 0.88, el cual es mas bajo que el R^2 obtenido cuando la ecuación incluyo 2 variables sensoriales (masticabilidad y tamaño de partícula). Estos resultados indican que es posible predecir aceptabilidad de frijol negro en base a un número limitado de punteos dados a atributos sensoriales por un panel bien entrenado.

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Thanks be to God! For through what
Christ has done, he has triumphed over us.

A Dios daré las gracias, el cual nos
lleva siempre en triunfo en Cristo Jesús.

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CHAPTER I

General Introduction

Grain legumes or pulses occupy an important place in the world nutrition and economy. Present world production is estimated to be 55 million metric tonnes per year (FAO, 1986). Beans account for about 25 percent of the total production of pulses (FAO, 1986). In Guatemala, annual production of beans is estimated to be 113,000 metric tonnes per year (FAO, 1986).

Beans, as well as other legume foods, predominate in the diets in Latin America. They constitute traditional food in the diets of subtropical and tropical areas (INCAP, 1969). The common dry bean, Phaseolus vulgaris, is the legume consumed in greatest quantity in the world as a whole. Beans are of particular importance in Central and South America where corn and beans are the most important staple foods consumed by the population.

In Guatemala, black beans are consumed by almost 95% of the population. They are high in protein (Bressani et al., 1961) as well as good sources of iron, calcium, magnesium, phosphorus, and B vitamins (Bressani et al., 1954, de Moraes and Angelucci, 1971). Since beans are one of the most significant food products for Guatemalans, availability and cooking quality of beans is very important. Decrease in the availability of this product, because of unacceptability among consumers, is high. Losses of beans from the time of harvest, due to insect infestation and deterioration due to improper storage, have been estimated at between 25 and 60% of the total production. Efforts to introduce new high-yielding varieties, some with better nutritional value, have often been unsuccessful because the improved lines have been rejected by consumers. This has occurred because little is known about consumers' criteria for acceptability. It is important to determine quantitatively the characteristics that consumers relate to good quality beans and to learn how those characteristics relate to acceptability. With this knowledge of consumers' requirements, varieties incorporating the desired characteristics could be developed.

The sensory attributes of beans have been evaluated both instrumentally and through the use of laboratory and consumer panels. Studies of consumers' preferences for various types of beans have also been carried out using questionnaire techniques, in which consumers stated their preferences and described the characteristics they liked and disliked about beans. However, none of these studies have quantitatively related the sensory attributes of beans to their perceived acceptability.

Better understanding of consumers' criteria for acceptability of beans would benefit agricultural production, breeding, post-harvest technology and nutrition programs. Research to define better methods to evaluate the quality of beans is presently being conducted by researchers in Canada as well as in many international centers around the world. The present project, sponsored by the International Development Research Centre, Ottawa, has among its objectives the development of methods for the assessment of consumer acceptability of beans in Guatemala. Knowledge of consumers' criteria would be particularly useful in research programs aimed at increasing the availability and consumption of beans throughout Central America.

The major purpose of this study was to use sensory characteristics to predict the acceptability (degree of liking) of samples of Guatemalan black beans, and to develop equations to use for this prediction.

Specific objectives of the study were:

1. To identify and quantify, using a trained laboratory panel, the sensory descriptors of appearance, flavour and texture of Guatemalan black bean samples using descriptive sensory analysis.
2. To examine the influence of storage, type of bean and growing location on the sensory characteristics.
3. To classify the sensory characteristics responsible for intersample variation into different components using principal component analysis.

4. To determine the overall acceptability (degree of liking) of 22 samples of beans using an in-house untrained panel.

5. To determine the most important sensory characteristics affecting acceptability (hedonic scores) of the samples by relating the results of the descriptive sensory analysis and the acceptability tests using multiple regression and principal component analysis.

CHAPTER II

REVIEW OF LITERATURE

In this chapter, factors that affect bean quality will be discussed and sensory studies that have been carried out to characterize and compare different types of common beans will be reviewed. The discussion of sensory methodology will focus on descriptive sensory analysis and methods used to determine acceptability or liking. Statistical methods to establish the relationship between sensory attributes and acceptability of food products will also be discussed.

2.1 TAXONOMY OF BLACK BEANS

The black bean is a variety belonging to the species _Phaseolus vulgaris_ L. It belongs to the genus _Phaseolus_ which includes all species known as "common bean". This genus belongs to the tribe _Phaseoleae_ and Family _Leguminoseae_ (CIAT, 1985). The region of its origin is possibly South America. Common beans are considered one of the most ancient crops of the world. They are the most important food legumes in Latin America and parts of Africa.

Phaseolus vulgaris is polymorphic. It shows great variation in vegetative characteristics, flower color, size, shape, color of pods and seeds (Kay, 1979). On the basis of growth form it can be classified as bush type or dwarf and vine type or climber. The bush type has strong stems; its height ranges from 30 to 50 cm. The blooming period is short and all the pods are ripe at the same time. The vine type or climber has a stem which grows more than two meters. It usually grows around a stick or another plant (CIAT, 1985). In Guatemala it grows around the corn plant. The blooming period is longer and the pods are not ready to be harvested at the same time (Kay, 1979).

In Guatemala, beans from these two growth forms and from some intermediate growth forms are cultivated. The principal growing regions are Chimaltenango (middle of the country), Jutiapa (east), and Peten (north). Generally, there are two harvest times in the year; one in August and one in November. Peten, however, presents a variation and beans are harvested in April (Garcia, 1988).

Most of the beans grown in Guatemala are "criollo" or native varieties that the farmers have saved from harvest to harvest. Improved varieties, introduced by the Institute of Agricultural Science and Technology (ICTA), are also grown by the farmers (CIAT, 1985).

2.2 FACTORS AFFECTING QUALITY OF BEANS

A number of agronomic and environmental factors have an influence on bean quality. Genetic variation, environmental, soil and handling factors related to growing location, storage conditions and duration of storage as well as chemical composition (moisture content, fat, protein, ash and phytic acid) are factors that affect the general quality and cookability of dry beans (Proctor, 1985).

2.2.1 Effect of Genetic Variation

Differences among cultivars of beans grown at one location and harvested and handled in an identical manner have been reported (Ghaderi et al., 1984; Proctor, 1985; Voisey and Larmond, 1971). Voisey and Larmond (1971) assessed the cooking time of four cultivars of navy beans. All samples were grown in the same location, treated in the same manner and tested when fresh. Several instrumental measurements of texture indicated that two of the samples cooked significantly faster than the others. Ghaderi et al. (1984) found a significant difference among cultivars of navy and pinto beans, grown in the same location, for seed weight, components of dry bean color, weight of soaked beans, texture and processed bean moisture. They reported that while genetic composition of the breeding lines and cultivars is a major determinant of quality, other factors such as environmental influences and processing procedures play important roles.

2.2.2 Effect of Growing Location

The effect of growing location is the result of the interaction of many variables, including seeding date, harvest date, soil type, climatic conditions, crop treatment, harvest conditions and post-harvest treatment (Proctor, 1985). Ghaderi et al. (1984) reported a highly significant effect of location when studying cultivars of navy and pinto bean (Phaseolus vulgaris L.) grown at three different locations in Michigan. Proctor and Watts (1987) compared the cookability of three cultivars of navy beans, Seafarer, Fleetwood and En Rico 23, grown at three locations in Manitoba. A significant effect of growing location was found which was greater than the effect of cultivar. These results were in agreement with the results of the studies of Quenzer et al. (1978) and Bhatty et al. (1983) who reported that differences in growing location of beans are likely to produce greater variability in cooking time than differences between cultivars.

2.2.3 Effect of Length and Conditions of Storage

Storage conditions play a major role in the problem of poor cookability of beans (Proctor, 1985). Prolonged storage and storage at high temperature and high moisture content have caused defects in the cookability of beans as well as in their sensory characteristics (Morris and Wood, 1956; Quast and DaSilva, 1977; Antunes and Sgarbieri, 1979; Jackson and Varriano-Marston, 1981; Moscoso, 1981; Hincks and Stanley, 1986; Hohlberg and Stanley, 1987). Jackson and Varriano-Marston (1981) reported that black beans (*Phaseolus vulgaris* L.) stored for 7 and 14 days at 41^{o}C and 100% RH required more cooking time than fresh beans and thus paralleled cooking times for beans stored for more than one year at room temperature. Hohlberg and Stanley (1987) stored black beans (*Phaseolus vulgaris*) for 10 months under three environmental conditions, high temperature/humidity (HTHH:30^{o}C,85%RH); medium temperature/humidity

(MTMH:25^{o}C,65%RH); low temperature/humidity (LTLH:15^{o}C,35%RH) in order to determine changes in physical characteristics, starch and protein and to assess their contribution to textural defects. The hardness of cooked beans, as measured by Instron and OTMS machines, was significantly different ($p<0.05$) among the three treatments after the third month of storage. HTHH, and to some extent MTMH, storage conditions promoted hardness in beans. The hardness values of beans stored under MTMH and HTHH were similar to those previously reported with the same type of beans under similar environmental conditions by Hincks and Stanley (1986). Hughes and Sandsted (1975) studied cookability and darkening in seed coat color of California Light Red Kidney beans stored at 1, 12 and 24^{o}C and 30 and 80% relative humidity for one year. The higher temperatures accelerated darkening of seed coat color. High relative humidity at 24^{o}C resulted in the darkest colored beans.

2.3 METHODS USED TO EVALUATE SENSORY CHARACTERISTICS OF FOOD

Sensory evaluation is a scientific discipline whose principles and methods have broad application over a wide range of products. A variety of test procedures are available for measuring product differences, perceived characteristics, quality and acceptability. There are four primary types of tests, and these may be classified as affective, discrimination, descriptive and quality tests (Sidel et al., 1980). Descriptive and affective methods, which have been used in the present study, are briefly described in the following sections.

2.3.1 Descriptive Analysis

Descriptive analysis is the process of describing the perceived sensory characteristics of a product. It is a sensory description, taking into account all sensations that are perceived - visual, olfactory, auditory, kinesthetic- when the product is evaluated (Stone and Sidel, 1985). Descriptive analysis is a valuable tool for providing information on appearance, aroma, flavor and/or texture of food products (Gillette, 1984).

In this technique, small groups of highly trained judges, who are thoroughly familiar with the product's sensory characteristics and who can accurately and precisely communicate their perceptions, develop adjectives to characterize the qualitative properties of the product (Pangborn, 1986). Under the guidance of an experienced leader, the group develops explicit terminology, with corresponding definitions. Judges convene in open discussion to generate and define terms and standardize test procedures (Gillette, 1984).

The training period is a very important step in descriptive analysis. Training optimises the chances of being able to characterize qualities consistently and of finding differences (Land and Shepherd, 1984). For accuracy and efficiency, the test product should be described with as precise and concise a list of adjectives as possible. To increase reliability, standards corresponding to each descriptor should be available during testing to anchor terms to known stimuli (Pangborn, 1986). It is important to define the terms to use for the evaluation.

The selection of panelists is made according to performance during participation in group sessions and according to ability to describe attributes of the test samples, reproducibly. Reliability and consistency are important for the selection of the panelists who will participate in the testing of the samples (Larson-Powers and Pangborn, 1978).

After the panelists have been selected and trained, the next step is to have them evaluate the samples. It is recommended that the analytical test be conducted in isolation, using separated booths to avoid distraction and socialization. In general, 4 or 5 samples are presented in each evaluation session. Land and Shepherd (1984) suggested that if too many samples are presented, the subjects will become fatigued, both in the physiological and sensory senses.

Replications of the evaluations are recommended for descriptive analysis. Stone et al. (1980) suggested that subject and panel reliability be monitored by evaluating replicated responses within each study, as an integral component of the data analysis. Schutz and Damrell (1974) reported the use of two replications in the descriptive analysis of the sensory characteristics of rice.

The intensity of each characteristic selected is evaluated in the different samples using unstructured or category scales. Unstructured scales have been widely used (Feria-Morales and Pangborn, 1983; Sanford et al., 1988; Piggott and Jardine, 1979; Dos Santos Garruti, 1981). This type of scale usually has verbal anchors at the ends and occasionally, also at the midpoint. The assessor is instructed to mark the line at a point appropriate to his perception. Category scales have also been used (Noble and Schmit, 1981).

2.3.1.1 Methods for descriptive analysis

The first and best-known method for descriptive flavor analysis is the "flavor profile" developed by the Arthur D. Little Co. Described in detail by Cairncross and Sjostrom (1950), the method has been reviewed by Cairncross (1978) and Miller (1978). Small groups of highly trained judges are used to evaluate aroma, flavor-by-mouth, feeling factors and aftertastes of products.

Modelled after the flavor profile, the texture profile was developed by General Foods Corporation (Civille and Szczesniak, 1973). The method consists of a detailed sensory analysis of the textural complex of foods in terms of mechanical, geometrical, fat and moisture characteristics.

Various investigators have modified or endeavoured to improve the descriptive methods to make them more applicable to particular uses or to overcome basic limitations (Cross et al., 1978; Larson-Powers and Pangborn, 1978; Schutz and Damrell, 1974).

Quantitative descriptive analysis is a statistical approach developed by the Tragon Corporation (Stone et al., 1984). Highly trained judges develop terms as a group, then assign intensities individually on a unstructured scale.

When appropriate, data from descriptive analysis panels can be analyzed statistically by use of common statistical methods (Gillette, 1984). Multivariate statistical treatment of data obtained from descriptive analysis is highly recommended (Pangborn, 1986). Applications of multivariate analyses of descriptive flavor and texture terms have been presented by Toda et al. (1971), Clapperton and Piggott (1979) and McLellan et al. (1984).

2.3.1.2 Application of descriptive analysis

Descriptive analysis methods have a wide range of applications. In product development, they provide a description of the selected product and/or competitive products. In storage testing, descriptive analysis, provides a basis on which changes can be evaluated. For process development, descriptive analysis describes the target product. Laboratory samples are compared to the target and the scaled-up product is monitored. In quality control, descriptive analysis could be used to identify the sensory limits for a product as well as to track long-term trends (Gillette, 1984). Descriptive analysis results provide a base for determining the sensory characteristics that are important to acceptance and also an aid in identifying underlying ingredients and process variables (Stone and Sidel, 1985).

2.3.2. Acceptance Tests

Acceptance and/or preference of food products are measured by affective sensory tests. Affective tests are sensory tests based on preference, pleasure - displeasure and like - dislike (Ellis, 1967). Affective tests use untrained panelists (consumers) selected to represent target or potential target populations (Anonymous, 1981). The use of laboratory acceptance tests and the measure of acceptance using hedonic scales will be described in the following sections.

2.3.2.1. Laboratory acceptance tests

In-house laboratory acceptance testing represents the most controlled environment in which to conduct acceptance tests. Within the laboratory testing area one can control a number of environmental variables (odor, light, temperature and humidity, etc.), a number of stimulus variables (serving temperature, portion size, etc.), and the degree of social interaction (isolation booths, group table settings, etc.). However, as it is the case with all laboratory research as compared with field research, realism is sacrificed for control (Meiselman, 1984). In-house testing normally utilizes laboratory personnel of the research organization.

Claims made in the literature vary regarding the number of panelists needed to measure acceptance or preference. Ellis (1967) considered that at least 24 consumers were required for small laboratory or pilot consumer studies. Abbot (1973) considers that at least 30 panelists should participate in rough product screening. Moskowitz (1983) stated that panel size can vary from 20 - 1000 panelists depending on availability and cost.

Some advantages of in-house panels are: the panelists are accessible; control can be exerted over product preparation, sample portion size, serving temperature, and time spent between presentation of samples. In-house panels are less costly than large scale consumer panels and need less time, because testing is done in the laboratory and many samples can be presented and evaluated in a short period of time. Use of in-house panels makes it possible to evaluate multiple prototypes prior to consumer testing.

Mixed views have been published on the difficulties of correlating in-house panels with large scale consumer tests (Ellis, 1967). Kiehl and Rhodes (1956) reported the effectiveness of a laboratory panel in predicting consumer panels results, when the acceptability of beef loin steaks were evaluated. Pearce (1980), found a high level of agreement between internal sensory panel and consumer panel using a hedonic scale for a food product evaluated during a two year period. Comparing the results of both tests, a correlation coefficient of 0.98 with an extremely high level of predictability was found. On the other hand, Pangborn and Dunkley (1964) found that laboratory panel judgments did not correspond well with consumer ratings of acceptability in the field. They concluded that the laboratory panel results agreed in direction but not in magnitude with consumer panel ratings. Calvin and Sather (1958) also reported that student laboratory panels and home consumer panels, carried out to evaluate the preference of different products, agreed in direction but not in magnitude.

According to Pearce (1980) several factors must be controlled to obtain consistency between internal acceptance testing and external consumer testing: it is necessary to have a consistent product for both laboratory and consumer tests; it is important to have consistent scaling techniques for both the internal and external testing; the judges participating in the internal and external panels must be representative of the target population. The test design for both in-house and large scale consumer tests must be compatible.

2.3.2.2. Methods of measuring food acceptance

The most common methods of measuring acceptance are ranking, paired comparison and rating scales (Peryam et al., 1960). Ranking methods are easily applied and interpreted (Peryam and Pilgrim, 1957). Paired comparison tests are widely used probably because of their simplicity.

Various rating scales have been developed for preference testing. The best known rating scale is the 9-point hedonic scale. This scale, developed by the Quartermaster Food and Container Institute (Peryam and Pilgrim, 1957) has been a major tool for measuring food acceptability. This scale comprises nine categories which range from "dislike extremely" to "like extremely" (Moskowitz and Sidel, 1971). Peryam and Pilgrim (1957) reported that the hedonic scale measured preference and acted as a predictive measure of acceptance, measuring the "pleasure" component of the "consumption with pleasure" of acceptance. Piggott, (1982) stated that acceptability can be measured in different ways and one of them is the degree of liking using hedonic scales.

Schutz et al. (1972), in a study relating carrot texture attributes to hedonic ratings, used a 42-member untrained consumer panel to rate degree of liking of carrot texture. A 7-point scale anchored at the ends with phrases "dislike a lot" and "like a lot" was used.

Advantages of the use of the hedonic scale to measure acceptance are: it is able to test more samples than paired comparison methods; it is a valid measuring instrument; it is easily explained to panelists (Horsfield and Taylor, 1976). The scale is easily used in statistical analysis such as analysis of variance and regression. It provides a measure of degree of liking which can be related to physical measures or sensory attribute intensity measures, to develop functional relationships (Moskowitz, 1983). Some disadvantages of the use of category scales (hedonic) are that categories may not be equal (Moskowitz and Sidel, 1971), and panelists may not use all points on the scale, avoiding end categories (Moskowitz, 1977).

2.4 SENSORY EVALUATION OF BEANS AND OTHER GRAIN LEGUMES

Sensory evaluation has been used only to a limited extent to determine and evaluate the sensory attributes of beans, and their perceived acceptability among consumers. Studies of black beans, which are especially limited, will be discussed first, then studies using other types of beans.

2.4.1 Studies on the Sensory Characteristics of Black Beans

Only a few studies dealing with the sensory characteristics of black beans (Phaseolus vulgaris L.) have been reported (Chan, 1988; Dos Santos Garruti and Dos Santos Garruti, 1983; Dos Santos Garruti, 1981). Those studies used descriptive analysis techniques to characterize the texture and flavor attributes of different varieties of Guatemalan and Brazilian black beans.

Dos Santos Garruti and Dos Santos Garruti (1983) used texture profile analysis to assess the textural properties of three varieties of common beans (Phaseolus vulgaris L.). Varieties Carioca, Aroana and Rosinha G2 were stored for six months under ambient conditions ($25 \pm 2^{o}C$) and 65-70% RH. Principal component analysis showed that 85.3% of the total variation among cooked samples was represented by the axis related to hardness and chewiness. Beans were harder and chewier after six months of storage at ambient conditions.

Dos Santos Garruti (1981) reported the use of quantitative descriptive analysis (QDA) to characterize the flavor of dry beans (Phaseolus vulgaris L.) of variety N40 grown in three different locations in Brazil. Seven trained panelists participated in development of flavor descriptors and in the evaluation of the samples. The flavor descriptors chosen were: natural, bitter, chemical, burnt, sour, insect, aftertaste and overall impression. Nine-cm unstructured line scales were used for the evaluation. Beans grown in the three different locations showed high intensity of natural flavor and intermediate intensity for chemical flavor and overall impression. The meaning of each of the descriptors used for the QDA was not well defined in this report. The terms "burnt" and "insect flavor" were not explained.

Six samples of Guatemalan black beans, stored under high temperature and high humidity conditions required longer cooking times, were more granular in texture and less acceptable overall, than the bean samples stored under low temperature and low humidity conditions (Chan, 1987).

2.4.2 Studies on Black Bean Acceptability

A survey aimed to obtain information about consumer practices in selection and utilization of black beans was carried out in Guatemala during July and August, 1985 (Watts, et al.,1987). Data on bean utilization and on factors influencing acceptability, were obtained from a cross-section of 600 Guatemalan consumers. Results of this survey refer specifically to the criteria and the methods used in judging quality, both in the raw and cooked beans. Consumers mentioned blackness, shininess, and softness as the principal characteristics that they looked for when assessing quality of raw beans. When consumers were asked about the principal characteristics of good quality cooked black beans, approximately 60% of the respondents mentioned high degree of splitting (broken in the middle), spreadability, doughiness, sponginess and softness, as most important.

Bressani and Elias (1979) stated that in Latin America, coloured beans are greatly preferred to white coated beans, by all populations. Seed-coat color is an important agronomic character determining the marketability of a dry bean variety in relation to geographic area. People in a location have a specific preference for a certain color

(Moh, 1971). Because of their seed-coat color, the cultivation of black beans is limited in many areas (Yglesias, 1964).

Silva et al. (1981) reported the evaluation of color, texture, flavor and overall acceptability of cooked black turtle soup beans (Phaseolus vulgaris L.), variety T-39. Samples were soaked in different media (distilled water, tap water, 0.5% sodium bicarbonate solution and a combination of four sodium solutions). They were canned and processed at 100 and 121^{o}C. Samples were evaluated by an in-house acceptability panel of 20 judges using a fully structured 9-point rating scale ranging from 1=excellent to 9=extremely poor. The results showed that all quality parameters improved as cooking time increased. The combined salt solution imparted a dark black color to the beans and maintained the integrity of the cooked beans. Those factors led to best sensory ratings for the salt combination solutions. The "overall acceptability" rating of cooked beans had the highest positive correlation with flavor (r=0.97), texture was next, with r=0.95.

2.4.3 Studies on the Sensory Characteristics of Different Types of Dry Beans

Because of the small number of reports in the literature regarding black beans, we will now refer to reports discussing sensory description and acceptability evaluation of other varieties of Phaseolus beans.

2.4.3.1 Analytical studies

A study to determine texture and flavor characteristics of different varieties of dry beans stored under different conditions was reported by Morris and Wood (1956). The samples were stored at 25^{o}C and they were adjusted to different moisture contents (3 to 16%). A trained panel rated hardness of cotyledon and presence of off flavor using 7-point category scales ranging from 7=soft cotyledon to 1=firm cotyledon and from 7=no off flavor to 1=much off flavor. Beans in the lower moisture range of 4 to 10% maintained their quality. Samples stored at the highest moisture content were rated as having the most firm cotyledon and the strongest off flavor.

Uebersax and Bedford (1980) reported the evaluation of texture, flavor and acceptability of navy beans (*Phaseolus vulgaris*) stored at 55, 70 and 85^{o}F under 75, 79, 86, 93 and 100% relative humidities. Ranking method and a category scale were used for texture evaluation. Bean firmness increased with increased relative humidity, storage time and temperature. Maximum firmness was found in beans stored for 84 days at 29^{o}C (85^{o}F) and 93 and 100% relative humidity. Flavor was evaluated by 16 panelists using a five point difference in flavor scale and a reference sample. The samples were evaluated in terms of "no difference" to "extreme flavor difference" from a reference sample. The reference beans possessed normal high quality flavor. The results indicated that as storage relative humidity increased, the flavor difference also increased. The samples stored at relative humidities of 93 to 100% had the greatest flavor differences. The definition of "normal high quality" flavor in beans was not given in this report.

Dos Santos Garruti and Bourne (1985) reported the use of texture profile analysis (TPA) to fully characterize the changes in textural properties of red kidney beans stored for six months under warm humid conditions (30 and 40^{o}C and 80% RH) and a control sample stored at 2^{o}C. All samples were canned, sealed and cooked for 30 minutes. The results indicated that after storage at 30 and 40^{o}C, the texture of cooked beans changed from a soft, moist, pasty, starchy type of texture into a hard, fracturable, lumpy, nonpasty dry texture similar to that of roasted peanuts. These last texture qualities are characteristic of undercooked beans. Hardness of beans stored at 2^{o}C (control) showed no change during storage for six months. Because the samples were all cooked for the same period of time, the beans stored under warm humid conditions were probably not cooked to their optimum degree of softness. Differences among the samples could have been a result of inadequate cooking of some of the stored material.

Duran and Calvo (1986) reported the use of descriptive sensory analysis to describe the sensory parameters of 14 samples of navy beans. A trained panel of eight judges was used. The attributes under evaluation were: color, integrity, hardness, skin consistency, graininess, adhesiveness, flavor intensity and off flavor. Unstructured line scales with end point descriptors were used for this evaluation. Acceptability of the 14 samples was determined by an in-house untrained panel of 60 people using a 9-point hedonic scale ranging to 9=extremely like to 1=extremely dislike. The relationship between trained panel scores and acceptability showed that the parameters that best defined the quality of the canned beans were hardness, skin consistency, graininess, adhesiveness, flavor intensity and off-flavor.

Koehler et al. (1987) used descriptive analysis to characterize the sensory attributes of nine commercially released cultivars of beans. Ten trained judges evaluated the samples for aroma, taste and texture using modified quantitative descriptive analysis plus a rating scale for overall acceptability. The aroma characteristics evaluated were: fragrant, fruity, beany, green, musty, rubbery, rich, browned and nutty; and the taste characteristics were: sweet, beany, brothy, "green vegetable", acid, sharp, astringent, "old rubber" and musty. For texture the characteristics were: seed coat toughness, cotyledon hardness, graininess, mealiness, seed coat residual and cotyledon residual. Larger amounts of each of these textural characteristics are considered undesirable in beans.

In the Koehler study, the results of the relation between sensory attributes and acceptability showed that the most acceptable beans had sweet, nutty and rubbery tastes and were lacking in undesirable texture characteristics. The least acceptable samples, on the other hand, were judged to have green, astringent and hay-like flavor characteristics. The firmest beans (least acceptable) were judged to have tough seed coat, grainy cotyledons and seed coat and cotyledon residues. In this study, the evaluation of acceptability was performed by a trained panel, a practice that is not recommended because the responses of trained panelists might be biased by their sensory experience, and they are therefore not representative of a consumers population (Schutz,1988). The same answers might not be obtained from an untrained in-house panel or a true consumer panel.

Adams and Bedford (1975) stated that for evaluating quality of cooked legume seeds, evaluations of wholeness, consistency, flavor, color and texture should be made. They mentioned firmness, gumminess and adhesiveness as the textural parameters of beans.

Hinchcliffe et al. (1977) used a group of seven trained panelists and a semistructured line scale to judge the flavor characteristics on fababean flour (Vicia faba minor). This panel identified dried pea flavor and bitter aftertaste as the dominant flavor characteristics. The presence of nutty flavor and some bitterness in fababean flours was mentioned by Vaisey et al. (1974).

2.4.4 Studies on the Acceptability of Different Types of Dry Beans

Several studies using questionnaire techniques to establish parameters that influence and determine consumers' acceptability of beans have been reported by the International Centre for Tropical Agriculture (CIAT) in Cali Colombia (van Herpen, 1983; van Herpen, 1984). In 1983 a survey consisting of sixteen interviews was held among middle/low class housewives in Cali, Colombia to learn about their preferences for bean varieties and their attitudes towards bean characteristics (van Herpen, 1983). The results showed that consumers in Cali preferred red mottled beans, big cream mottled beans and big/medium red beans. Important characteristics influencing the decision to buy beans were broth quality, seed color and freshness of the seeds. Characteristics which were not important for 50% of the sample but were important for the other 50% were: price, water absorption, seed size, shape and tenderness.

The methodology used in the above survey was improved and tested in a second survey carried out among 27 housewives in Medellin, Colombia in 1984 (van Herpen, 1984). Objectives of this survey were to understand the importance of the different characteristics in the decision of the consumer to buy a specific bean variety, and to identify the concrete preferences towards these bean characteristics. Strong preference for large round beans existed. The most important characteristics taken into account when buying beans were: seed size, freshness, broth color and seed coat thickness. In relation to seed color, all black and coffee colored beans were strongly disliked by the entire population. Because of the small sample size, these results may not be representative of the entire population of middle/low income house-wives in these cities.

Some studies had been reported using trained panels to evaluate acceptability in bean samples. Quenzer et al. (1978) reported the use of a trained panel of nine members to score acceptability of color, flavor, texture and appearance aside from color of three cultivars of pinto beans. In relation to color, the medium reddish brown beans were the most preferred. Texture evaluation showed that a tender bean without noticeable seed coats was preferred. In flavor, the panelists preferred a mild, distinguishable flavor. The samples of whole, plump beans received the highest hedonic scores for appearance.

2.5 RELATING SENSORY DESCRIPTIVE AND ACCEPTABILITY DATA

Until recently, few studies had been published relating the sensory parameters of a food product to its perceived acceptability (Horsfield and Taylor, 1976). The ability to relate the sensory characteristics of an agricultural product to its palability or hedonic value would be useful in the development of new varieties, improvement of the present product, and development of more meaningful quality control procedures (Schutz and Damrell, 1974). To achieve products that have optimal sensory acceptance, the sensory properties important to consumer acceptance must be identified (Schutz, 1983).

Correlation and multiple regression techniques have been used to relate sensory descriptive data to consumer affective responses (Schutz, 1988). The basic principle is that for a group of samples, a model of the relationship between one regressand variable (dependent variable, eg. hedonic response) and several regressor variables (independent variables, eg. sensory attributes) be established.

Sanford et al. (1988) used regression techniques to relate trained panel attribute characteristics to consumer acceptance of 15 samples of frozen peas. A trained sensory panel, using descriptive analysis, selected 15 descriptive sensory attributes to describe and quantify differences in frozen peas. An in-house panel of 76 members evaluated the samples for overall acceptability. Principal component analysis (PCA) indicated that the 15 descriptive attributes could be reduced to five uncorrelated sensory dimensions which could be used in multiple regression. The five dimensions produced from PCA were related to consumer ratings for overall sensory acceptance of frozen peas. This approach was taken because the individual sensory attributes were too highly intercorrelated to provide stable estimates of regression coefficients. By including the five factor scores in the regression equation, the coefficient of determination (R^2) was 0.83, indicating that the model accounted for 83% of the variation in sensory acceptance. The authors concluded that the model was useful for predicting sensory acceptance of frozen peas, but that cross validation and more testing was necessary.

Schutz and Damrell (1974) used correlation and stepwise multiple regression analysis to relate 15 sensory attributes,obtained from descriptive analysis to hedonic scores of cooked rice. Based on the multiple regression results, the first prediction equation included 13 of the 15 sensory attributes as predictors. The high coefficient of determination (0.94) indicated that 94% of the variability of the average hedonic ratings could be accounted for by the 13 sensory characteristics. They recognized that 13 variables for prediction is a large number to utilize in practice. In order to provide a smaller number of variables for prediction, the regression program was stopped after including five variables. Schutz and Damrell (1974) concluded that the high multiple R (0.90) with only five variables indicated that this regression equation could be used with reasonable confidence in predicting rice hedonic value as measured in this study. However, validation must be carried out with different groups of consumers to determine if the results obtained were similar.

Schutz and associates (1972) reported a study relating carrot texture descriptive attributes to an in-house panel degree of liking scores. A regression equation using flexibility, hardness and chewiness was found to predict 88% of the variability in the average hedonic ratings.

According to the literature reviewed, no studies relating sensory attributes to the acceptability of black beans have been reported.

2.6 MULTIVARIATE ANALYSIS METHODS

Multivariate analysis can aid us to understand the underlying properties that are measured in sensory research. According to Powers (1981), the objectives of multivariate analysis are:

1. Differentiate among products or treatments, evaluate the performance of judges, or effect of other differentiations.
2. Classify various materials or attributes, brands, treatments or panelist's responses.
3. Predict sensory quality.

2.6.1. Principal Component (PCA) and Factor Analysis

The function of PCA is to reduce a set of individual items into components such that the first component has maximum correlation with all the variables and accounts for the greatest amount of variance, the second for the second largest amount, etc., until as much of the variance has been accounted for as is reasonable (Powers, 1984). There are many illustrations of the use of PCA in the literature: Piggott and Jardine (1979), classification of whiskies; Horsfield and Taylor (1976), classification of sensory descriptors for meat; Novais et al., (1982), classification of texture characteristics of mashed potatoes.

Factor analysis is also a data reduction process but it differs from PCA in that not only does it permit reduction of a set of variables to a lesser number of factors (Powers, 1984), but it also attempts to account for the variance of each attribute by partitioning its variance among the factors. It is looked upon as a means of detecting underlying structure or order among variables, which might otherwise seem to have no elements in common. The objective of factor analysis is to find a relatively small number of factors which together can replace the original variables which were measured in the experiment (Powers, 1984; Ennis et al., 1982). While a correlation analysis identifies existing correlations, factor analysis suggests that members of the same factor have certain elements in common (Stungis, 1976).

2.6.2 Multiple Regression Analysis

In a situation where a single metric dependent variable is to be related to a set of independent variables, multiple regression analysis should be used (Stungis, 1976). The method investigates the dependence of one variable y on several others x1,.....,xp. The usual procedure involves the determination of coefficients bo, b1,....., bp in the regression equation

$$y = bo + b1\ x1 + \ldots + bp\ xp.$$

It is possible to obtain the coefficients by the application of matrix algebra to the solution of a system of p simultaneous equations to give the best fit using all the variables (Powers, 1984). It usually happens that a fit which is almost as good can be obtained using fewer variables, and it is of interest to know which are the most important variables in the regression (Draper and Smith, 1981). Stepwise regression is usually performed, as follows: the first x-variable to enter the regression is that one which gives the best fit for the simple regression of y on a single variable, the next to enter is that one which gives the best improvement to the fit, and so on. A "stopping criterion" is specified so that if the degree of improvement or reduction in the error variance is less than a certain amount no more variables will be entered (Powers, 1981; Powers, 1984).

Among the possible applications of regression in

Among the possible applications of regression in sensory evaluation are: relationship between sensory ratings and instrument readings; prediction of consumer acceptance based on internal panel results; relationship between product characteristics and acceptance; relationship between process characteristics and acceptance (Korth, 1982).

The use of multiple regression analysis to predict acceptance based on sensory characteristics has been reported (Schutz et al., 1972; Schutz and Damrell, 1974; Sanford, 1988; Horsfield and Taylor, 1976). Researchers have shown that the relationship between hedonic measures and attribute intensity measures are not always linear. Two approaches to nonlinear relationships have been taken. Moskowitz (1984) uses quadratic equations to fit nonlinear variables in models. Martens et al.(1983), contends that whenever possible the approach should be to transform variables to make them linear prior to fitting the model. If good predictability is obtained using linear models, it is better to use them than the quadratic equations. Linear relationships are considered desirable as they are easy to understand, use and explain (Schutz, 1988).

CHAPTER III

MATERIALS AND METHODS

3.1 BEAN SAMPLES

Twenty-seven samples of Guatemalan black beans (*Phaseolus vulgaris*) were obtained from growers, and from mixed lots that had been stored at the Institute of Nutrition of Central America and Panama (INCAP) after having been purchased from the government storage system (INDECA). Different types (bush and vine) and varieties of black beans, from various growing locations were chosen. Native varieties (criollos) and improved varieties introduced by the Institute of Agricultural Science and Technology (ICTA) were included. Beans differing in physical characteristics and beans which had been stored for various lengths of time under different conditions were selected to provide a wide range of samples with differing sensory characteristics. Beans commonly considered by Guatemalan consumers to be good quality beans and beans considered to have bad quality characteristics were also included. Details on the collection, selection and storage methods will be given in the following sections.

3.1.1. Collection and Selection

The majority of the beans were collected from growers in five different areas which represented the range of growing conditions existing in Guatemala. These 5 areas were: Chimaltenango, an area in the middle of the country with an altitude of 1600 m, Jutiapa and Jalapa, regions in the east of the country with an altitude of 1000 m or less, Peten, a region in the north of the country with an altitude of approximate 600 m, and Suchitepequez, an area in the south of the country with an altitude of 1000 m or less (Garcia, 1988).

At the time of purchase each farmer was interviewed by the researcher to obtain general information about sowing, harvesting, drying and storage of the different samples. The questionnaire form used is shown in Appendix 1.

Based on the results of a preliminary in-house acceptability test, sensory characteristics, availability and agronomical background, 22 samples were selected for evaluation in the descriptive analysis test (section 3.5.2) and the acceptability test (section 3.5.3). The 22 samples are listed in Table 3.1. Each sample has been identified with a name that includes the type of bean, a letter (A to Q) and an indication of the seed origin. The common name (given by the producer) of each variety is also included in this table. Eighteen of these 22 samples were of the bush type and 4 were vine, 13 were native samples (criollos) and 9 were improved varieties introduced by ICTA. Twenty of the samples were harvested between August 1986 and February 1987 (fresh samples); the other two samples (bush P and Q) were harvested in 1981. Bush L, was chosen to be the reference sample for the descriptive analysis. This sample had a

Table 3.1 - Description of samples

Sample identification	Growing location	Type of variety	Common name	Harvest date (mon/year)	Storage Temperature (°C)[a]
Bush A	Jutiapa	Criollo	Cuarenteno	Jan/87	4
Bush B	Jutiapa	Criollo	Rabia de gato	Aug/86	4
Bush C	Jutiapa	Criollo	Sesenteno	Dec/86	4
Bush D	Jutiapa	Criollo	Vaina morada	Nov/86	4
Bush E	Jutiapa	Improved	Tamazulapa	Nov/86	4
Bush F	Jutiapa	Improved	Quetzal	Sept/86	4
Bush G	Jutiapa	Improved	Suchitan	Sept/86	4
Bush H	Jutiapa	Improved	Quetzal	Nov/86	4
Bush I	Jutiapa	Criollo	Pata de zope	Nov/86	4
Bush J_1	Jutiapa	Improved	Ostua	Dec/86	4
Bush J_2	Jutiapa	Improved	Ostua	Dec/86	34
Bush K	Chimaltenango	Criollo	Itzapa	Jan/87	4
Bush L	Chimaltenango	Criollo	Parramos	Dec/86	4
Bush M	Peten	Criollo	Pinteno	Feb/87	34
Bush N	Jalapa	Criollo	Sn. Pedro Pinula	Dec/86	4
Bush O	Suchitepequez	Improved	Tamazulapa	Nov/86	18-26
Bush P	Unknown	Unknown	Nacional	1981	18-26
Bush Q	Unknown	Improved	Tamazulapa	1981	18-26
Vine A	Chimaltenango	Criollo	Itzapa	Jan/87	4
Vine B_1	Chimaltenango	Criollo	Parramos	Jan/87	4
Vine C	Chimaltenango	Criollo	Itzapa	Jan/87	4
Vine B_2	Chimaltenango	Criollo	Parramos	Jan/87	34

[a] all samples were stored under ambient conditions until they were collected in January and were placed in storage at the temperatures indicated above.

known genetic and agronomical background and intermediate acceptability among consumers. It served as a reference point against which all the other samples were compared in the evaluation of each sensory characteristic during the subsequent descriptive sensory analysis (section 3.5.2). Bush A, was chosen as the blind control. This sample was present in all sessions of the descriptive sensory analysis and the final acceptability test, as a measure of consistency among judges.

In this study we will refer to the 20 samples evaluated during the sensory testing as the experimental samples. The reference and the blind control samples are not included in this group of experimental samples.

3.1.2 Storage and Handling

An average of 15 kg of each sample of beans was obtained. The beans were cleaned by hand to remove small stones, insects and damaged seeds. An insect problem was noted in three samples (Bush N, Bush J and Vine B) and these samples were exposed to an isolation treatment to remove the insects. This treatment was ineffective and a fumigant (phostoxin) was applied to those 3 samples for 24 h.

Each sample of beans was divided into three equal lots of 5 kg each. Each lot was placed in a sealed polyethylene bag. The 22 bean samples were stored under three different storage conditions as listed in Table 3.1.

Fourteen experimental samples, the reference and the blind control were stored under optimum conditions at 4°C. Three additional experimental samples, bush O, which was harvested in 1986, and bush P and Q which were harvested in 1981, continue their storage at room temperature (18-26°C). The three other samples (Bush J_2, M and Vine B_2) were stored under accelerated conditions (34°C and 65% RH). Two of them (Bush J_2 and Vine B_2 samples) were duplicates of two samples stored at 4°C. To avoid moisture loss of the samples during accelerated storage, each lot of beans was kept in three layered sealed polyethylene bags. Each bag was 0.07 mm thick. Moisture measurements were taken periodically throughout the entire storage period. The samples were kept under accelerated storage for a period of 14 weeks.

3.2 MOISTURE ADJUSTMENT AND MEASUREMENT

The three accelerated storage samples were adjusted to an initial moisture content of 14 to 16% while the other samples had moisture contents between 11 and 13%. The water content of some samples needed to be increased, to reach the desired moisture content. They were placed on damp newspaper in a warm oven (20°C) for 2-4 hours, mixing them occasionally with distilled water from an atomizer. To reduce the water content, beans were placed out of doors, on newspapers, under the sun for 2-3 hours until the required moisture content was reached. Moisture content was estimated using the Dole 400 Moisture Tester for grains.

Three readings of each sample were taken using thirty grams of beans for each reading. An average of the three readings, recorded as percent moisture, was taken to be representative of each sample. All samples were measured for moisture content before their storage. The moisture content of the samples kept under accelerated conditions was measured before storage, but also throughout the storage period and at the end of it, before the sensory evaluation.

3.3 PHYSICAL CHARACTERISTICS

The physical tests carried out on raw bean samples were seed weight, percent seed coat and 4h water absorption. These determinations were conducted according to INCAP standard methods (Appendix 2). Measurements were made on the samples immediately after collection, except for the samples under accelerated storage conditions which were tested after completion of the storage period.

3.4 DETERMINATION OF OPTIMUM COOKING TIME

Three different tests and criteria were used to determine the optimum cooking time for each of the 22 samples. The tests included:

1. Ottawa Texture Measurement System (OTMS) measurements of the hardness of cooked bean samples.
2. Tactile texture assessment of the softness, smoothness and spreadability of cooked bean cotyledons.

3. Visual assessment of the percent of split beans in a sample of 25 cooked beans.

3.4.1 Sample Preparation

To determine the optimum cooking time for each bean sample, beans were initially cooked to 6 different cooking times. The range of cooking times differed for each sample, but for most varied from 90 to 300 minutes.

Six 60g subsamples were randomly taken from each of the 22 samples of beans, to allow enough sample for all the testing. Subsamples were rinsed with tap water, drained on a metal sieve for 2 min, and put into a 2 L pyrex pot with 300 ml of distilled water (5:1 ratio of water:beans). Pots were randomly assigned to either an electric or a gas stove, covered and heated at high power until the water began to boil. Then, the heat was reduced such that the samples boiled gently throughout the pre-established cooking period. This reduced temperature setting was determined and standardized for each stove at the beginning of the study. At the end of the cooking time, samples were drained on a metal sieve for 2 min and allowed to cool in an appropriately coded 250 ml plastic cup. Samples were covered with a tight fitting lid to prevent moisture loss. Samples were kept at room temperature for 1.5 to 2 h before the OTMS, visual and tactile tests.

3.4.2 OTMS Cooking Curves

An OTMS connected to an Apple computer was used to measure the hardness of cooked bean samples. The OTMS was equipped with a 10 cm2 OTMS wire extrusion cell with 8 parallel wires. The Texture Data Acquisition and Analysis computer program (Agriculture Canada, 1986) was set with the force transducer equal to 90 kg, expected test time to 90 sec, expected maximum force to 90 kg and crosshead speed to 6.6 cm/min (Sefa-dedeh et al.,1978). The plunger of the test cell was adjusted to travel downward until the base of the plunger stopped 3 mm above the wire grid. The system was calibrated using 0.5 and 1.0 kg metal weights. A 30g sample of cooked beans was placed in the extrusion cell for each test, and the peak force (N) to extrude was recorded. Each test was replicated immediately and when the duplicate values differed by more than 50 N, a third test of the same sample was done.

The mean peak force values (N) were plotted against cooking time. The criterion for doneness for each sample was chosen as the lowest peak force value in the curve. This value was different for each sample because the samples were not of equal hardness when the lowest peak force was reached.

3.4.3 Visual Assessment of Percent Split Beans in Cooked Samples

Each time a sample was taken for testing in the OTMS a count of the number of split beans in a sample of 25 beans was also done by three assessors. Mean values were taken over the three evaluations. The criterion of doneness for this test was that 80 to 100% of the beans should be split. For hardened beans which never reached the 80% split point, the criterion for doneness was chosen as the time when the highest percentage of split beans was reached.

3.4.4 Tactile Texture Assessment

A tactile assessment of the softness, smoothness and spreadability of the cotyledon was also carried out. The criterion for doneness, according to this test, was that the beans should be soft, smooth, and spread easily, but not be mushy, under moderate pressure with the first finger and the thumb. Ten beans from each sample were tested, by three experienced evaluators.

The optimum cooking time for each sample was determined using the results of these three tests in a sequential manner. Ideally samples would be optimally cooked when they reached the lowest point in the OTMS curve and they were soft and smooth with 80 to 100% split.

The sequence used to decide the optimum cooking time was as follows. The first criterion used was the value of the lowest peak in the OTMS curve. If samples reached the lowest point in the OTMS curve, but according to the tactile assessment they were either undercooked (granular) or overcooked (watery and mushy), the optimum cooking time was chosen according to the criterion from the tactile assessment, which considered samples optimally cooked when they were soft and smooth. If samples reached the lowest point in the OTMS curve and, according to the tactile assessment the cotyledon, remained granular, the cooking time was chosen when the highest degree of splitting was obtained.

3.5 SENSORY TESTING

Three different sensory tests were used in the evaluation of the 22 samples of beans. A preliminary acceptability test was used for sample selection. Descriptive sensory analysis was used to identify and describe the sensory attributes of the samples. A final acceptability test was used to determine overall acceptability of the samples. The methodology used for these tests will be discussed in the following sections.

3.5.1 Acceptability Test for Sample Selection

A preliminary acceptability test was conducted at the beginning of the study to determine acceptability ratings and the range of variability among the 24 samples collected (not including 3 samples under accelerated storage, which were not available at that time).

3.5.1.1 Experimental design

Twenty-four samples of black beans were evaluated for overall acceptability and acceptability of appearance, texture and flavor by an untrained panel of 28 judges, who were regular consumers of beans. Thirteen of the 28 judges were present in all 7 sessions. A completely balanced block design was used to decide the order and position assignments of the samples in the sessions. Five samples (4 experimental and a hidden control) were presented in each session. Nine-point hedonic scales were used for this evaluation.

3.5.1.2 Sample preparation

For each panel session, two 125g portions of each bean sample to be evaluated were cooked. Each 125g portion was placed in a 2 L pyrex pot and 625 ml of distilled water added. The level of water was kept constant throughout the cooking period by the addition of boiling distilled water. Samples were heated on electric or gas stoves until they reached the optimum cooking time, which was calculated previously (section 3.4). The starting time for each pot of beans was staggered so that all 5 samples reached the completion of their cooking periods at the same time (10 min before the panel session). Approximately half of the broth was drained from the cooked beans using a metal sieve. The pots with the beans and half the broth were placed on warming trays to keep them warm (60^{o}C) for up to 1h to cover the entire panel session.

3.5.1.3 Test description

Preliminary information sessions were held to inform participants about the nature of the study and the time commitments required. The measurement scale, the terms to be used and the task to be performed were described, however, no information about the specific samples or their sensory characteristics was given.

Nine-point hedonic scales, ranging from 1=like extremely to 9=dislike extremely, were used to determine the overall acceptability and acceptability of the appearance, flavor and texture of the samples. The ballot is shown in English in Figure 3.1 and in Spanish in Appendix 3. Seven panel sessions were necessary to present the 24 bean samples to the panelists. The hidden control sample was present in all sessions as a measure of consistency among the panelists. A criollo sample (Santa Rosita) was chosen to be this control and it was different from the blind control used in the descriptive analysis and the final acceptability test.

Samples were evaluated for acceptability of appearance, flavor and texture and for overall acceptability. To evaluate appearance, 25 beans from each sample were placed in plastic petri dishes and covered. Four sets of the five bean samples were prepared for each session and placed in four different stations in the preparation area, under direct fluorescent illumination. For evaluation of flavor and texture acceptability, 15 to 20 beans of each sample were placed in coded 30 ml styrofoam cups. Each set of 5 samples was placed inside a tortillera (styrofoam tortilla container) with a tight fitting styrofoam lid. Evaluation

Name:

Date:

Evaluation of the Acceptability of Black Bean Varieties

There are 5 samples of black beans. Please evalute them in the order shown on the ballot. Look at and taste the samples and indicate how much you like or dislike the samples by checking the descriptive phrase you consider most appropriate, for each sample.

Code	Code	Code	Code	Code
---Like extremely	---Like extremely	---Like extremely	---Like extremely	---Like extremely
---Like very much	---Like very much	---Like very much	---Like very much	---Like very much
---Like moderately	---Like moderately	---Like moderately	---Like moderately	---Like moderately
---Like slightly	---Like slightly	---Like slightly	---Like slightly	---Like slightly
---Neither like nor dislike	---Neither like nor dislike	---Neither like nor dislike	---Neither like nor dislike	---Neither like nor dislike
---Dislike slightly	---Dislike slightly	---Dislike slightly	---Dislike slightly	---Dislike slightl
---Dislike moderately	---Dislike moderately	---Dislike moderately	---Dislike moderately	---Dislike moderately
---Dislike very much	---Dislike very much	---Dislike very much	---Dislike very much	---Dislike very much
---Dislike extremely	---Dislike extremely	---Dislike extremely	---Dislike extremely	---Dislike extremely
<u>Comments</u>	<u>Comments</u>	<u>Comments</u>	<u>Comments</u>	<u>Comments</u>

Fig. 3.1 - 9-Point Hedonic Scale Sample Ballot for Cooked Black Bean Varieties

of flavor and texture was conducted in individual booths under incandescent light.

The panel sessions were held three times a week. Panelists attended the sessions in groups of five, every 20 min. Prior to each session, panelists were advised to read the general instructions posted at the entrance of the laboratory. Panelists evaluated the characteristic of appearance first. With the set of five samples in front of him/her, they were asked to shake each dish, open it and evaluate their degree of liking of the appearance of each sample. After the evaluation of appearance, judges evaluated the flavor, texture and overall acceptability of the samples. Flavor acceptability was evaluated first, texture acceptability second and then the overall acceptability. The average time required to complete each panel session was 30 min.

3.5.2 Descriptive Analysis of Samples

Descriptive sensory analysis was used to identify, describe and quantify the characteristics of appearance, flavor and texture of 22 black bean samples.

3.5.2.1 Experimental design

Twenty different experimental samples and a blind control were evaluated using sensory descriptive analysis. A reference sample was also included. Ten sensory characteristics, representing the appearance, flavor and texture of the samples, were evaluated by a trained panel of ten judges using unstructured line scales. Five samples (three experimental, the blind control and the reference) were presented to the panelists in each session. The serving order was predetermined before the trials using a partially balanced incomplete block design to make the session and position assignments. Fifteen sessions were needed to present all of the samples to the ten judges two or three times.

3.5.2.2 Panel training and procedure

A group of 25 people (students and staff from INCAP) were screened as potential panelists. They were individually interviewed to establish their interest and availability. Forms requesting information about health conditions, sensory perception, food habits and interest in sensory evaluation were completed by each potential panelist. During screening, basic taste, odor recognition and texture evaluation tests were carried out.

For the basic taste test, solutions containing the four basic tastes and blank solutions were presented to the potential panelists. They were asked to identify the flavor in each solution. The solutions were sucrose .031M (sweetness), sodium chloride 0.034M (saltiness), citric acid 0.003M (sourness) and caffeine 0.003M (bitterness). For odor identification, a set of 10 samples of solutions and spices of common odor were presented to the judges. They were asked to sniff each sample and identify the substance.

The substances used were: powdered coffee, vanilla, cloves, cinnamon, olive oil, anis, lemon extract, vinegar, almond extract and garlic powder.

The last screening test was the texture evaluation test. Judges were asked to rank a series of products according to hardness using products on the standard hardness scale developed by Szczesniak (1963). The products, presented in a random order, were: cream cheese, egg white, wiener, cheddar cheese, olive, peanut, carrot, almond and rock candy.

Ten judges were selected and trained to participate in the sensory descriptive analysis of the bean samples. They were members of INCAP staff or students, four females and six males, ranging from 21 to 38 years of age. This group was selected based on sensory acuity (results from the screening tests), interest and availability to participate.

At the first training session, panelists were informed about the purpose and objectives of the study and of the importance of their participation. A general description of the product under evaluation and the involvement of the panelists was provided. A time schedule suitable for each panelist was set and questions answered.

Initially panelists evaluated samples which possessed different sensory characteristics. These samples were bush N, E, B, L and H for one session and bush P, O, G, J, and vine C for the other session. Under the guidance of the panel leader (the researcher), the judges developed explicit terminology to describe the appearance, texture and flavor characteristics of the bean samples. Round table discussions were held to explain redundancy, similarities or ambiguities of the terms used by each one of the evaluators. At the end of each training session, descriptors were defined, definitions were established and recommendations were made about products that could be used as reference standards for each descriptor.

The terms the panelists agreed upon as the most meaningful in describing the bean characteristics of interest were: darkness of color, degree of splitting, hardness, particle size, cohesiveness, chewiness, seed coat toughness, bitterness, beany flavor and beany aftertaste. After the descriptors were decided, the ballot to be used in the descriptive sensory method was designed. The ballot consisted of 15 cm unstructured line scales, one for each characteristic under evaluation. The line scales were labelled with none or weak presence of the attribute at the left end point of the scale, and with strong or extreme presence of the attribute at the right end point of the scale. The end points of the scales were demonstrated using reference standards which were provided to the panelists. The end point standards used during the training period are listed in Appendix 4.

As a part of the training, panelists developed the techniques for evaluating the sensory characteristics of black beans. Written instructions and definitions (Appendix 5) for each characteristic under evaluation were provided to the judges. At each session the leader asked them to read the guidelines carefully prior to evaluating the samples. Changes were made to the guidelines when necessary. Panelists also gained experience in the proper use of scales, descriptors and terminology.

The next step was to set the intensity of the reference sample on the scales for each characteristic under evaluation. The reference sample was used as an anchored point against which all the other samples were compared when evaluating the different characteristics during the formal panel sessions. The line scale ballot, end point standards, attribute definitions and the reference sample were presented to the panelists. For each attribute, each panelist's task was to evaluate the end point standard and then evaluate the reference sample (coded with a three-digit random number), placing a mark on the horizontal line at the point that best described the level of intensity of each characteristic in the reference. Six sessions of this type were needed to obtain agreement on the location of the reference sample on the line scales, for each characteristic. After agreement was reached, mean values calculated from all panelists' scores were obtained for each characteristic and positioned on the scales.

As part of the training, six experimental samples (with known sensory differences) were presented to the panelists during two sessions. In each session panelists were presented with three coded samples, the blind control (coded sample), and the reference (identified with the letter R) and ballots having the intensity of the reference positioned on the scales. Their task was to taste the reference sample first, then taste the other samples and rate the intensity of each characteristic of the coded samples in relation to the reference sample. They scored one attribute at a time for all samples under evaluation. The particular beans that were evaluated were predetermined before the sessions. The aim was to present beans with different sensory characteristics in each session. The serving order was randomized, using a table of random numbers to make the session and position assignments. At the end of each session, group discussions were held to clarify the panelists' understanding of panel instructions, methodology and descriptors. Each panelist's results were written on the blackboard and discussed. Results were transformed to numerical scores and tabulated. If differences or problems were found, the leader would rediscuss the definitions and use of end point standards with the panel at the next session. To measure panelists consistency during training, standard deviations of the scores given to the samples were calculated. The training continued until standard deviations did not decline further.

3.5.2.3 Sample preparation

For each session 150g of each experimental bean sample and 200g of the reference sample were used. Beans were washed in tap water, drained and then each sample was placed in a 2000 ml beaker and covered with distilled water (5:1 ratio of water:beans). Beakers were covered, heated on electric or gas stoves at high power until the water began to boil. The heat was then reduced to keep the water and beans simmering throughout the cooking period. The starting times for each beaker of beans were staggered so that all five samples reached the completion of their cooking period at the same time (10 min before the panel session). The level of water in each beaker was kept constant throughout the cooking period by the occasional addition of boiling distilled water. Water was kept simmering specifically for this purpose throughout the period of time that the samples were being cooked. Each sample was cooked to its optimum cooking time for doneness according to previous calculations (section 3.4).

3.5.2.4 Test description

Twenty-one different bean samples (including the blind control) were evaluated for the characteristics of appearance, flavor and texture. Ten trained judges participated in the evaluation and were selected on the basis of consistency and reproducibility of responses during the training period. The ballot used in the test was the one developed and pretested during the training period. It had 15 cm unstructured line scales for evaluation of the intensity of each characteristic in the different samples. The intensity of the reference, as set in the training sessions, was already marked on the scales.

The characteristics were evaluated in the following order: darkness of color, degree of splitting, intensity of beany flavor, beany aftertaste, hardness, particle size, cohesiveness, seed coat toughness, chewiness and bitterness. The ballot is shown in English in Figure 3.2 and in Spanish in Appendix 6.

Five samples (three experimental, the blind control and the reference) were presented to each judge in every session.

The experimental samples and the blind control were identified with 2 sets of three-digit random numbers, each sample having a code for evaluation of appearance and a different code for evaluation of flavor and texture. The reference sample was always identified with the letter R.

The evaluation was carried out in the sensory analysis laboratory at INCAP. The ten panelists were split into two groups of five people. The groups evaluated the samples 40 min apart. Judges evaluated the beans for appearance in the preparation area under fluorescent white light. For this evaluation 50 beans from each sample were placed in two

DESCRIPTIVE ANALYSIS OF BLACK BEANS

EVALUATION OF APPEARANCE

Order of Evaluation ______ ______ ______ ______ ______

Darkness of color

R

Light Dark

Degree of splitting

R

0% 10 20 30 40 50 60 70 80 90 100%

Fig. 3.2 - DESCRIPTIVE ANALYSIS BALLOT

Name ______________________

Date ______________________

DESCRIPTIVE ANALYSIS OF BLACK BEANS
EVALUATION OF FLAVOR AND TEXTURE

Order of evaluation ______ ______ ______ ______ ______

BEANY FLAVOR

R

Weak — Strong

BEANY AFTERTASTE

R

Weak — Strong

HARDNESS

R

Soft — Hard

PARTICLE SIZE

R

Small — Large

COHESIVENESS

R

No cohesive — Extremely cohesive

SEED COAT TOUGHNESS

R

Tender — Tough

Fig. 3.2 (cont'd)

CHEWINESS

R

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

BITTERNESS

R

Not bitter

Extremely bitter

COMMENTS

Fig. 3.2 (cont'd)

covered plastic petri dishes; 25 beans in each. Two sets of samples were prepared and placed in different locations. One dish was used to evaluate color and the other to evaluate percentage of split beans. Separate samples were used for these characteristics, since the color evaluations required the judges to shake the sample before opening the dish while percentage of split beans samples were not shaken. Samples for color evaluations were shaken to prevent the drying of the surface of the beans from affecting the color judgments.

The characteristics of flavor and texture of the samples were evaluated in individual booths under red light. The red light masked color differences in the samples which could have influenced flavor and texture judgments. Panelists tasted the reference sample first, then tasted the coded samples in a pre-established order. They placed a vertical line across the horizontal line at the point that best described the intensity of each characteristic, comparing each sample to the reference. At the end of each session the ballots were checked and the values from the scales were obtained by measuring the distance between the left end point of the scale and the score mark given to each coded sample. The left end point was given a score of zero and scores to the right of this point had positive values from zero to 30 (0.5 cm apart). The maximum intensity score was 30.

3.5.2.5 Data analysis

All statistical analysis was conducted using the Statistical Analysis System (SAS, 1985). Specifically, the ANOVA, GLM, REG, and FACTOR procedures were used.

The statistical analysis carried out with the data from the descriptive analysis included analysis of variance of the scores given to the blind control, to determine whether means for individual panelists and for panel sessions differed, and analysis of variance of the descriptive analysis scores for the ten characteristics under evaluation, to determine significant differences and variability among the samples. Duncan's test was used to determine which samples were significantly different from the other samples, for each of the characteristics.

Principal component analysis using factor analysis procedures was used to determine underlying structures responsible for intersample variation.

3.5.3 Acceptability of samples

An acceptability test was carried out on the 22 samples of beans to determine their overall acceptability. The terms acceptability, and degree of liking were used interchangeable due to their similar meaning when used in Spanish.

3.5.3.1 Experimental Design

The overall acceptability of 22 samples of black beans was evaluated by an untrained panel of 30 judges who were selected on the basis of availability and willingness to participate. For this panel, no reference sample was used but the blind control was served at each panel session. The sample used as the reference in the descriptive analysis, was included as one of the experimental samples, bringing the total number of experimental samples to 21, plus the blind control sample. Approximately half of the samples were served to the untrained panel at each of two sessions (10 or 11 experimental samples plus the blind control). This test was replicated, four sessions necessary to present the samples twice to each judge. The serving order was predetermined before the trials to make the session and position assignments random. Nine-point hedonic scales were used for the evaluation.

3.5.3.2 Preparation of samples

For each session approximately 225g of each bean sample was used. Each 225g portion was placed in a 2000 ml glass beaker and covered with 1115 ml of distilled water (5:1 ratio of water:beans). Samples were heated on electric or gas stoves until they reached the optimum cooking time, which was calculated previously for each bean sample (Section 3.4).

3.5.3.3 Description of the test

Nine-point hedonic scales, ranging from 1=like extremely to 9=dislike extremely, were used to determine the overall acceptability of the 22 samples. The ballot is shown in English in Figure 3.1 and in Spanish in Appendix 3. The 22 samples of beans were randomly divided into two groups of 11 and 12 samples each. The sample used as the reference in the descriptive analysis was included in this test as another coded sample. The test was replicated with different samples in each group. Four panel sessions were necessary to present the 22 samples to the judges. The judges came to the panel area in groups of five, every 15 minutes. Beans, 10 for each panelist, were served in 2 oz styrofoam cups.

The beans were evaluated in individually partitioned booths under fluorescent white illumination. Panelists observed and tasted each sample and checked the category on the nine-point hedonic scale which best described their overall degree of liking or disliking of the sample. Panelists were advised to rinse their mouth with water and eat crackers after each sample evaluation.

3.5.3.4 Data analysis

Analysis of variance was applied to determine significance differences among the acceptability scores for the samples. Duncan's test was applied to determine which samples were significantly different from the others.

3.5.4 Relationship Between Descriptive Analysis and Acceptability

The relationship between the sensory attributes and the acceptability of the bean samples was established to determine which sensory attributes were related to the acceptability of beans and to predict acceptability based on sensory attributes and factors derived from PCA.

3.5.4.1 Statistical Analysis

Correlations were calculated between mean value descriptive analysis scores and acceptability scores. In each case a 5% level of significance was used to test the null hypothesis that there was no correlation between sensory characteristics scored by the trained panel and acceptability scores.

Multiple regression analysis using both Max r^2 and stepwise methods were applied to predict the acceptability of the samples of beans. Based on this analysis, equations to predict acceptability of the 22 samples, and of the 15 of these that were fresh samples, were calculated. Residual values were obtained, comparing the actual hedonic values to the predicted ones from the equations. The equation to predict acceptability based on factors derived from PCA was calculated. Residual values were obtained as well.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 SELECTION OF SAMPLES FOR DESCRIPTIVE ANALYSIS AND HEDONIC TESTS

Samples of Guatemalan black beans were collected from growers, and from mixed lots stored at INCAP, which had been purchased from the government storage system (INDECA).

A preliminary in-house acceptability test was carried out among the first 24 samples collected. Evaluation of appearance, texture and flavor acceptability and overall acceptability was performed. The aim was to have samples with differences in acceptability for each of the four attributes to provide a wide range of sensory characteristics.

Table 4.1 shows the acceptability scores (maximum = 9) given to the different samples for the four characteristics. For appearance, scores ranged from 5.3 to 7.5. For texture, the scores ranged from 2.8 to 7.4. For flavor, the range was 3.9 to 7.4 and for overall acceptability the scores ranged from 3.6 to 7.4. The lowest scores were given to the samples "Nacional" and Tamazulapa (2), which were samples stored for six years under ambient conditions.

From this group of 24 samples, 19 were selected to be used for the main study. Samples with scores in the extremes of the distributions and samples which would give a good range of characteristics were included. The selection

Table 4.1 - Hedonic scores and selection categories for 24 black bean samples

Sample identification (common name)	Appearance[a]	Texture[a]	Flavor[a]	Overall[a] acceptability	Selection[b] category
Cuarenteno	6.7	6.9	7.0	6.7	BC
Enredo-Parramos	5.3	6.5	6.6	5.5	E
Enredo-Itzapa (1)	5.5	7.4	6.7	7.2	E
Enredo-Itzapa (2)	5.7	6.2	6.7	6.4	E
Hondureno	7.4	6.5	6.7	7.0	O
Nacional	5.5	2.8	3.9	3.6	E
Ostua	6.8	6.7	6.3	6.7	E
Pata de zope	6.3	6.4	6.7	7.0	E
Pecho Amarillo	6.0	6.4	6.8	6.4	O
Quetzal (1)	7.5	5.4	6.7	6.2	E
Quetzal (2)	6.1	7.4	7.4	7.1	E
Rabia de Gato	7.2	6.4	6.3	6.2	E
San Pedro Pinula	6.6	6.8	6.7	6.6	E
Santa Rosita	6.4	6.6	5.7	6.2	O
Sesenteno	6.6	6.7	7.0	6.9	E
Suelo-Chimaltenango	6.8	6.7	6.7	6.8	O
Suelo-Itzapa (1)	5.3	6.9	5.9	6.7	E
Suelo-Itzapa (2)	6.9	6.6	6.7	6.8	O
Suelo-Parramos	6.0	6.9	7.1	6.7	R
Suchitan	7.1	5.9	6.4	6.0	E
Tamazulapa (1)	6.7	6.9	6.4	7.4	E
Tamazulapa (2)	5.4	3.0	4.4	3.7	E
Tamazulapa (3)	6.3	6.4	6.4	6.5	E
Vaina Morada	7.1	6.9	7.4	7.1	E

[a]Scored in a hedonic scale where 1 = dislike extremely and 9 = like extremely
[b]Categories: BC = blind control O = omitted
E = experimental R = reference

was based not only on the results of this acceptability test but also on the criteria of having samples from different types, varieties, locations and storage conditions. Availability of sample was also an important criterion for selection. The other 3 samples included in this study were samples stored under accelerated storage conditions. They were not included in the preliminary test.

4.2 PHYSICAL TESTS

Four physical characteristics were evaluated in the bean samples. They were seed weight, percent water absorption at 4h, percent seed coat and percent moisture. The results are shown in Table 4.2.

For seed weight (100 seeds), the values ranged from 16.9 to 32.4 g. The effect of type of bean was evident. The four vine beans (A, B, C and B_2) had weights of 29.9g/100 beans or higher. For the bush types, 100-seed weights ranged from 17.5 to 25.0g.

The values for percent water absorption at 4h ranged from 12.4 to 99.6%. The effect of type of bean was strong for this characteristic. Vine beans (A, B_1, C and B_2) absorbed less water in the 4h period than the bush beans, with values ranging from 12.4 to 20.9% for the vine beans and from 26.0 to 99% for the bush beans. Storage conditions might also have influenced this characteristic. Bush P beans which had been stored for a long period and Bush M beans which had been stored under accelerated conditions,

Table 4.2 - Physical characteristics of bean samples

Sample identification	Seed weight (100 seeds)	Water absorption at 4 h (%)	Seed coat (% of dry seed weight)	Moisture (%)
Bush A	22.2	67.2	9.6	12.0
Bush B	18.7	61.3	9.7	11.6
Bush C	23.1	85.6	8.9	12.0
Bush D	23.3	89.6	9.6	13.7
Bush E	19.6	53.2	9.4	12.9
Bush F	17.7	37.9	10.5	11.4
Bush G	16.9	55.7	10.0	12.9
Bush H	25.0	69.9	8.7	11.0
Bush I	20.5	48.2	8.8	11.4
Bush J_1	18.1	46.0	9.2	12.5
Bush J_2	19.8	84.0	11.7	14.2
Bush K	22.7	29.0	9.2	11.0
Bush L	23.0	26.0	9.1	11.7
Bush M	17.5	99.0	13.2	14.8
Bush N	21.5	66.4	9.7	11.4
Bush O	18.0	58.3	11.3	11.4
Bush P	20.8	99.6	11.6	11.0
Bush Q	18.8	67.9	11.7	11.6
Vine A	30.3	12.4	9.2	13.6
Vine B_1	29.9	20.9	9.0	14.3
Vine C	31.1	17.0	9.0	12.3
Vine B_2	32.4	18.0	11.0	15.3

were the samples that absorbed the most water (99%) in the 4h period.

Percent seed coat showed values ranging from 8.7 to 13.2. Length of storage and storage conditions both had an effect on this characteristic. Samples stored under accelerated conditions (Bush M and J_2 and Vine B_2) and beans stored for long periods under ambient conditions (Bush P, Q and O) were the samples with the highest percent of seed coat. Values ranged from 11.0 to 13.2%. The influence of conditions of storage can also be observed when comparing the values obtained for Vine B_1 and Vine B_2 samples. Vine B_1 beans, held under refrigeration, had 9% seed coat, while Vine B_2 beans, which came from the same original lot as B_1 beans, but were held under accelerated conditions, had 11% seed coat. Similar results were observed for Bush J^1 sample (stored under refrigeration) and Bush J^2 sample (stored under accelerated conditions), which had values of 9.2% and 11.7% respectively.

Percent moisture values ranged from 11.0 to 15.3%. The moisture content was fixed in each sample before bagging and storage. The beans with the highest percent moisture were the three samples stored under accelerated conditions.

Table 4.3 presents the correlation matrix of physical measurements. A highly significant negative correlation was found between seed weight and percent water absorption at 4hr. The smaller beans generally absorbed water more

Table 4.3 - Pearson correlation matrix of physical measurements

	Seed weight	Water absorption %	Seed coat %	Moisture %
Seed weight	1.00	-0.58[b]	-0.38	0.36
Water absorption		1.00	0.48[c]	-0.08
Seed coat %			1.00	0.29
Moisture %				1.00

[b]significant at $p<0.01$

[c]significant at $p<0.05$

rapidly than the larger beans, possibly because of the greater surface area for a given quantity. Percent seed coat was negatively correlated with percent water absorption.

4.3 COOKING TIME

Three different criteria, OTMS measurement of hardness, visual assessment and tactile assessment, were used to estimate bean doneness and to arrive at the optimum cooking time for each sample under evaluation (Table 4.4). The times needed for the samples to reach doneness ranged from 105 to 390 min. Length of storage and storage conditions both had a strong effect on cooking time. Beans harvested in or later than November 1986 and stored under refrigeration had the shortest cooking times, ranging from 105 to 135 min. Samples harvested in September 1986 and stored under ambient conditions until they were collected for the study (Bush F and G) and Bush O beans, which was stored under ambient conditions for more than 6 months, had longer cooking times (between 185 and 155 min). The samples with the longest cooking times were two samples that had been stored for six years under ambient conditions (Bush P and Q) and three samples stored for 14 weeks under accelerated storage (Bush M, B_2 and J_2). These samples had cooking times between 300 and 390 min.

4.4 DESCRIPTIVE ANALYSIS

A 10-member trained panel used the descriptive sensory

Table 4.4 - Cooking times for bean samples

Sample identification	Harvest date (mon/year)	Storage temperature (°C)	Optimum[a] cooking time (min)
Bush A	Jan/87	4	105
Bush H	Nov/86	4	105
Bush C	Dec/86	4	110
Bush I	Nov/86	4	115
Bush J_1	Dec/86	4	120
Vine B_1	Jan/87	4	120
Bush K	Jan/87	4	120
Bush L	Dec/86	4	130
Vine A	Jan/87	4	130
Bush B	Aug/86	4	135
Bush D	Nov/86	4	135
Bush N	Dec/86	4	135
Vine C	Jan/87	4	135
Bush E	Nov/86	4	140
Bush F	Sept/86	4	155
Bush G	Sept/86	4	165
Bush O	Nov/86	18-26	185
Bush P	1981	18-26	300
Bush J_2	Dec/86	34	360
Vine B_2	Jan/87	34	360
Bush Q	1981	34	375
Bush M	Feb/87	34	390

[a]Determined using three different criteria.

analysis technique to identify, describe and quantify the sensory attributes of appearance, flavor and texture of 22 samples of black beans. Results of panelists' performance and sample variability will be presented in the following sections.

4.4.1 Panelists' Performance

Evaluations of the blind control sample, included in every session of the sensory descriptive analysis, was used as a measure of panelists' consistency. ANOVA, carried out with the scores given to the blind control in the 15 sessions, indicated significant differences ($p<0.001$) among panelists for all the characteristics evaluated (Appendix 7). Nevertheless, when the results of the panel as a group were tested for differences among sessions, F-ratios showed no significant differences among sessions ($p<0.05$) for any of the sensory characteristics evaluated except for darkness of color (Appendix 7). Thus, based on the scores given to the blind control, the panel as a group performed consistently for the evaluation of the sensory characteristics.

4.4.2 Sensory Characteristics

Analysis of variance showed that there were significant differences ($p<0.001$) among the 20 experimental bean samples for each of the 10 descriptive sensory attributes (Table 4.5). This indicated that the sensory characteristics selected by the panel were appropriate to discriminate

Table 4.5 - Analysis of variance for sensory attributes evaluated by trained panel

Attribute	Source of variation	Degrees of freedom	Mean square	F-ratio versus error
Darkness of color	panelists	9	122.77	10.63[a]
	samples	19	743.43	64.39[a]
	panelist * sample	171	13.59	1.18
	error	240	11.54	
Degree of splitting	panelist	9	240.160	11.20[a]
	samples	19	1431.30	66.75[a]
	panelist * sample	171	21.65	1.01
	error	240	21.44	
Beany flavor	panelist	9	187.93	14.48[a]
	samples	19	118.78	9.15[a]
	panelist * sample	171	15.77	1.22
	error	240	12.98	
Beany aftertaste	panelist	9	286.51	16.14[a]
	samples	19	132.54	7.47[a]
	panelist * sample	171	20.99	1.18
	error	240		
Bitterness	panelist	9	281.78	18.03[a]
	samples	19	63.61	4.07[a]
	panelist * sample	171	20.85	1.33[c]
	error	240	15.62	
Particle size	panelist	9	337.66	22.02[a]
	samples	19	703.07	45.84[a]
	panelist * sample	171	23.77	1.55[a]
	error	240	15.33	
Hardness	panelist	9	160.5	11.55[a]
	samples	19	308.47	22.20[a]
	panelist * sample	171	14.87	1.07
	error	240	13.89	
Cohesiveness	panelist	9	131.48	9.55[a]
	samples	19	290.79	21.11[a]
	panelist * sample	171	18.02	1.31[c]
	error	240	13.77	
Seed coat toughness	panelist	9	111.69	9.25[a]
	samples	19	104.35	8.64[a]
	panelist * sample	171	17.58	1.46[b]
	error	240	12.07	
Chewiness	panelist	9	275.26	40.84[a]
	samples	19	73.38	10.89[a]
	panelist * sample	171	8.38	1.24
	error	240	6.74	

[a]significant at $p<0.001$

[b]significant at $p<0.01$

[c]significant at $p<0.05$

differences among the samples.

Significant panelist effects ($p<0.001$) (Table 4.5) were found for all the sensory characteristics. Also, small but significant ($p<0.001$ and $p<0.05$) panelist by treatment interactions (Table 4.5) existed for the attributes particle size, seed coat toughness, cohesiveness and bitterness. In descriptive sensory analysis data, significant differences among panelists suggest that the panelists were using different portions of the scales for the evaluation of the samples. The small F-ratio for interaction and the fact that there was no difference in F value when the main effects were tested against the error term rather than against the interaction term indicated that the effect of panelist by sample interaction was not important.

4.4.3 Appearance

Two appearance characteristics, darkness of color and degree of splitting, were evaluated by the trained panel. The trained panelists identified these two as being the most important for the description of the appearance of black beans. Guatemalan consumers consider both of these characteristics important quality indicators (Watts et al., 1987).

4.4.3.1 Darkness of color

Color differences among the samples were marked. Mean darkness of color scores ranged from 4.9 to 25.1, on a 0 to 30 scale, with the lower score representing the lightest color. Significant differences among the means (Table 4.6) indicated a number of important groupings (Table 4.6).

The darkest beans were two samples that had been stored for six years under ambient conditions (Bush P and Q) and one sample that had been stored for 14 weeks under accelerated storage conditions (Vine B_2). These three samples were significantly darker than all of the others.

Length of storage and conditions of storage both appeared to influence color scores. Three samples of bush beans from Jutiapa harvested in August or September and stored under ambient conditions until they were collected for the study (Bush F, B and G), were significantly darker in color than the Jutiapa beans harvested in November and December 1986 or January 1987 and put directly into refrigerated storage (Bush D, C, H, J_1, E and I). The influence of storage method on darkening was evident when the Vine B_1 and B_2 samples were compared. Vine B_2, held under accelerated storage, had a color score of 23.7 and was significantly darker than Vine B_1 beans (color score of 16.4), which came from the same original lot but had been held under refrigeration. A similar influence of the accelerated storage was apparent for the Bush J_2 sample, which was significantly darker than the Bush J_1 sample, which came from the same original lot but was stored at $4^{o}C$. Burr et al. (1968), Hughes and Sanstead (1975) and Uebersax and Bedford (1980) also reported darkening of several types

Table 4.6 - Darkness of color scores

Sample identification		Harvest date (mon/year)	Storage temperature (°C)	Panel mean score[a]	Result of means comparison[b]
Bush	Q	1981	18-26	25.1	
Vine	B_2	Jan/87	34	23.7	
Bush	P	1981	18-26	23.0	
Bush	F	Sept/86	4	20.4	
Vine	C	Jan/87	4	16.7	
Vine	B_1	Jan/87	4	16.4	
Bush	G	Sept/86	4	16.2	
Bush	N	Dec/86	4	15.6	
Bush	B	Aug/86	4	15.4	
Vine	A	Jan/87	4	15.1	
Bush	K	Jan/87	4	14.1	
Bush	M	Feb/87	34	12.2	
Bush	D	Nov/86	4	12.0	
Bush	J_2	Dec/86	34	11.7	
Bush	C	Dec/86	4	9.6	
Bush	H	Nov/86	4	8.9	
Bush	J_1	Dec/86	4	8.0	
Bush	O	Nov/86	18-26	6.5	
Bush	E	Nov/86	4	5.2	
Bush	I	Nov/86	4	4.9	

[a]Higher values = darker color on a scale of 0-30.
Each mean represents two or three evaluations by each of ten panelists.

[b]Mean scores which fall within the range of the same bar are not significantly different.

of beans after storage at high temperature and humidity.

Type of bean also appeared to be a factor affecting the color scores. The three vine samples stored at 4^{o}C (Vine A, B and C) had scores in the upper half of the distribution, while the majority of the bush beans stored at 4^{o}C had scores in the lower half of the distribution.

4.4.3.2 Degree of splitting

The second appearance characteristic evaluated by the trained panel was the degree of splitting. Scores for this characteristic were based on the percent of beans split. A score of 0 was equal to 0% split beans, and of 30 was equal to 100% split. As shown in Table 4.7, the range of scores for this characteristic was from 2.0 to 25.9.

Long storage time, or storage under accelerated conditions generally resulted in low percent split scores. The two samples stored for six years, Bush P and Q, had scores of 5.8 and 6.9 respectively, and the Bush M sample, which had been held under accelerated conditions, had a score of 2.0. The other three samples with scores of less than 15 (50% split) were Bush O, F and J_2. The first two samples had been held for four months or longer under ambient conditions, and the third sample was stored at 34^{o}C. The influence of storage method on the degree of splitting of beans can be observed when comparing the scores given to Bush J_1 and Bush J_2 samples. Bush J_2, held under

Table 4.7 - Degree of splitting scores

Sample identification		Harvest date (mon/year)	Storage temperature (^{o}C)	Panel mean score[a]	Result of means comparison[b]
Bush	B	Aug/86	4	25.9	
Vine	A	Jan/87	4	25.4	
Bush	C	Dec/86	4	25.2	
Vine	C	Jan/87	4	25.0	
Bush	I	Nov/86	4	24.8	
Bush	J_1	Dec/86	4	24.7	
Vine	B_1	Jan/87	4	24.6	
Bush	D	Nov/86	4	24.5	
Bush	N	Dec/86	4	24.2	
Vine	B_2	Jan/87	34	23.4	
Bush	G	Sept/86	4	22.4	
Bush	K	Jan/87	4	20.3	
Bush	H	Nov/86	4	20.3	
Bush	E	Nov/86	4	17.6	
Bush	J_2	Dec/86	34	14.3	
Bush	F	Sept/86	4	9.5	
Bush	Q	1981	18-26	6.9	
Bush	P	1981	18-26	5.8	
Bush	O	Nov/86	18-26	5.1	
Bush	M	Feb/87	34	2.0	

[a]Higher values = higher degree of splitting beans on a scale of 0-30.
Score of 0 represents 0% split.
Score of 30 represents 100% split.
Each mean represents two or three evaluations by each of ten panelists.
[b]Mean scores which fall within the range of the same bar are not significantly different.

accelerated storage, had a score of 14.3 and had significantly less split beans than Bush J_1, with a score of 24.7, which came from the same original lot but was stored at $4^{o}C$.

These results suggest the influence of length and conditions of storage on the number of split beans in the samples. Long storage times and the accelerated conditions resulted in low percentages of split beans. Similar results were reported by Davis et al. (1980), who found a significant decrease in the percentage of split beans in cooked pinto and lima beans which had been stored from one day to one month at $26^{o}C$.

Type of bean did not have an important effect on the degree of splitting of the beans. Fresh samples from both types, bush and vine, had high scores for this characteristic, ranging from 24.6 to 25.9. Significant difference was not found between beans of the different types.

Location did not have a significant influence on the scores obtained for degree of splitting. Samples from different locations (Jutiapa and Chimaltenango) had scores in the upper half of the distribution.

4.4.4 Flavor

As indicated in the Review of Literature, only a few studies have focused on the flavor characteristics of beans (Dos Santos Garruti, 1983, Uebersax and Bedford, 1980, Morris and Wood, 1956). These studies concentrated on the presence of off-flavors or the flavor differences in beans as influenced by different storage conditions. In the present study, the intensity of beany flavor, beany aftertaste and bitterness of black beans were attributes suggested by the panelists as being important to characterize the flavor in the bean samples.

4.4.4.1 Beany flavor

Differences in intensity of beany flavor was detected among the samples. The range in flavor scores was less than the range for the two appearance characteristics. Mean beany flavor scores ranged from 13.9 to 22.5 (Table 4.8), with the lower scores representing milder beany flavor.

The samples rated as having lower scores for beany flavor were those that had been stored for an extended period under ambient conditions (Bush P and Q) and one sample stored under accelerated conditions (Bush M). These three samples had scores of 13.9, 15.0 and 14.9 respectively. The Bush P sample, the one with the lowest score, had significantly less beany flavor than the three vine beans from Chimaltenango and the Bush K, F, H, J^1, C, G, I, N, D, and J_2 beans. Storage for a long period under suboptimal conditions appeared to decrease beany flavor in the samples. The effect of storage conditions was observed for the Vine B_1 and Vine B_2 samples. Although both samples came from the same original lot, Vine B_1 (stored at 4^o C),

Table 4.8 - Beany flavor scores

Sample identification		Harvest date (mon/year)	Storage temperature (^{o}C)	Panel mean score[a]	Result of means comparison[b]
Vine	A	Jan/87	4	22.5	
Vine	B_1	Jan/87	4	21.9	
Vine	C	Jan/87	4	21.6	
Bush	K	Jan/87	4	20.2	
Bush	F	Sept/86	4	20.1	
Bush	H	Nov/86	4	20.1	
Bush	J_1	Dec/86	4	20.0	
Bush	C	Dec/86	4	19.6	
Bush	G	Sept/86	4	18.9	
Bush	I	Nov/86	4	18.8	
Bush	N	Dec/86	4	18.7	
Bush	D	Nov/86	4	18.5	
Bush	J_2	Dec/86	34	18.4	
Vine	B_2	Jan/87	34	17.7	
Bush	E	Nov/86	4	17.4	
Bush	O	Nov/86	18-26	16.7	
Bush	B	Aug/86	4	16.6	
Bush	Q	1981	18-26	15.0	
Bush	M	Feb/87	34	14.9	
Bush	P	1981	18-26	13.9	

[a]Higher values = more intense beany flavor on a scale of 0-30. Each mean represents two or three evaluations by each of ten panelists.
[b]Mean scores which fall within the range of the same bar are not significantly different.

had a score of 21.9 while Vine B_2 (stored under accelerated conditions) scored 17.7.

Type of bean appeared to be a factor affecting beany flavor. The three vine beans (A, B_1 and C) were given the highest scores for this characteristic. These samples had beany flavors which were significantly more intense than the flavors of Bush P, M, Q, B, O, E, J_2 and D beans and also Vine B_2 beans.

Location of growth also had a strong influence on the intensity of beany flavor. The beans grown in Chimaltenango (Vine A, B_1, C and Bush K beans) were given the highest scores, having the most intense beany flavor, while the beans from Jutiapa had an intermediate beany flavor. For most Guatemalan consumers, black beans from Chimaltenango have the "best flavor" of all black beans grown in Guatemala (Elias et al., 1985). Although consumers know that the flavor of these beans is good, they are unable to describe or identify this characteristic. The above results suggest that this "good flavor" reported by consumers is an intense beany flavor (the flavor characteristic of beans).

As it was mentioned before, most studies focused on beans reported the presence of off-flavors or musty, hay-like, earthy or chemical flavors (Swanson, 1985, Dos Santos Garruti, 1981) in beans, as influenced by different storage conditions. According to the sensory panel results in the present study, the loss of beany flavor, appear to be a phenomenon occurring in black beans during storage under suboptimal conditions. In this study panelists did not identify off-flavors although off flavors have been identified in other studies.

4.4.4.2 Beany aftertaste

Mean beany aftertaste scores ranged from 9.9 to 19.8 (Table 4.9), the lower score representing milder beany aftertaste. The range and order of samples, when scored for aftertaste, were similar to those obtained for beany flavor.

Length of storage and storage conditions both appeared to influence beany aftertaste scores. The samples rated as having the lowest scores for beany aftertaste were the Bush P and O samples, stored under ambient conditions for six years and for six months respectively, and Bush M beans that had been stored for 14 weeks under accelerated storage conditions. The influence of storage conditions was also found when comparing the scores given to Vine B_1 and Vine B_2 samples. Vine B_1 (stored at 4^oC) received a score of 19.2 and it had a significantly stronger beany aftertaste than the Vine B_2 sample (stored under accelerated conditions) which scored 15.6.

Beany aftertaste was also influenced by the type of bean. Vine bean samples obtained the highest scores (between 18.6 and 19.8) while bush beans obtained scores between 9.9 and 17.6. A strong influence of location of

Table 4.9 - Beany aftertaste scores

Sample identification		Harvest date (mon/year)	Storage temperature (°C)	Panel mean score[a]	Result of means comparison[b]
Vine	A	Jan/87	4	19.8	
Vine	B_1	Jan/87	4	19.2	
Vine	C	Jan/87	4	18.6	
Bush	J_1	Dec/86	4	17.6	
Bush	K	Jan/87	4	17.4	
Bush	H	Nov/86	4	16.6	
Bush	C	Dec/86	4	16.3	
Bush	F	Sept/86	4	16.3	
Bush	J_2	Dec/86	34	16.2	
Bush	G	Sept/86	4	15.8	
Vine	B_2	Jan/87	34	15.6	
Bush	I	Nov/86	4	15.5	
Bush	N	Dec/86	4	14.8	
Bush	D	Nov/86	4	14.5	
Bush	B	Aug/86	4	13.6	
Bush	Q	1981	18-26	13.6	
Bush	E	Nov/86	4	13.5	
Bush	O	Nov/86	18-26	13.3	
Bush	M	Feb/87	34	11.8	
Bush	P	1981	18-26	9.9	

[a]Higher values = more intense beany aftertaste on a scale of 0-30. Each mean represents two or three evaluations by each of ten panelists.

[b]Mean scores which fall within the range of the same bar are not significantly different.

growth on the intensity of beany aftertaste was observed. Three samples from Chimaltenango (Vine A, B_1 and C beans) had the highest scores for this characteristic, ranging from 18.6 to 19.8.

The correspondence between the scores given to the samples for beany flavor and aftertaste suggests either that these two characteristics are very closely related or that the panelists measured both in the same way, even though the instructions for measuring them were different.

4.4.4.3 Bitterness

Mean scores for bitterness are shown in Table 4.10. The values ranged from 11.6 to 17.9 with the higher scores indicating greater bitterness. This narrow range of scores showed that there was not a very good discrimination among the samples based on this characteristic.

Length of storage did not have an influence on the bitterness of the bean samples. The Bush O beans, stored for six months and Bush P and Q beans, stored for six years, scored 13.6, 13.9, and 14.3 respectively, and were in the middle of the distribution of scores. The effect of conditions of storage on bitterness scores was not evident when the scores for Bush J_1 and J_2 samples were compared. Bush J_1 (stored at 4^{o} C) had a score of 15.0 while Bush J_2 (stored under accelerated conditions) had a score of 13.6. a significant difference between both scores was not found.

Type of bean had a strong influence on bitterness

Table 4.10 - Bitterness scores

Sample identification		Harvest date (mon/year)	Storage temperature (°C)	Panel mean score[a]	Result of means comparison[b]
Vine	C	Jan/87	4	17.9	
Vine	B_1	Jan/87	4	17.1	
Vine	A	Jan/87	4	15.8	
Vine	B_2	Jan/87	34	15.7	
Bush	N	Dec/86	4	15.5	
Bush	F	Sept/86	4	15.1	
Bush	J_1	Dec/86	4	15.0	
Bush	K	Jan/87	4	14.4	
Bush	Q	1981	18-26	14.3	
Bush	P	1981	18-26	13.9	
Bush	O	Nov/86	18-26	13.6	
Bush	J_2	DEc/86	34	13.6	
Bush	M	Feb/87	34	13.3	
Bush	H	Nov/86	4	13.1	
Bush	C	Dec/86	4	12.6	
Bush	I	Nov/86	4	12.6	
Bush	G	Sept/86	4	12.5	
Bush	D	Nov/86	4	12.5	
Bush	B	Aug/86	4	11.8	
Bush	E	Nov/86	4	11.6	

[a]Higher values = more bitter sample on a scale of 0-30.
Each mean represents two or three evaluations by each of ten panelists.
[b]Mean scores which fall within the range of the same bar are not significantly different.

scores. Four vine beans (three stored at 4^{o} C and one under accelerated storage) were given the highest scores for this characteristic. The three refrigerated (4^{o} C) vine samples were significantly more bitter than the majority of the refrigerated bush samples.

Location of growth also appeared to influence bitterness scores. The five bean samples from Chimaltenango (Vine A, B_1, B_2, C and Bush K) had scores in the upper half of the distribution while most of the beans grown in Jutiapa had scores in the lower half of the distribution. The samples with the lowest scores were Bush E and B from Jutiapa. They were significantly less bitter than four vine beans from Chimaltenango and a bush bean from Jalapa.

4.4.5 Texture

Guatemalan consumers consider textural characteristics as important quality indicators for black beans. Doughiness, softness, and spreadability were mentioned among the principal characteristics of good quality cooked beans (Watts et al., 1987). In the present study, five textural characteristics of black beans were selected and evaluated by the trained panel. They were particle size of the cotyledon, hardness, cohesiveness, seed coat toughness, and chewiness.

4.4.5.1 Cotyledon particle size

Mean scores for particle size of the cotyledon are given in Table 4.11. Particle size differences among the

Table 4.11 - Cotyledon particle size scores

Sample identification		Harvest date (mon/year)	Storage temperature (°C)	Panel mean score[a]	Result of means comparison[b]
Bush	P	1981	18-26	22.9	
Bush	Q	1981	18-26	21.1	
Bush	M	Feb/87	34	19.0	
Bush	J_2	Dec/86	34	16.6	
Vine	B_2	Jan/87	34	14.6	
Bush	O	Nov/86	18-26	11.3	
Bush	F	Sept/86	4	8.8	
Bush	N	Dec/86	4	8.4	
Bush	G	Sept/86	4	8.3	
Bush	I	Nov/86	4	7.5	
Bush	C	Dec/86	4	6.6	
Bush	B	Aug/86	4	6.3	
Vine	C	Jan/87	4	6.0	
Vine	B_1	Jan/87	4	5.8	
Bush	D	Nov/86	4	5.5	
Vine	A	Jan/87	4	5.2	
Bush	K	Jan/87	4	5.1	
Bush	J_1	Dec/86	4	5.0	
Bush	H	Nov/86	4	4.9	
Bush	E	Nov/86	4	4.4	

[a]Higher values = larger particle size on a scale of 0-30.
Each mean represents two or three evaluations by each of ten panelists.

[b]Mean scores which fall within the range of the same bar are not significantly different.

samples were marked. The values ranged from 4.4 to 22.9. Higher values indicated larger particles (greater granularity). This wide range of values showed good discrimination among the samples based on this characteristic.

Length of storage and conditions of storage both appeared to be factors that influenced particle size scores. The largest particles were found in the cotyledon of Bush P and Q samples (stored for six years) and Bush M, J_2 and B_2 (stored under accelerated conditions). These five samples had particles significantly larger than the other samples, scores ranging from 14.6 to 22.9. The Bush O sample, which had been stored under ambient conditions for six months, also scored high for this characteristic. The influence of storage method on particle size was evident when comparing the scores given to Bush J_1 and Bush J_2 samples. Bush J_1 beans (stored under refrigeration) scored 5.0, having particles significantly smaller than Bush J_2 beans, which scored 16.6. Bush J_2 beans came from the same original lot but were stored under accelerated conditions for 14 weeks. A similar difference occurred with Vine B_1 beans (stored at $4^{o}C$) and Vine B_2 beans (stored under accelerated conditions), which scored 5.8 and 14.6 respectively. The sample stored at $4^{o}C$ had particles significantly larger than the sample stored under accelerated conditions.

Type of bean did not appear to be an important determinant of cotyledon particle size scores. The samples given the lowest scores for particle size were Bush E, H, J_1 and K, ranging from 4.4 to 5.1. Vine A, B_1 and C samples were the next in the score distribution, also having small particles. There was no significant difference between the scores given to the samples in the two groups.

Location of growth did not have a strong influence on the particle size scores. Beans grown in Jutiapa and Chimaltenango had scores in the lower half of the distribution and significant differences did not exist between the two groups.

4.4.5.2 Hardness

Mean hardness scores ranged from 8.4 to 22.8, with the higher scores representing harder samples (Table 4.12). Some samples remained much harder than others, even though all of the samples were cooked to their individual points of optimum doneness as determined using three different criteria (Section 3.4). The score distribution followed an order similar to the one for particle size.

The hardest beans were the two samples stored under ambient conditions for six years (Bush P and Q) and Bush M beans, which had been stored under accelerated conditions for 14 weeks. These three samples were significantly harder than all the other samples.

Length of storage and conditions of storage both appeared to influence hardness scores. Bush B and F samples from Jutiapa, harvested in August and September and stored

Table 4.12 - Hardness scores

Sample identification		Harvest date (mon/year)	Storage temperature (°C)	Panel mean score[a]	Result of means comparison[b]
Bush	P	1981	18-26	22.8	
Bush	Q	1981	18-26	20.5	
Bush	M	Feb/87	34	19.8	
Bush	F	Sept/86	4	15.4	
Vine	B_2	Jan/87	34	15.2	
Bush	J_2	Dec/86	34	15.1	
Bush	O	Nov/86	18-26	13.6	
Bush	B	Aug/86	4	13.2	
Bush	N	Dec/86	4	12.8	
Bush	G	Sept/86	4	12.6	
Bush	C	Dec/86	4	11.6	
Vine	B_1	Jan/87	4	11.3	
Bush	K	Jan/87	4	11.1	
Bush	J_1	Dec/86	4	10.9	
Vine	A	Jan/87	4	10.8	
Bush	E	Nov/86	4	10.7	
Bush	D	Nov/86	4	10.6	
Bush	I	Nov/86	4	10.3	
Bush	H	Nov/86	4	9.1	
Vine	C	Jan/87	4	8.4	

[a]Higher values = harder sample on a scale of 0-30.
Each mean represents two or three evaluations by each of ten panelists.
[b]Mean scores which fall within the range of the same bar are not significantly different.

under ambient conditions until they were collected, and Bush O beans, also stored under ambient conditions, were harder than most of the beans harvested between November 1986 and January 1987, and stored under refrigeration. The influence of storage conditions is evident when comparing the scores given to Bush J_1 and Bush J_2 samples. Bush J_1 beans, stored under refrigeration, scored 10.9 and it was significantly softer than Bush J_2 beans, stored under accelerated conditions which had a score of 15.1.

Type of bean did not appear to have an effect on hardness scores. Samples from both types, bush and vine, are located in distinctly different regions of the score distribution. Location did not have a strong influence in the scores given to hardness. Beans grown in different regions (Jutiapa and Chimaltenango) had scores that were not statistically different and which were located in different places in the distribution of scores.

Length and conditions of storage were the most important characteristics affecting hardness of black beans. The beans stored for extended periods or stored under suboptimal conditions were the hardest ones, even though each sample was cooked to its optimum cooking time (Section 3.4). Table 4.4 shows that those samples were the ones with the longest cooking times. Several authors (Antunes and Sgarbieri, 1979; Burr et al., 1968; Dos Santos Garruti and Bourne, 1985) have reported the development of hardness and an increase in cooking time for beans stored for extended periods of time under high temperature, high humidity conditions.

4.4.5.3 Cohesiveness

The third texture characteristic evaluated by the trained panel was cohesiveness. As shown in Table 4.13, the range of scores for this characteristic was 9.5 to 22.5, lower scores representing less cohesive samples. This range was similar to the range for hardness and particle size but in an inverted order.

Long storage or storage under accelerated conditions generally resulted in low scores for cohesiveness. Three samples stored under ambient conditions for extended periods (Bush P, Q and O samples) and three samples stored under accelerated conditions (Bush M, J_2 and B_2 beans) were significantly less cohesive than the majority of the other samples, having scores between 9.5 and 17.1. The influence of storage conditions on cohesiveness of the bean samples can be noticed when looking at the scores given to Bush J_1 and Bush J_2 samples. Bush J_1 beans (stored at 4^oC) scored 20.4 while Bush J_2 beans (stored under accelerated conditions) scored 14.5. A similar difference occurred with Vine B_1 beans (stored at 4^oC) and Vine B_2 beans (stored under accelerated conditions) samples, which scored 21.5 and 16.3 respectively. In both cases, the samples stored at 4^oC were significantly more cohesive than those stored under

Table 4.13 - Cohesiveness scores

Sample identification		Harvest date (mon/year)	Storage temperature (°C)	Panel mean score[a]	Result of means comparison[b]
Vine	C	Jan/87	4	22.5	
Bush	E	Nov/86	4	22.2	
Vine	A	Jan/87	4	22.0	
Bush	D	Nov/86	4	21.9	
Bush	H	Nov/86	4	21.6	
Bush	K	Jan/87	4	21.5	
Vine	B_1	Jan/87	4	21.5	
Bush	J_1	Dec/86	4	20.4	
Bush	B	Aug/86	4	20.1	
Bush	G	Sept/86	4	19.9	
Bush	C	Dec/86	4	19.8	
Bush	I	Nov/86	4	19.1	
Bush	F	Sept/86	4	18.8	
Bush	N	Dec/86	4	18.2	
Bush	O	Nov/86	18-26	17.1	
Vine	B_2	Jan/87	34	16.3	
Bush	J_2	Dec/87	34	14.5	
Bush	M	Feb/87	34	12.5	
Bush	Q	1981	18-26	12.4	
Bush	P	1981	18-26	9.5	

[a]Higher values = more cohesive sample on a scale of 0-30. Each mean represents two or three evaluations by each of ten panelists.

[b]Mean scores which fall within the range of the same bar are not significantly different.

accelerated conditions.

Type of bean appeared to be a factor affecting cohesiveness scores. The three vine beans stored at 4° C (Vine A, B_1, C) had scores in the upper half of the distribution while most of the bush beans stored at 4°C had scores in the lower half of the distribution.

Location also appeared to influence cohesiveness in these samples. The four samples grown in Chimaltenango, stored under refrigeration (Vine A, B_1, C and Bush K samples) were more cohesive than the majority of the samples grown in Jutiapa and stored under refrigeration.

4.4.5.4 Seed coat toughness

Mean scores for toughness of the seed coat are given in Table 4.14. The scores ranged from 11.7 to 20.9, lower scores representing more tender seed coats. This narrow range of scores shows that there was not very good discrimination among the samples based on this characteristic.

Long storage time under suboptimal conditions appeared to have an influence on the toughness of seed coat scores. Bush P sample (stored for six years under ambient conditions) had a score of 20.9 and it was the sample with the toughest seed coat. Bush Q (stored for six years) and Bush O, B and F samples, stored for four or six months under ambient conditions, also had high scores for toughness of seed coat. Their scores were located in the upper half of

Table 4.14 - Seed coat toughness scores

Sample identification		Harvest date (mon/year)	Storage temperature (°C)	Panel mean score[a]	Result of means comparison[b]
Bush	P	1981	18-26	20.9	
Vine	A	Jan/87	4	20.0	
Vine	C	Jan/87	4	18.8	
Vine	B_2	Jan/87	34	18.7	
Bush	O	Nov/86	18-26	18.6	
Bush	M	Feb/87	34	18.5	
Bush	Q	1981	18-26	18.0	
Bush	B	Aug/86	4	17.6	
Bush	F	Sept/86	4	17.5	
Vine	B_1	Jan/87	4	17.2	
Bush	J_2	Dec/86	34	16.7	
Bush	N	Dec/86	4	16.6	
Bush	E	Nov/86	4	16.2	
Bush	C	Dec/86	4	16.0	
Bush	J_1	Dec/86	4	15.9	
Bush	G	Sept/86	4	15.7	
Bush	H	Nov/86	4	14.9	
Bush	K	Jan/87	4	14.3	
Bush	I	Nov/86	4	13.5	
Bush	D	Nov/86	4	11.7	

[a] Higher values = tougher seed coat on a scale of 0-30.
Each mean represents two or three evaluations by each of ten panelists.

[b] Mean scores which fall within the range of the same bar are not significantly different.

the distribution.

Type of bean had a very important effect on toughness of seed coat scores. The three vine samples stored at 4°C had scores in the upper half of the distribution. Two of them, Vine A and C samples, scored 20.0 and 18.8 respectively . Vine A had seed coat significantly tougher than the majority of bush beans harvested after November 1986 and stored at 4°C.

Location did not have an important influence on the scores for seed coat toughness. Samples grown in the different locations had scores located in different areas of the distribution.

From the results presented above, the influence of type of bean and storage on toughness of seed coat was observed. Bush beans had more tender seed coats than three of the four vine beans studied. These results are in agreement with the criterion of Guatemalan consumers; that vine beans are not well accepted because they have tough and thick seed coats which, according to the consumers, causes digestive problems (Elias, 1985). Long term storage appeared to increase toughness in the seed coats of the bean samples. These results are compatible with what is reported by several authors. Saio (1976) found differences between seed coats of hard and normal soybeans, and reported that hard beans had more fiber and calcium in their seed coat than normal soybeans. She also observed that the micropyle seemed to be more dense in hard beans. Jackson and Varriano-Marston (1981) reported that biophysical and biochemical changes in both seed coat and cotyledon occur during storage. They claimed that the seed coat of hard beans, from accelerated storage, was the major barrier to bean softening during cooking. When they decorticated the bean samples before cooking, a significant reduction in cooking time was observed. Sefa-Dedeh et al. (1979) also reported that after removing the seed coat in cowpeas the force to extrude them was dramatically reduced, indicating that the seed coat plays an important role in texture.

4.4.5.5 Chewiness

Mean scores for chewiness are shown in Table 4.15. The scores ranged from 14.3 to 21.6, with higher scores representing chewier beans. This range was similar to the range for seed coat toughness.

The largest values for chewiness were given to the samples stored for six years under ambient conditions (Bush P and Q) and to two samples stored under accelerated conditions (Bush M and Vine B_2). They had scores ranging from 19.3 to 21.6. Bush O and Bush B samples, stored under ambient conditions for four or six months, had scores in the upper half of the distribution.

Type of bean appeared to have an important effect on chewiness scores. The four vine bean samples had scores in the upper half of the distribution. The vine B_2 beans

Table 4.15 - Chewiness scores

Sample identification		Harvest date (mon/year)	Storage temperature (^{o}C)	Panel mean score[a]	Result of means comparison[b]
Bush	P	1981	18-26	21.6	
Bush	Q	1981	18-26	19.9	
Bush	M	Feb/87	34	19.9	
Vine	B_2	Jan/87	34	19.3	
Vine	A	Jan/87	4	18.8	
Vine	B_1	Jan/87	4	18.7	
Bush	B	Aug/86	4	18.0	
Bush	O	Nov/86	18-26	17.9	
Bush	C	Dec/86	4	17.6	
Bush	J_2	Dec/86	34	17.3	
Vine	C	Jan/87	4	17.2	
Bush	N	Dec/86	4	16.6	
Bush	F	Sept/86	4	16.3	
Bush	J_1	Dec/86	4	16.2	
Bush	K	Jan/87	4	16.1	
Bush	I	Nov/86	4	15.9	
Bush	G	Sept/86	4	15.8	
Bush	H	Nov/86	4	15.5	
Bush	D	Nov/86	4	15.2	
Bush	E			14.3	

[a]Higher values = chewier sample on a scale of 0-30.
Each mean represents two or three evaluations by each of ten panelists.
[b]Mean scores which fall within the range of the same bar are not significantly different.

(stored under accelerated conditions) got the highest score among the vine samples, probably showing the combined effect of type of bean and storage conditions on the chewiness of the sample. Location did not influence the scores for chewiness.

4.4.6 Correlations Between Sensory Characteristics

The results presented above suggested that there were interrelationships among the sensory characteristics. As shown in Table 4.16, the correlations between many of the sensory characteristics were significant.

Cooked beans that had high scores for darkness of color also had high scores for hardness and chewiness. Darkness of color and hardness had a significant correlation of 0.37 while darkness of color and chewiness had a correlation of 0.26. The harder beans, stored for long periods under suboptimal conditions, were dark in color and also had large particles in the cotyledon and tough seed coats, which made them chewier than the fresher samples.

A relationship among the three flavor characteristics, beany flavor, beany aftertaste and bitterness, was found. The highly significant correlation between beany flavor and beany aftertaste (0.84) suggested that these two characteristics were very closely related (a bean with strong beany flavor left strong aftertaste after it was swallowed) or that the panelists were measuring the same thing for the two characteristics. Most of the bean samples that had high

Table 4.16 - Pearson correlation matrix of sensory scores

	Beany flavor	Beany aftertaste	Hard-ness	Particle size	Cohesi-veness	Seedcoat toughness	Chewi-ness	Bitter-ness	Darkness of color	Degree of splitting
Beany flavor	1.00	0.84[a]	-0.29[a]	-0.35[a]	0.25[a]	0.01	-0.05	0.12[c]	0.03	0.29[a]
Beany aftertaste		1.00	-0.23[a]	-0.26[a]	0.18[a]	-0.00	-0.05	0.15[b]	0.04	0.26[a]
Hardness			1.00	0.66[a]	-0.47[a]	0.16[a]	0.17[a]	0.07	0.37[a]	-0.47[a]
Particle size				1.00	-0.58[a]	0.12[b]	0.25[a]	0.04	0.33[a]	-0.47[a]
Cohesiveness					1.00	-0.09[c]	-0.12[b]	0.05	-0.20[a]	0.41[a]
Seed coat toughness						1.00	0.38[a]	0.14[b]	0.20[a]	-0.10[c]
Chewiness							1.00	0.24[a]	0.26[a]	-0.11[c]
Bitterness								1.00	0.18[a]	0.00
Darkness of color									1.00	-0.15
Degree of splitting										1.00

[a]significant at $p<0.001$
[b]significant at $p<0.01$
[c]significant at $p<0.05$

scores for beany flavor and beany aftertaste, also had high scores for bitterness. Bitterness appears to be an important part of the characteristic flavor of black beans. The beans given the lowest scores for beany flavor also received low values for beany aftertaste and intermediate values for bitterness. This suggests that length and conditions of storage may have an effect on beany flavor and aftertaste and, to a lesser extent, on bitterness.

A strong relationship was observed among the textural characteristics of cotyledon particle size, hardness and cohesiveness. The correlations found for these characteristics were: particle size and hardness (0.66), cohesiveness and hardness (-0.47), cohesiveness and particle size (-0.58). Bush bean E from Jutiapa had the smallest particle size in the cotyledon and also was the second most cohesive bean. Samples bush H and J had low scores for particle size as well as for hardness. The old samples (bush P and Q) and the three samples stored under accelerated conditions (bush M, J and B) were the least cohesive samples. They were also the hardest samples and had the greatest cotyledon granularity.

A high positive correlation was found between degree of splitting and cohesiveness (0.41). A high negative correlation existed between degree of splitting and hardness (-0.47) and between degree of splitting and particle size (-0.48). The samples with the lower percentage of split beans were also the samples that received high scores for hardness and size of particles in the cotyledon and low scores for cohesiveness. The number of split beans in a sample was mentioned as an important characteristic of good quality cooked beans by Guatemalan consumers (Watts et al., 1987). Consumers use the number of beans that have split during cooking to judge the cooking time and quality.

A relationship between chewiness and toughness of seed coat was also found, with a correlation of 0.38. The samples with the highest scores for seed coat toughness (bush P, vine A, C and B_2) also had high scores for chewiness. Significant correlations of 0.17 and 0.25 were found between chewiness and hardness and between chewiness and particle size respectively. The samples with the highest scores for chewiness were also given high scores for particle size and hardness. Adams and Bedford (1972) reported that chewiness is a parameter that should be included when evaluating textural characteristics in beans. They mentioned that gumminess and adhesiveness are characteristics perceived during chewing. Chewiness scores appear to be influenced by a number of different texture qualities.

An examination of texture and flavor characteristics showed a positive correlation (0.14) between bitterness and seed coat toughness. This finding confirms what is reported in the literature; that tannins, the compounds that contribute to bitterness of beans, are concentrated in the seed coat (Bressani & Elias, 1979).

Hardness was negatively correlated with beany flavor (-0.29) and with beany aftertaste (-0.23). Cohesiveness was positively correlated to beany flavor (0.25). The harder beans, which had low scores for cohesiveness, were the ones with lower scores for beany flavor and beany aftertaste.

The strong relationships presented above show either that some attributes were strongly related or that some attributes were measuring the same characteristic in the samples. Therefore, a procedure to reduce the ten variables to a lesser number of factors was followed.

4.4.7 Principal Component Analysis

Principal component analysis (PCA), using Factor analysis procedures from Statistical Analysis System (SAS, 1985), was carried out to identify underlying characteristics which provided common elements among the sensory attributes. PCA indicated common structures among some sensory attributes. Five principal components were extracted (Table 4.17). Communalities, which are the amounts of variance for individual variables explained by all components (Berenson et al., 1983), indicated that the number of components extracted was adequate and that outliers were not evident. Communalities greater than one would indicate problems with the solution, usually indicating that too many or two few components were

Table 4.17 - Rotated factor loadings for each component for 10 sensory attributes evaluated by a trained panel

Sensory Attribute	Factors: Cotyledon Texture 1	Flavor 2	Seed Coat 3	Color 4	Bitterness 5	Communalities
Cohesiveness	0.79	0.04	-0.06	-0.05	0.14	0.65
Degree of splitting	0.77	0.15	-0.06	0.14	-0.06	0.64
Hardness	-0.72	-0.15	0.06	0.36	0.06	0.69
Particle size	-0.78	-0.19	0.09	0.28	0.05	0.74
Aftertaste	0.14	0.94	-0.02	0.03	0.07	0.92
Beany flavor	0.22	0.93	0.01	-0.00	0.03	0.91
Seed coat toughness	-0.08	0.05	0.88	0.01	-0.04	0.79
Chewiness	-0.09	-0.08	0.73	0.19	0.24	0.65
Darkness of color	-0.18	0.05	0.16	0.91	0.07	0.90
Bitterness	0.00	0.10	0.12	0.07	0.96	0.95
Percent of variance	24.96	18.74	13.89	11.18	10.30	
Cumulative percent of variance	24.96	43.70	67.59	79.77	90.07	

extracted. Low communalities would indicate that the variables with low values were outliers.

The PCA solution accounted for 90% of the variance among samples. Factor loadings (Table 4.17), which are the correlations between the components and the variables, were examined to interpret the components. Component one, which accounted for 24.9% of the variance, was interpreted as a cotyledon texture component due to high loadings for cohesiveness (0.79), degree of splitting (0.77), hardness (-0.72) and particle size (-0.78). Particle size and hardness were directly related and they were inversely related to cohesiveness and degree of splitting. Component two accounted for 18.74% of the variance. This component was interpreted as a flavor component as it had high loadings for beany aftertaste (0.94) and beany flavor (0.93). Component three was interpreted as a seed coat component as evidenced by high loadings for the attributes seed coat toughness (0.88) and chewiness (0.73). It explained 13.89% of the variance. Component four, a color component, had high loadings for the attribute darkness of color only. Component four accounted for 11.18% of the variance. Component five, a bitterness component, accounted for 10.3% of the variance.

These results suggested the possibility of measuring the sensory perception of black beans using fewer descriptive terms. Five descriptors, one representing each of the principal components, could be chosen on the basis of their factor loadings to characterize samples. The descriptor with the highest loading within a single factor should be chosen. However, in this research, several attributes within a single factor had similar loadings. Therefore a combined criterion to select attributes, based on size of the loading and ease and convenience to measure the attribute by the trained panel, may be used.

According to the results, in component one, cohesiveness and cotyledon particle size showed the highest loadings (0.79 and -0.78 respectively). Because the measurement of particle size is more objective and better standards are available to define the extremes of this characteristic, particle size may be chosen.

Component two included beany aftertaste and beany flavor, both having similar loadings (0.94 and 0.93 respectively). Because both attributes are equally difficult to measure, either one could be chosen. Beany aftertaste may be selected.

Component three included seed coat toughness and chewiness with loadings of 0.88 and 0.73 respectively. Seed coat toughness may be chosen, because it had a higher loading. Nevertheless, because of the high correlation between those two characteristics (Table 4.16), and the fact that chewiness is easy to measure, one could consider including chewiness instead, for this component. From component four and five, the measurement of darkness of color and bitterness may be included.

4.5 ACCEPTABILITY OF SAMPLES

Twenty-two different samples of beans (20 experimental samples, the blind control and the reference) were evaluated for overall acceptability using a 9-point hedonic scale ranging from 1=dislike extremely to 9=like extremely. As shown in Table 4.18 the range of scores for this characteristic was 2.5 to 6.8.

Conditions of storage and length of storage both appeared to influence the acceptability of the samples. The samples stored under accelerated conditions for 14 weeks (Bush M, J_2 and Vine B_2) and the beans that had been stored for 6 years under ambient conditions (Bush P and Q) were significantly less acceptable than all the other samples, with scores ranging from 2.5 to 3.5.

Type of bean also influenced the scores for acceptability. The most acceptable samples were the bush beans from Jutiapa and Chimaltenango. Among the vine beans, Vine C sample was the most acceptable.

The results indicated that texture played a major role in determining the acceptability of the 22 bean samples. The bush E sample, which was one of the two most acceptable samples, was also the sample with the smallest particle size, the second most cohesive sample and also the least chewy sample. The Vine C bean, which was also highly

Table 4.18- Overall hedonic scores

Sample identification		Harvest date (mon/year)	Storage temperature (°C)	Panel mean score[a]	Result of means comparison[b]
Bush	E	Nov/86	4	6.8	
Bush	K	Jan/87	4	6.8	
Bush	D	Nov/86	4	6.7	
Bush	L	Dec/86	4	6.5	
Bush	J_1	Dec/86	4	6.4	
Bush	H	Nov/86	4	6.4	
Bush	C	Dec/86	4	6.3	
Vine	C	Jan/87	4	6.2	
Bush	A	Jan/87	4	6.1	
Bush	G	Sept/86	4	6.1	
Bush	I	Nov/86	4	5.9	
Vine	B_1	Jan/87	4	5.7	
Bush	F	Sept/86	4	5.7	
Bush	N	Dec/86	4	5.5	
Vine	A	Jan/87	4	5.3	
Bush	B	Aug/86	4	5.0	
Bush	O	Nov/86	18-26	5.0	
Bush	J_2	Dec/86	34	3.5	
Vine	B_2	Jan/87	34	3.4	
Bush	Q	1981	18-26	3.0	
Bush	P	1981	18-26	2.9	
Bush	M	Feb/87	34	2.5	

[a]Higher values = more liked sample on a scale of 0-9. Each mean represents two evaluations by each of 30 panelists.
[b]Mean scores which fall within the range of the same bar are not significantly different.

acceptable, was the softest and most cohesive sample among all the other samples and the least chewy in the group of vine bean samples. On the other hand, the least acceptable beans were those which had the largest particle size and the hardest and least cohesive cotyledon. They were also the most chewy samples. Most of the unacceptable samples also had a low score for degree of splitting.

Flavor characteristics also played an important role in determining the acceptability of the samples. Bush E, one of the most acceptable samples, had the lowest mean score for bitterness and intermediate score for beany flavor. The least acceptable samples (old samples and those stored under accelerated conditions) had the lowest mean scores for of beany flavor. The vine beans from Chimaltenango, which were highly scored for flavor intensity, had an intermediate overall acceptability, ranging from 5.3 to 6.2. Texture was therefore the major determinant of acceptability.

These results are in agreement with the survey results reported by Watts et al (1987). The survey, conducted among Guatemalan consumers, reported that the principal characteristics of good quality cooked beans were: splitting across the middle of the beans, easy spreading of the cotyledon, soft, spongy and doughy grains. From the present study, it is clear that the size of the particles and the cohesiveness of the cotyledon were very important characteristics in determining acceptability. Chewiness was also a determining characteristic and since principal component analysis showed that it was closely related to seed coat toughness, it can be assumed that the toughness of the seed coat was also influencing the acceptability of the samples. This may explain why the samples which had the most intense beany flavor (considered desirable among consumers), but also had the toughest seed coat, were rated as having only an intermediate overall acceptability. The results of the final acceptability test might suggest that the influence of length and conditions of storage and type of bean had more effect on acceptability than the location influence.

To represent graphically the outstanding characteristics of the most acceptable and the least acceptable samples, spider-web diagrams were produced. Superimposed spider-webs, showing the intensity of each characteristic for the three most acceptable and the three least acceptable samples, are presented in Figures 4.1 and 4.2, respectively.

The three most acceptable samples had high values for cohesiveness and degree of splitting and low values for particle size, hardness, seed coat toughness and darkness of color. The three least acceptable beans had high values for particle size, hardness, seed coat toughness and chewiness and low values for degree of splitting and cohesiveness. Flavor characteristics did not show a big difference between the two groups.

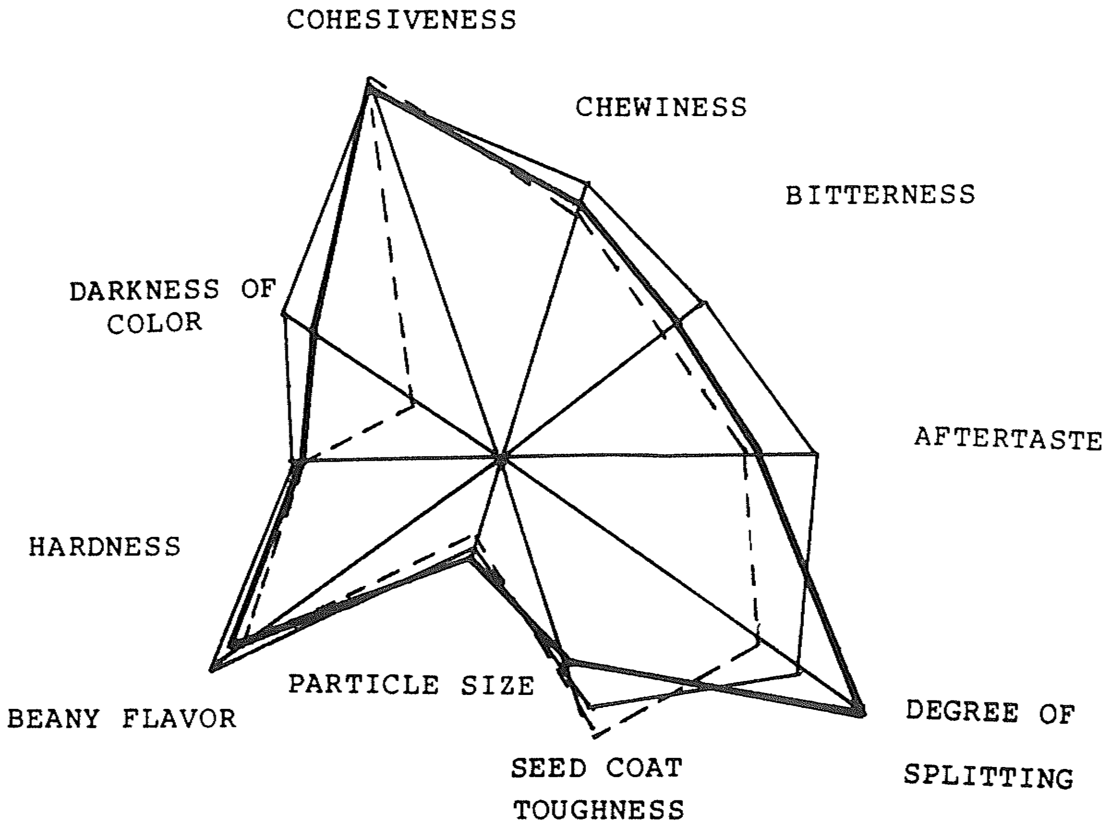


Fig. 4.1 - Graphic representation of sensory attribute intensities of the three most acceptable samples

BUSH D --- BUSH E — BUSH K

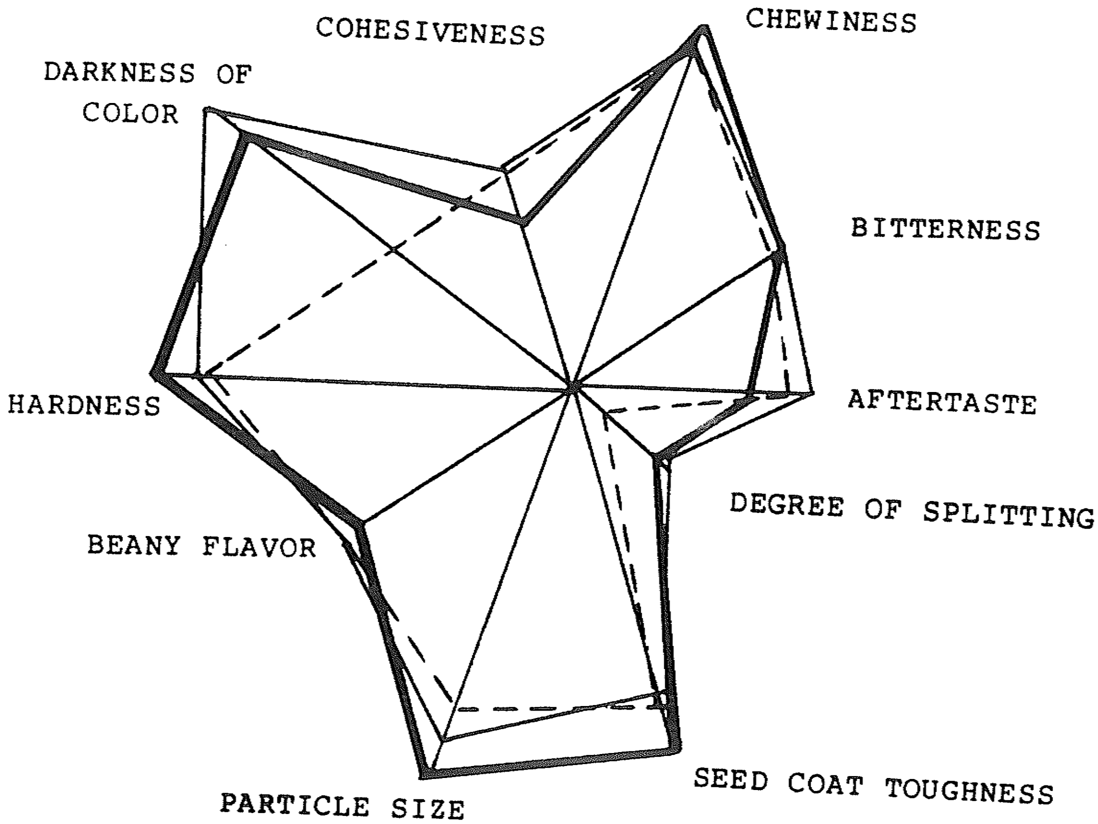


Fig. 4.2 - Graphic representation of sensory attribute intensities of the three least acceptable samples
— BUSH Q ▬ BUSH P --- BUSH M

Figure 4.3 shows superimposed spider-web diagrams to contrast the most acceptable (Bush E) and the least acceptable (Bush M) bean samples.

4.6 CORRELATIONS BETWEEN HEDONIC AND SENSORY SCORES

The results presented suggest that some sensory characteristics were more important than others in influencing the hedonic scores (acceptability) given to the different samples. Table 4.19 shows the correlations obtained between sensory attributes and hedonic scores. A highly significant positive correlation was found between cohesiveness and hedonic score (0.91). Figure 4.4 illustrates this correlation. As can be seen, samples were distributed in two different groups. One group contained the 17 fresh beans with cohesiveness scores between 17 and 23 and hedonic values between 5 and 7, and the other group contained the 5 old beans (including long term storage and accelerated storage beans) which had cohesiveness scores between 9 and 17 and hedonic values between 2.5 and 3.5.

A highly significant negative correlation (-0.93) was found between particle size and hedonic values. Figure 4.5 graphically shows this correlation. Here again, the beans were split into two different groups, the fresh or recently harvested beans and the old/stored beans. The fresh beans had small particles (scores between 4.4 and 11.3) and hedonic scores between 5 and 6.8. The old/stored samples had large particles (scores between 14.6 and 22.9) and

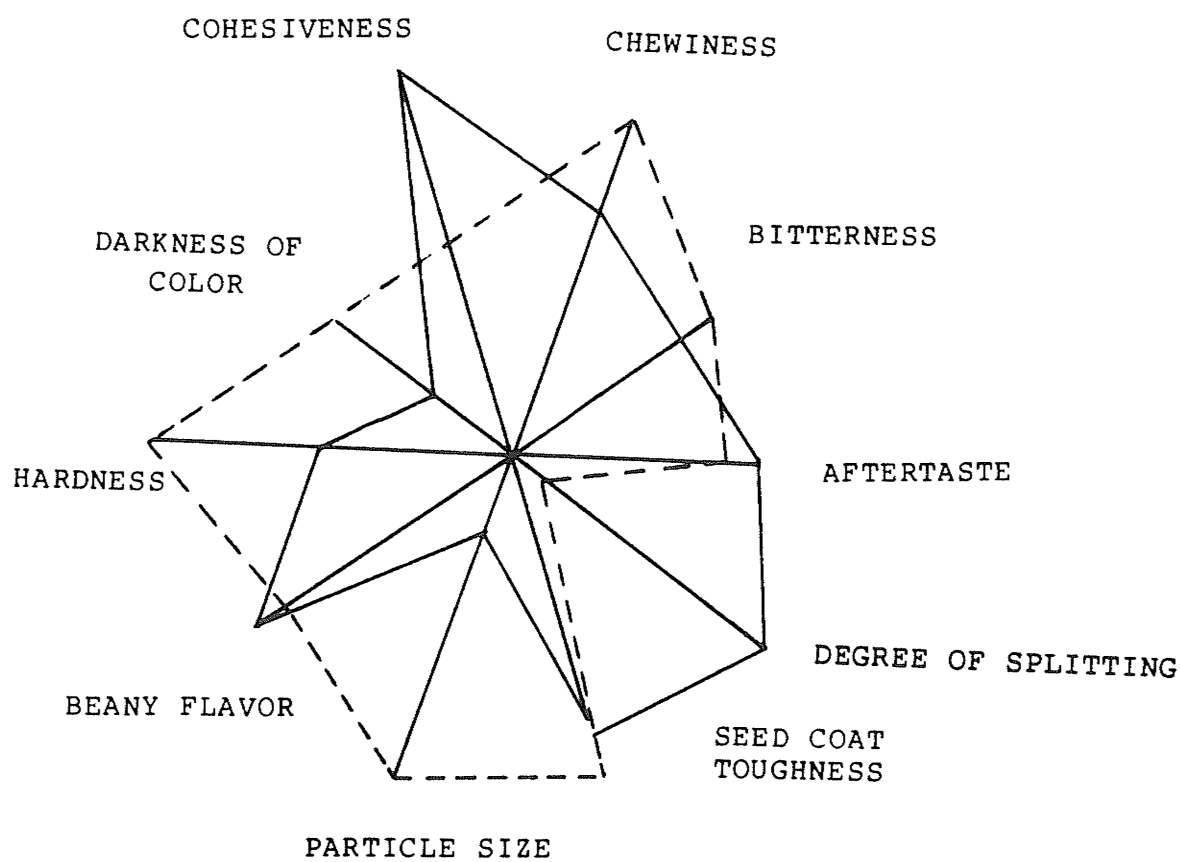


Fig. 4.3 - Graphic representation of sensory attribute intensities of the most acceptable (Bush E) and the least acceptable (Bush M) samples

— BUSH E --- BUSH M

Table 4.19 - Pearson correlation matrix of hedonic and sensory scores

	Hedonic scores
Beany flavour	0.68[b]
Beany aftertaste	0.54[c]
Hardness	-0.88[a]
Particle size	-0.93[a]
Cohesiveness	0.91[a]
Seed coat toughness	-0.64[b]
Chewiness	-0.83[a]
Bitterness	-0.06
Darkness of color	-0.53[c]
Degree of splitting	0.65[b]

[a]significant at $p<0.001$
[b]significant at $p<0.01$
[c]significant at $p<0.05$

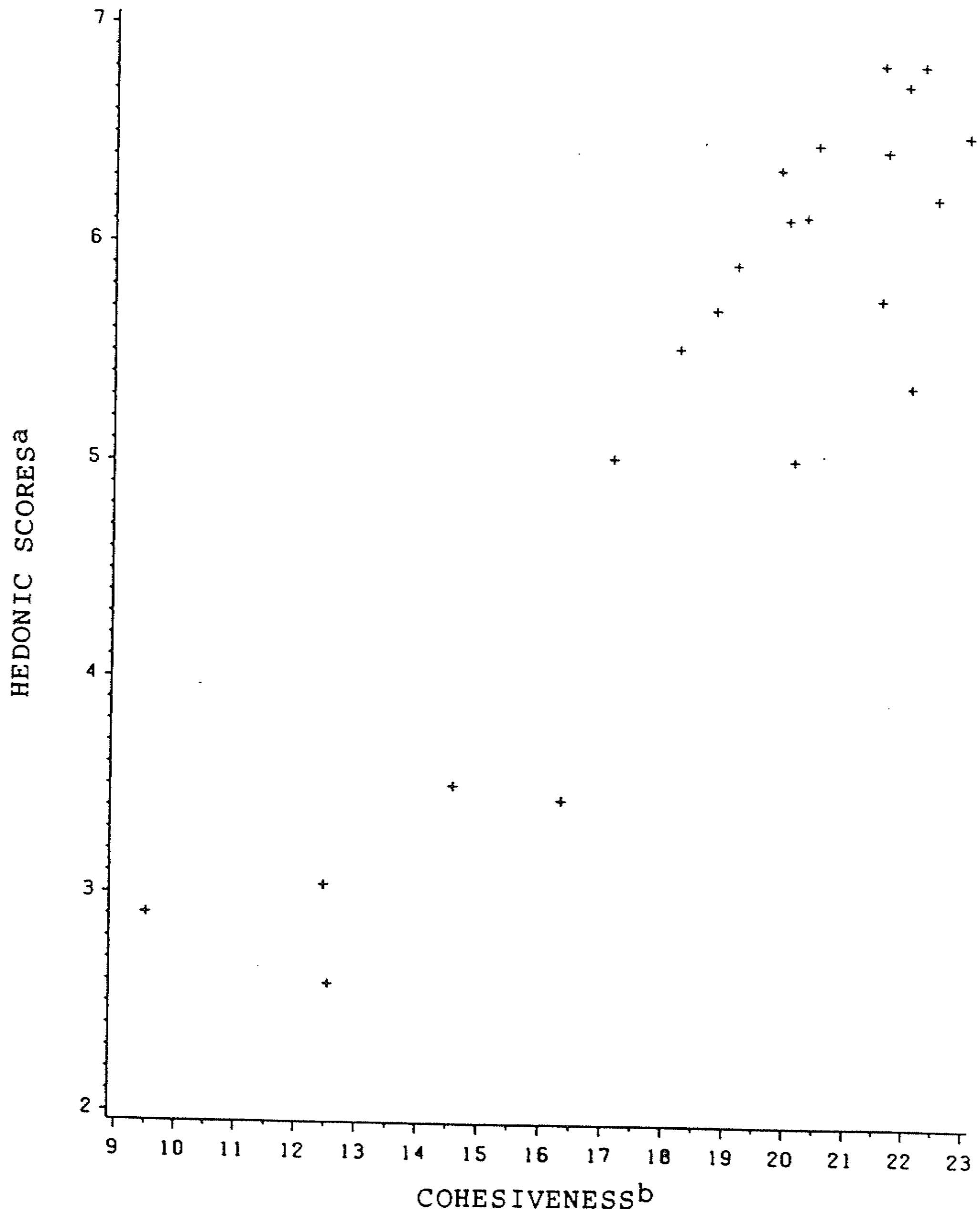
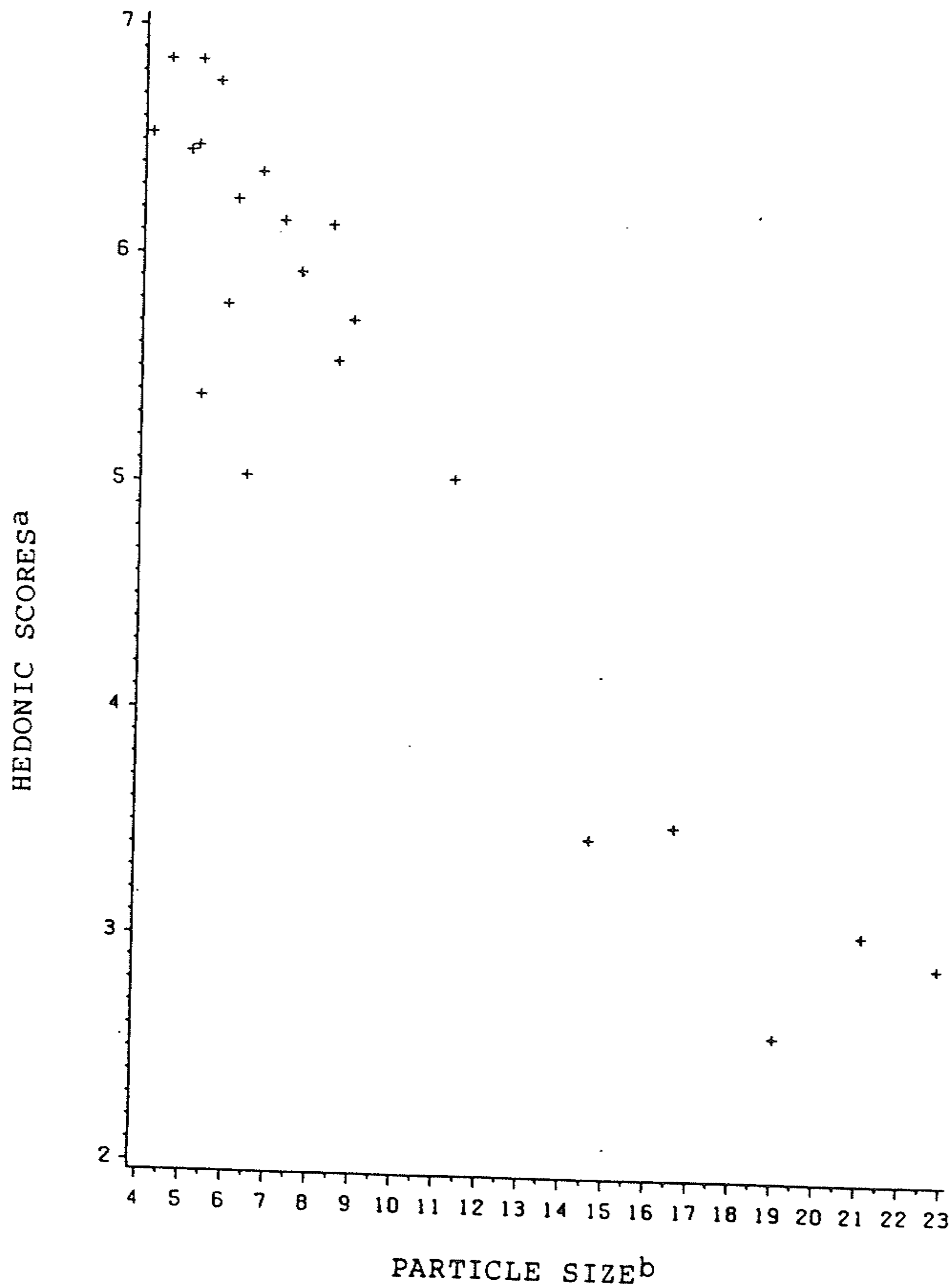


Fig. 4.4 - Correlation between hedonic scores and cohesiveness

[a]mean untrained panel scores (N=22,30 panelists)
scores ranged from 2.5 to 6.8
scales ranged from 1 to 9

[b]mean trained panel scores (N=20,10 panelists)
scores ranged from 4.4 to 22.9
scales ranged from 0 to 30



Particle Size[b]

Fig. 4.5 - Correlation between hedonic scores and particle size

[a]mean untrained panel scores (N=20,30 panelists) scores ranged from 2.5 to 6.8

[b]mean trained panel scores (N=20,10 panelists) scores ranged from 4.4 to 22.9

hedonic values less than 3.5.

High negative correlations were also found between hardness and hedonic value (0-.88) and between chewiness and hedonic score (-0.83). Figure 4.6 shows the correlation between chewiness and hedonic score. The bean samples were once again split into two different groups, the fresh beans and the old/stored beans. The fresh samples were less chewy and had high hedonic scores ranging from 5 to 6.8. The old/stored samples were more chewy than the fresh ones and had low hedonic scores of 2.5 to 3.5.

A high positive correlation (0.68) was found between beany flavor and hedonic score. This relationship is presented in Figure 4.7. Once again, the old/stored samples were grouped in a different universe than the fresh samples, with low intensities of beany flavor (between 13.9 and 18.4) and low hedonic scores (2.5 to 3.5).

Significantly negative correlations were found between seed coat toughness and hedonic score (-0.64) and between darkness of color and hedonic score (-0.53). A positive correlation (0.65) was found between degree of splitting and hedonic score.

4.7 PREDICTION OF HEDONIC RATINGS FROM DESCRIPTIVE ANALYSIS DATA

The establishment of the relationship between sensory parameters of a food product and its perceived acceptability is an important step in the development of new food

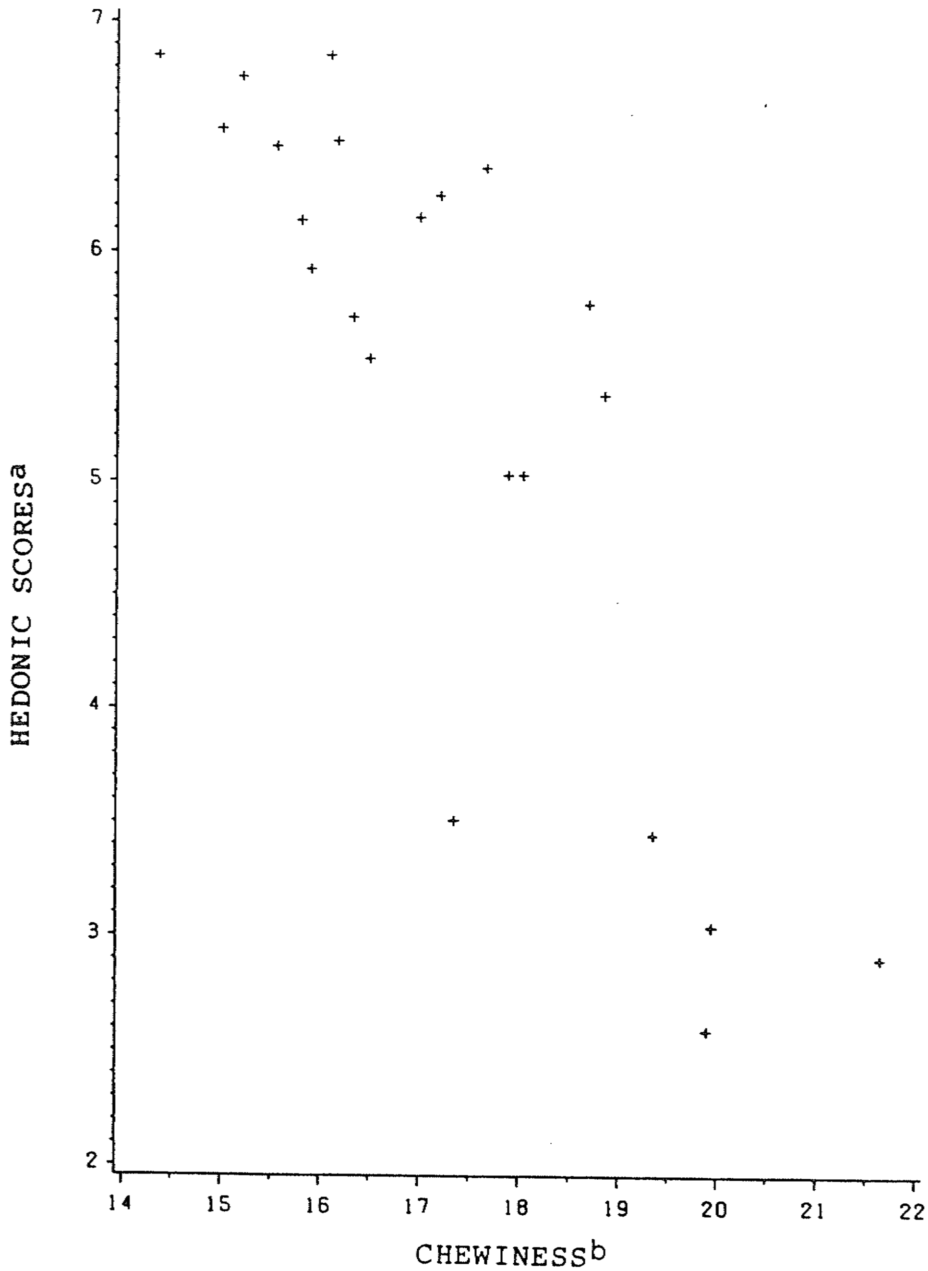


Fig. 4.6 - Correlation between hedonic scores and chewiness

[a]mean untrained panel scores (N=20,30 panelists) scores ranged from 2.5 to 6.8

[b]mean trained panel scores (N=20,10 panelists) scores ranged from 14.3 to 21.6

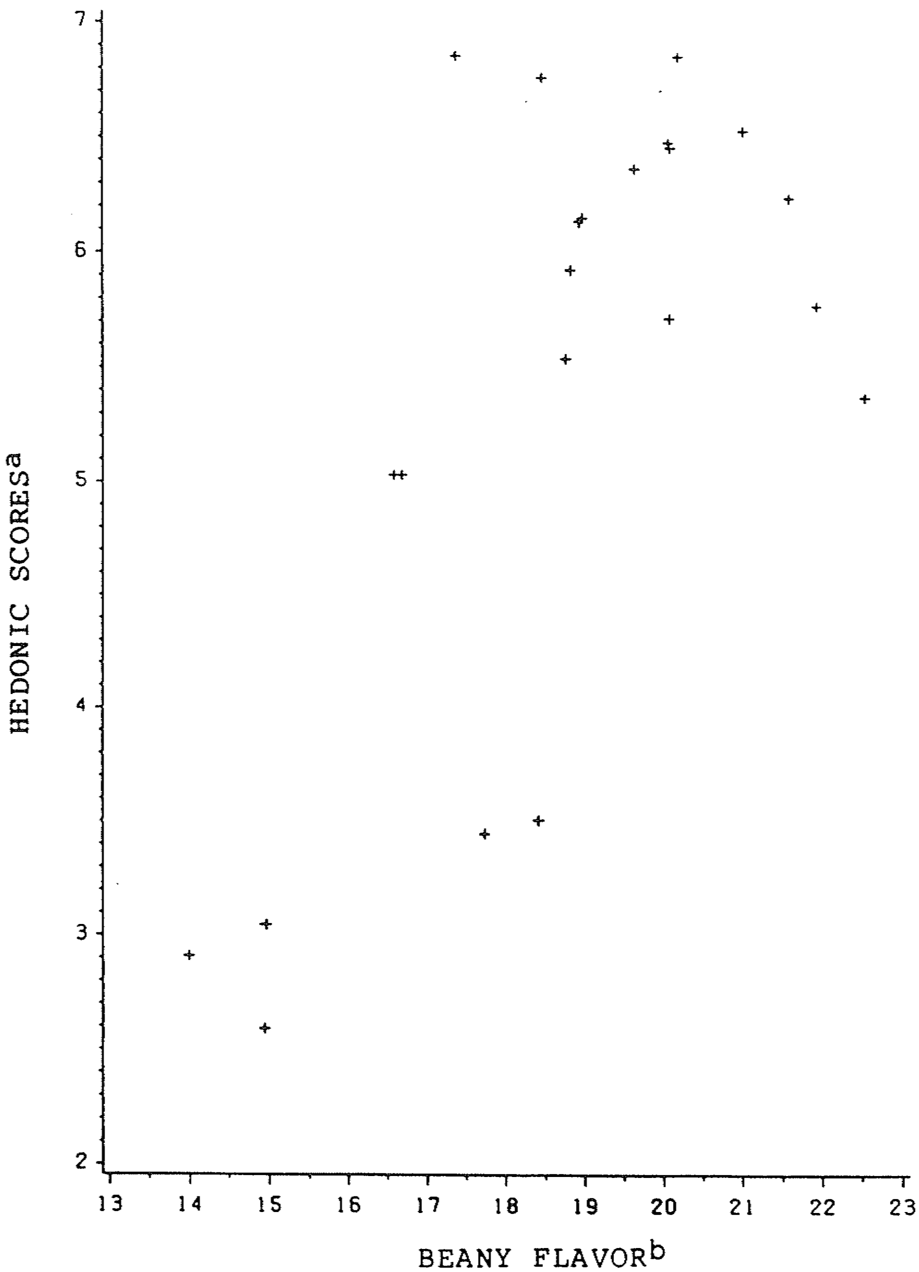


Fig. 4.7 - Correlation between hedonic scores and beany flavor

[a]mean untrained panel scores (N=20,30 panelists) scores ranged from 2.5 to 6.8

[b]mean trained panel scores (N=20,10 panelists) scores ranged from 13.9 to 22.5

products, the improvement of existing food products and the direct quantification of quality control parameters (Horsfield and Taylor, 1976). Various methods interrelate sensory and hedonic measures. The two principal methods that have been used are correlation and regression analysis (Moskowitz et al., 1979).

4.7.1 Prediction From Sensory Variables

Equations to predict hedonic ratings, from attribute scores given to black beans, were developed using stepwise multiple regression analysis and the maximum R^2 procedure. Table 4.20 shows the multiple regression analysis carried out to identify the sensory characteristics that were the most important to the hedonic scores for the 20 samples of beans (without including the reference sample and the control). Stepwise procedure showed that very good predictability was possible with the two variable model, based on scores for cotyledon particle size and for chewiness. The equation derived from this combination was:

$$\text{Acceptability} = 10.89 - (0.17)x_1 - (0.22)x_2$$

The coefficient of determination (r^2) for this equation was 0.91. The r^2 measures that portion of the total variability in Y that is "accounted for" by the fitted simple linear regression model (Berenson et al., 1983). This model, therefore, accounted for 91% of the variation in the hedonic scores. Only small improvements in this value were evident

Table 4.20 - Multiple regression analysis using Max R^2 and stepwise for prediction of hedonic ratings of 20 samples[a] of black beans

Variable Description	Beta Value (Regression Coefficient)				
	1 var	2 var[b]	4 var	6 var	7 var
Y Intercept	7.49	10.89	11.03	8.98	9.58
X1 Particle Size	-0.22	-0.17	-0.20	-0.17	-0.19
X2 Chewiness		-0.22	-0.11	-0.10	-0.11
X3 Seed Coat Toughness			-0.078	-0.09	-0.10
X4 Split			-0.0186	-0.14	-0.02
X5 Color				0.022	0.02
X6 Aftertaste				-0.20	-0.21
X7 Intensity				0.26	0.25
X8 Hardness					
X9 Cohesiveness					
X10 Bitterness					
R^2	0.876	0.914	0.921	0.929	0.933

[a]without including the reference and the blind control sample

[b]In the stepwise regression procedure no other variables met the 0.1500 significance level for entry into the model.

when 4 or 6 variables were included in the equation. It was concluded that, in this case, two variables were sufficient for the prediction of hedonic scores.

Table 4.21 shows the residual values obtained from the difference between the actual and the predicted hedonic scores. Residual values were very low (between 0.02 and 0.8) indicating that the equation worked well in predicting the acceptability of the samples. The influence of particle size and chewiness on the hedonic scores is shown in Figure 4.8.

Regression analysis was also applied to predict the acceptability of the 15 fresh samples of the group of 20 samples, leaving out the scores given to the old samples and the samples stored under accelerated conditions. Table 4.22 shows that the use of a three variable equation, including chewiness, particle size and aftertaste, was sufficient to predict hedonic scores for these 15 samples, with an r^2 of 0.79. The equation derived from this combination was:

$$\text{Acceptability} = 11.25 - (0.35)x_1 + (0.09)x_2 - (0.11)x_3$$

These results showed that similar characteristics to the ones included in the first equation (for 20 samples), emerged when the 5 old/stored samples were left out. However, aftertaste as well as cotyledon particle size and chewiness contributed significantly to the equations.

4.7.2 Prediction From Factors

The five factors produced from PCA were related to

Table 4.21 - Residual between actual and predicted hedonic values of 20 samples of black beans

Actual[a] Hedonic Value	Predicted[b] Hedonic Value	Residual[c]
5.38	5.77	-0.39
5.03	5.75	-0.72
6.36	5.79	0.57
5.03	4.93	0.10
6.75	6.49	0.26
6.85	6.37	0.48
5.54	5.71	-0.17
5.77	5.70	0.07
6.85	6.87	-0.02
6.24	5.99	0.25
5.71	5.69	0.02
6.13	5.89	0.24
6.45	6.53	-0.08
5.92	5.99	-0.07
6.47	6.36	0.11
2.91	2.11	0.80
3.50	4.11	-0.61
3.04	2.78	0.26
2.59	3.15	-0.56

[a]Each mean represents two evaluations by each of 30 untrained panelists.

[b]Each mean score was calculated from the predictive equation $ACC = 10.89 - (0.17)X_2 - 0.22\ (X_2)$.

[c]actual value - predicted value

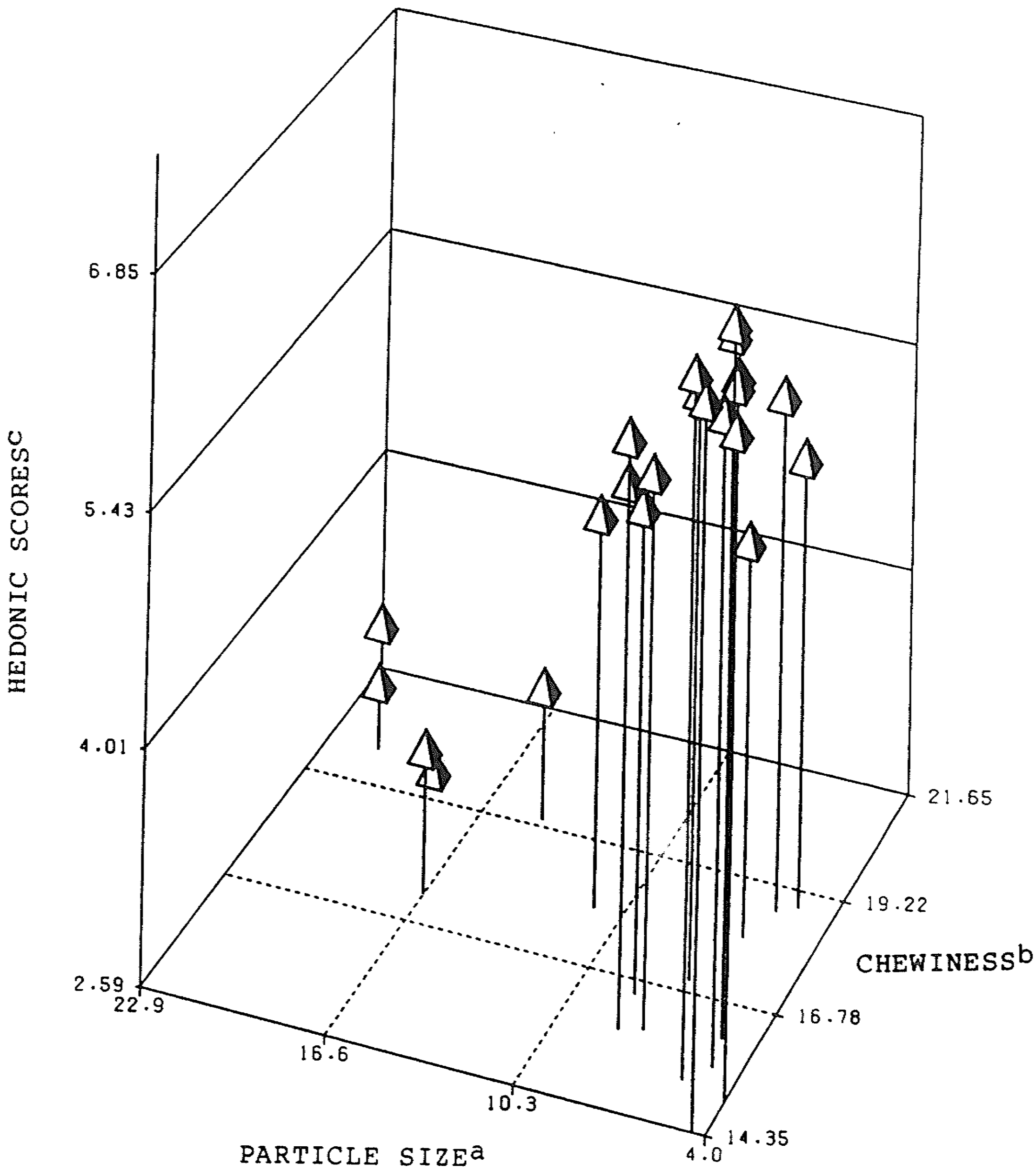


Fig. 4.8 - Relationship among particle size, chewiness and hedonic scores

[a]mean trained panel scores (N=20,10 panelists) higher values represent larger particles in the cotyledon

[b]mean trained panel scores (N=20,10 panelists) higher value means chewier sample

[c]mean untrained panel scores (N=22,30 panelists) higher value means more acceptable bean sample

Table 4.22 - Multiple regression analysis using Max R^2 and stepwise for prediction of hedonic ratings of 15 fresh black bean samples (without old beans, the reference and the control)

Variable description	1 var	2 var*	3 var	4 var	5 var
Intercept	11.53	7.14	11.25	7.9	7.77
Chewiness	-0.32	0.29	-0.35	-0.27	-0.26
Cohesiveness		0.18		0.12	0.12
Aftertaste			0.09	0.08	0.09
Particle size			-0.11		
Seed coat toughness				-0.07	-0.07
Color					-0.01
R^2	0.505	0.748	0.792	0.828	0.841

*In the stepwise regression procedure no other variable met the 0.1500 significance level for entry into the model consumer ratings for overall sensory acceptance of black beans. Factor scores (Table 4.23) were computed for each of the 20 bean samples and used as the predictor variables in the regression analysis. Mean values of hedonic scores were used as the dependent variable. Table 4.24 shows the values of the parameters for the multiple regression equation based on the 5 factors. This equation, which included the five components, was:

$$\text{Acceptability} = 5.35 - 1.00(\text{factor } 1) + 0.15(\text{factor } 2) + 0.62(\text{factor } 3) - 1.07(\text{factor } 4) + 1.60(\text{factor } 5)$$

The coefficient of determination (r^2) for this equation was 0.88. This high value was obtained only when all five factors were included in the equation. Table 4.25 shows the residual obtained from the difference between the actual and the predicted hedonic scores. The scores ranged between 0 to 1.01, showing that good prediction was obtained based on this equation using the factors. The r^2 value for the five factor equation was not as high as the r^2 obtained with the equation including the two sensory variables (chewiness and particle size).

Through the use of MVA we were able to identify sensory descriptors critical to the acceptance of beans as these beans were rated by the in-house consumer panel. It would be interesting to verify the importance of these attributes through further studies with true consumer groups representative of different ethnic and socioeconomic sectors

Table 4.23 - Factor scores for 20 black bean samples

Samples used in regression	Factor Name					
	Cotyledon texture 1	Flavor 2	Seed coat 3	Color 4	Bitterness 5	Hedonic scores
Vine A	-1.1271	0.46499	-0.03327	0.9232	0.35655	5.37879
Bush B	-0.8091	-0.63975	-0.52679	0.4264	-0.00821	5.03030
Bush C	-0.8549	-0.18168	0.11123	-0.0365	0.13310	6.36364
Bush Q	-0.0126	-0.79490	-0.52539	0.0751	0.28123	5.02985
Bush D	-0.7536	-0.29882	-0.33819	-0.7303	0.08617	6.75758
Bush K	-0.5511	0.21509	-0.30757	-0.2686	0.18677	6.85075
Bush N	-0.2838	-0.08144	-0.13499	0.0935	0.16697	5.53731
Vine B_1	-0.5622	0.65616	-0.30181	0.4794	0.28346	5.77612
Bush P	1.5990	-0.87944	-0.17226	1.2864	0.02881	2.90909
Bush E	-0.5624	-0.54319	-0.21191	-0.8652	-0.16212	6.85075
Vine C	-0.6175	0.65796	-0.28604	0.4145	0.18817	6.24242
Bush F	0.4532	0.31967	0.46687	0.1171	0.06314	5.71642
Bush G	-0.0283	0.12176	0.58764	-0.3810	-0.24589	6.13433
Bush J_2	0.8942	0.15374	-0.06952	-0.2786	-0.13562	3.50746
Bush H	-0.2558	0.27941	0.04667	-0.8510	-0.23151	6.45455
Bush I	-0.1193	0.03930	-0.12775	-1.1188	-0.24495	5.92424
Bush Q	1.8202	-0.15114	0.08720	0.6131	-0.17997	3.04478
Bush J_1	-0.1057	0.46306	0.23509	-0.7129	-0.16720	6.47761
Bush M	1.7090	-0.55458	0.23034	0.0195	-0.21089	2.59091
Vine B_2	0.9463	0.39142	0.70422	0.4984	-0.34148	3.44776
						6.53030

Table 4.24 - Multiple regression analysis using Max R^2 for prediction of hedonic ratings of 21 samples[a] of black beans

Variable description	5 factors
Intercept	5.35
Factor 1	-1.00
Factor 2	0.15
Factor 3	0.62
Factor 4	-1.07
Factor 5	1.60
R^2	0.88

[a]without including the control sample

Table 4.25 - Residual between actual and predicted hedonic values of 20 samples of black beans (using factors)

Actual[a] hedonic value	Predicted[b] hedonic value	Residual[c]
5.4	6.1	-0.75
5.0	5.2	-0.23
6.3	6.5	-0.14
5.0	5.2	-0.25
6.7	6.7	-0.02
6.8	6.3	0.50
5.5	5.7	-0.17
5.7	5.7	0.0
2.9	2.1	0.74
6.8	6.3	0.47
6.2	5.7	0.48
5.7	5.2	0.49
6.1	5.7	0.34
3.5	4.5	1.01
6.4	6.2	0.22
5.9	6.2	-0.28
3.0	2.6	0.43
6.4	6.1	0.29
2.6	3.3	-0.70
3.4	3.8	-0.40
6.5		

of the Guatemalan population. Under different experimental conditions the actual predictive equations could well be modified. However, evidence from this study and the information gained with the earlier survey of Guatemalan consumers indicate that the critical characteristics identified through the PCA and regression analysis are likely to be good predictors of bean quality under any circumstances.

CHAPTER V

GENERAL DISCUSSION AND CONCLUSIONS

Little work has been published on ways to establish the relationships between sensory attributes and consumer acceptability of food products (Schutz and Damrell, 1974). Few studies relating sensory characteristics to acceptability have been reported for horticultural products (Sanford et al., 1988), and none have been reported for legumes. Information gained in the present study, on the relative importance for acceptability of the main sensory attributes of black beans, should be useful for future research on bean quality improvement.

The first objective of this study was to identify and quantify appearance, flavor and texture attributes of black beans using descriptive sensory analysis. A ten member trained panel selected 10 attributes as representative of black bean sensory attributes. These were: darkness of color, degree of splitting, beany flavor, beany aftertaste, bitterness, cotyledon particle size, hardness, cohesiveness, seed coat toughness, and chewiness. Analysis of Variance showed that there were significant differences ($p<0.001$) among the samples for all of the attributes selected. The means comparisons showed that there was good discrimination among the samples using these attributes.

The second objective of the study was to examine the influence of storage, bean type and growing location on sensory quality. Storage length and conditions appear to be factors that had the greatest effect of the characteristics of the samples. Type of bean and location of growth also appeared to determine some sensory characteristics. Samples that had been stored for long periods, and samples stored under accelerated conditions had darker seed coats and fewer split beans than the fresher or well-stored samples. Storage appear to affect texture as well as appearance of the beans. The beans stored for longer periods and under accelerated storage were rated as having the hardest and least cohesive cotyledon, and the greatest cotyledon granularity.

Seed coat toughness and chewiness were affected by storage, bean type and growing location. Old beans and vine beans grown in Chimaltenango had the highest scores for seed coat toughness and chewiness.

For flavor characteristics a combined effect of storage time and conditions and of type of beans and growing location was observed. The old samples and samples stored under accelerated conditions had the least intense beany flavor and beany aftertaste. Vine beans, grown in Chimaltenango, had the most intense beany flavor, beany aftertaste, and bitterness.

The third objective was to classify the sensory characteristics responsible for intersample variation into different factors using principal component analysis (PCA).

Five factors, responsible for 90% of the variance, were extracted by the analysis. The factors were related to cotyledon texture (factor 1), to beany flavor (factor 2), to seed coat characteristics (factor 3), to color (factor 4), and to bitterness (factor 5). This suggests the possibility that much of the variability in sensory quality among black beans could be accounted for fewer descriptors. One attribute representative of each component could be chosen based on the size of the factor loading and the ease to be measured. Based on this criteria, cotyledon particle size, beany aftertaste, seed coat toughness or chewiness, bitterness and darkness of color may be selected and evaluated.

The fourth objective was to determine the overall acceptability of the 22 samples of beans using an in-house untrained panel of 30 untrained judges. Analysis of variance indicated that there were significant differences among hedonic scores and comparison of mean scores showed a good discrimination among the samples. Texture played a major role in determining acceptability of the samples. The most acceptable samples were the most cohesive samples which had small particles in the cotyledon. The least acceptable samples were the samples with the hardest and least cohesive cotyledon and the largest particles in the cotyledon. Flavor was less important in determining acceptability of the samples. Beans with the most intense beany flavor and aftertaste had only intermediate acceptability. Because samples with intense flavor also had tough seed coats, it is believed that the tough seed coat and the chewiness affected the hedonic scores given to these samples.

The final objective was to determine the most important sensory characteristics affecting acceptability of the samples by relating the results of the descriptive sensory analysis and the acceptability test using multiple regression analysis. Prediction of hedonic scores based on sensory attributes was carried out using multiple regression analysis. Stepwise procedure showed that good predictability was possible with the two variable model, based on scores for cotyledon particle size and chewiness. The high coefficient of determination obtained from the equation (0.91) indicated that the model accounted for 91% of the variation in the acceptance scores. Using the five factors, a good prediction of acceptability can be achieved ($r^2 = 0.88$).

In the present study a good prediction was obtained using two variables instead of the equation which included the five factor scores. Because, it cannot be assumed that the two variable model (particle size and chewiness) will apply to all groups of beans or to different groups of consumers, the evaluation of the five characteristics identified using PCA factors is recommended.

The number of sensory characteristics was appropriate.

Nevertheless it should be possible to use fewer characteristics to evaluate bean acceptability. Fewer characteristics would reduce time spent in training, and could make testing faster and easier.

The results from this study suggests that a good prediction of acceptability based on attribute scores given by a well-trained panel can be obtained. By reducing the amount of variables this testing will not demand an excessive amount of time and resources.

CHAPTER VI

SUGGESTIONS FOR FURTHER RESEARCH

1. The use of five sensory attributes derived from PCA factors (cotyledon particle size, beany aftertaste, seed coat toughness or chewiness, bitterness and darkness of color) to evaluate the sensory qualities of black beans, should be validated using different samples of black beans and different groups of Guatemalan consumers.
2. Studies should be carried out to determine prediction equations appropriate for different groups of Guatemalan consumers: the Indian consumers living in the highlands, the Ladino consumers living in rural areas, and the urban Ladino consumers.
3. Flavor characteristics should be investigated using a wider group of bean samples, to determine whether off-flavors may present problems to acceptance.
4. Physical tests that correlate well with appearance and texture attribute scores as determined by the trained panels, should be developed. Special attention should be given to percent seed coat as a possible predictor of bean quality.

REFERENCES

Abbot, J. 1973. Sensory assessment of textural attributes of foods. Ch.3. In "Texture Measurements of Foods," A. Kramer and A.S. Szczesniak (Ed.), p. 17. D. Reidel Publishing Co., Dordrecht, Holland.

Agriculture Canada. 1986. The Apple II computer based texture data acquisition and analysis system. Engineering and Statistical Research Institute. Ottawa, Canada.

Adams, M.W. and Bedford, C.L. 1972. Breeding food legumes for improved processing and consumer acceptance properties. In "Nutritional Improvement of Food Legumes by Breeding," M. Milner (Ed.), p. 299. John Wiley and Sons, New York, NY.

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

Berenson, M.L., Levine, D.M. and Goldstein, M. 1983. Multiple regression: an introduction and basic concepts. In "Intermediate Statistical Methods and Applications: A Computer Package Approach," p. 280,428. Prentice-Hall, Inc., Englewood Cliffs, NJ.

Bhatty, R.S., Nielson, M.A., and Slinkard, A.E. 1983. Comparison of the cooking quality of Laird and commercial Chilean lentils grown in the Canadian prairies. Can. Inst. Food Sci. Technol. J. 16:104.

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

Brandt, D.A., Skinner, E.Z., and Coleman, J.A. 1963. Texture profile method. J. Food Sci. 28:404.

Bressani, R. and Elias, L.G. 1979. The nutritional role of polyphenols in beans. In "Polyphenols in Cereals and Legumes," J.H. Hulse (Ed.), IDRC-145e. Proceedings of a symposium, IFT, June, 1979.

Bressani, R., Elias, L.G., and Navarrete, D.A. 1961. Nutritive value of Central American beans. IV. Essential amino acid content of samples of black beans, red beans, rice beans and cow peas of Guatemala. J. Food Sci. 26:525.

Bressani, R., Marcucci, E., Robles, C.E., and Scrimshaw, N.S. 1954. Nutritive value of Central American beans. I. Variation in the nitrogen, tryptophan, and niacin content of ten Guatemalan black beans (Phaseolus vulgaris, L.), and the retention of the niacin after cooking. Food Res. 19:263.

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

Cairncross, S.E. 1978. Introduction to the flavor profile. In "Flavor: Its Chemical, Behavioral and Commercial Aspects," C.M. Apt (Ed.), p.1. Westview Press, Boulder, Col.

Cairncross, S.E. and Sjostrom, L. 1950. Flavor profiles - a new approach to flavor problems. Food Technol. 4:308.

Calvin, L.D. and Sather, L.A. 1959. A comparison of student preference panels with a household consumer panel. Food Technol. 13:469.

Cardello, A. and Maller, O. 1982. Relationship between food preferences and food acceptance ratings. J. Food Sci. 47:1553.

Cardello, A., Maller, O., Kapsalis, J.G., Segars, R.A., Sawyer, F.M., Murphy, C., and Moskowitz, H.R. 1982. Perception of texture by trained and consumer panelists. J. Food Sci. 47:1186.

Central American Technological Research Institute. 1979. Grain legumes: processing and storage problems. Food and Nutrition Bulletin. 1(2):1.

Chan, L. 1987. Bean utilization project. Unpublished report. Department of Food and Nutrition, Univ. of Manitoba, Winnipeg, Manitoba.

CIAT. 1985. Introducion, CH 1. In "Frijol: Investigacion y Produccion,". M. Lopez, F. Fernandez and A. van Schoohoven (Ed.) p.8. PNUD/CIAT. Cali, Colombia.

Civille, G.V. and Szczesniak, A.S. 1973. Guidelines to training a texture profile panel. J. Text. Stud. 4:204.

Clapperton, J.F. and Piggott, J.R. 1979. Differentiation of ale and lager flavors by principal components analysis of flavor characterization data. J. Inst. Brew. 85(9):271.

Cross, H.R., Moen, R., and Stanfield, M.S. 1978. Training and testing of judges for sensory analysis of meat quality. Food Technol. 7:48.

Davis, D.R., Twogood, M.L. and Black, K.R. 1980. Effect of blanch treatment on quality attributes of canned dry pinto and small and large lima beans. J. Food Sci. 45:817.

de Moraes, R.M. and Angelucci, E. 1971. Chemical composition and amino acid content of Brazilian beans (Phaseolus vulgaris). J. Food Sci. 36:493.

Deshpande, S.S., Sathe, S.K., and Salunke, D.K. 1984. Interrelationships between certain physical and chemical properties of dry beans (Phaseolus vulgaris, L.). Qual. Plant Foods Hum. Nutr. 34:53.

Dethmers, A.E. 1968. Experienced vs. inexperienced judges for preference. Food Prod. Dev. 2:22.

dos Santos Garruti, R. 1981. Unpublished data. Quoted in Sartori, M.R. (1983) "Methodology Used by Brazilian Researchers for the Evaluation of Technological Quality of Dry Beans,"Instituto de Technologia de Alimentos. Campinas, Brazil

dos Santos Garruti, R. and Bourne, M.C. 1985. Effect of storage conditions of dry beans (Phaseolus vulgaris L.) on texture profile parameters after cooking. J. Food Sci. 50:1067.

dos Santos Garruti, R. and dos Santos Garruti, D. 1983. Texture profile analysis studies of stored common beans (Phaseolus vulgaris). Ch 4.4 In "Sensory Quality in Foods and Beverages". A.A. Williams and R.K. Atkin (Ed.) p.259. Verlag Chemli International. Florida, U.S.

Draper, N. and Smith, H. 1981. "Applied Regression Analysis." 2nd ed. Wiley, Chichester.

Duran, L. and Calvo, C. 1982. Calidad de alubias blancas en conserva. I. Seleccion de los parametros que definen sucalidad sensorial. Rev. Agroquim. Technol. Aliment. 22(2):271.

Elias, L.G., Rios, B., Ramirez, D.E., Garcia, A., Brenes, R.G., Bressani, R., Diamant, R., Watts, B. and Vaisey-Genser, M. 1985. Preliminary study on consumer acceptability of beans in Guatemala. CIFST Proc. 28:57.

Ellis, B.H. 1967. A critical review of recent literature on preference testing methodology. Food Technol. 21(5):49.

Ennis, D.M., Boelens, H., Haring, H., and Bowman, P. 1982. Multivariate analysis in sensory evaluation. Food Technol. 36(11):83.

FAO. 1986. Production Yearbook. Vol.40 Statistics series No. 76. FAO.

Feria - Morales, A. and Pangborn, R.M. 1983. Sensory attributes of corn tortillas with substitution of potato, rice, and pinto beans. J. Food Sci. 48:1124.

Garcia, A. 1988. Private communication. Instituto de Nutricion de Centro America y Panama (INCAP), Guatemala.

Ghaderi, A., Hosfield, G.L., Adams, M.W., and Uebersax, M.A. 1984. Variability in culinary quality, component interrelationships, and breeding implications in navy and pinto beans. J. Amer. Soc. Hort. Sci. 109:85.

Gillette, M. 1984. Applications of descriptive analysis. J. Food Prot. 47:403.

Hanson Mook, J. 1984. Correlation of consumer and professional sensory descriptions. Cereal Foods World. 29(7):403.

Hinchcliffe, C., McDaniel, M., Vaisey, M., and Eskin, N.A.M. 1977. The flavor of fababeans as affected by heat and storage. Can. Inst. Food Sci. Technol. J. 10(3):181.

Hincks, M.J. and Stanley, D.W. 1986. Multiple mechanisms of bean hardening. J. Food Technol. 21:731.

Hoehn, E., Vaisey, M., and Medeiros, A.F. 1976. Note on seed coat effects on color and flavor of fababean flours. Cereal Chem. 53:597.

Hohlberg, A.I. and Stanley, D.W. 1987. Hard to cook defect in black beans. Protein and starch considerations. J. Agric. Food Chem. 35:571.

Horsfield, S. and Taylor, L.J. 1976. Exploring the relationship between sensory data and acceptability of meat. J. Sci. Food Agric. 27:1044.

Hosfield, G.L., Ghaderi, A., and Uebersax, M.A. 1980. Variability in physico-chemical properties and nutritional components of tropical and domestic dry beans germplasm. J. Amer. Soc. Hort. Sci. 1105:246.

Hosfield, G.L., Uebersax, M.A., and Isleib, T.G. 1984. Seasonal and genotypic effects on yield and physico-chemical seed characteristics related to food quality in dry, edible beans. J. Amer. Soc. Hort. Sci. 109:182.

Hughes, P.A. and Sansted, R.F. 1975. Effect of temperature, relative humidity, and light on the color of California light red kidney bean seed during storage. Hort. Sci. 10(4):421.

IFT. Sensory Evaluation Division. 1981. Sensory evaluation guide for testing food and beverage products. Food Technol. 35(11):50.

INCAP. 1969. "Evaluacion Nutricional de la Poblacion de Centro America y Panama. Guatemala." Instituto de Nutricion de Centro America y Panama (INCAP); Oficina de Investigaciones Internacionales de los Institutos Nacionales de Salud (EE. U.U.); Ministerio de Salud Publica y Asistencia Social de Guatemala. Instituto de Nutricion de Centro America y Panama, Guatemala.

INCAP. 1986. "Metodos para Establecer la Calidad Tecnologica y Nutricional del Frijol (Phaseolus Vulgaris)," L. G. Elias, A. Garcia-Soto and R. Bressani (Ed.), p.3. Publicacion L-33. Instituto de Nutricion de Centro America y Panama, Guatemala.

Iyer, V., Salunkhe, D.K., Sathe, S.K. and Rockland, L.B. 1980. Quick - cooking beans (Phaseolus vulgaris, L.): I. Investigations on quality. Qual. Plant. Plant Foods Hum. Nutr. 30:27.

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.

Kay, D.E. 1979. "Food Legumes," Trop. Prod. Inst. Rep. Ministry of Overseas Development, London.

Kiehl, E.R. and Rhodes, V.J. 1956. New techniques in consumer preference research. Farm Econ. 38:1335.

Kloek, M., dos Santos Garruti, R., and Timbers, G.E. 1983. Description and evaluation of two methods to measure cooked bean (Phaseolus vulgaris L.) texture. First draft. Unpublished data. Engineering and Statistical Research Institute. Research Branch, Agriculture Canada, Ottawa, Ontario.

Koehler, H.H., Chang, C.H., Scheier, G., and Burke, D. 1987. Nutrient composition, protein quality, and sensory properties of thirty six cultivars of dry beans (Phaseolus vulgaris L.). J. Food Sci. 52:1335.

Korth, B. 1982. Use of regression in sensory evaluation. Food Technol. 36(11):71.

Land, D.G. and Shepherd, R. 1984. Scaling and ranking methods. In "Sensory Analysis of Foods," J.R. Piggot (Ed.), p.141. Elsevier Applied Science Publishers, Essex, England.

Larson-Powers, N. and Pangborn, R.M. 1978. Descriptive analysis of the sensory properties of beverages and gelatins containing sucrose or synthetic sweetness. J. Food Sci. 43:47.

Malcolmson, L., Vaisey - Genser, M., and Walker, B. 1978. Some textural and flavor characteristics of selected plant protein and water systems. Proc. 5th Inter. Rapeseed Conf. 2:197.

Martens, M., Martens, H., and Wold, S. 1983. Preference of cauliflower related to sensory descriptive variables by partial least squares (PLS) regression. J. Sci. Fd. Agric. 34:715.

McLellan, M.R., Lin, L.R. and Kime, R.W. 1984. Determination of sensory components accounting for intervarietal variation in apple sauce and slices using factor analysis. J. Food Sci. 49:751.

Meiselman, H.L. 1984. Consumer studies on food habits. In "Sensory Analysis of Foods," J.R.Piggott (Ed.), p.243. Elsevier Applied Science Publishers, Essex, England.

Miller, I. 1978. Statistical treatment of flavor data. In "Flavor: Its Chemical, Behavioral and Commercial Aspects," C.M. Apt (Ed.), p.149. Westview Press, Boulder, Col.

Moh, C. 1971. Mutation breeding in seed coat color of beans (Phaseolus vulgaris L.). Euphytica. 20:119.

Molina, M.R., Baten, 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 phenmomenon in black beans (Phaseolus vulgaris L.). J. Food Sci. 41:661.

Morris, H.J. and Wood, E.R. 1956. Influence of moisture content on keeping quality of dry beans. Food Technol. 10(5):225.

Moscoso, W. 1981. Relationships between the hard to cook phenomenon in red kidney beans and water absorption, puncture force, pectin, phytic acid, and minerals. Ph.D. thesis, Cornell University, Ithica, NY.

Moscoso, W., Bourne, M.C. and Hood, L.F. 1984. Relationships between the hard-to-cook phenomenon in red kidney beans and water absorption, puncture force, pectin, phytic acid, and minerals. J. Food Sci. 49:1577-1583.

Moskowitz, H.R. 1977. Psychophysical and psychometric approaches to sensory evaluation. Crit. Rev. Food Sci. Nutr. 9:41.

Moskowitz, H. 1981. Relating subjective and instrumental measures a psychophysical overview. J. Food Qual. 4:15.

Moskowitz, H.R. 1983. "Product Testing and Sensory Evaluation of Foods," p.326-342, 311-313. Food and Nutrition Press, Inc., Westport, CT.

Moskowitz, H. 1984. Relative importance of sensory factors to acceptance; theoretical and empirical analyses. J. Food Qual. 7:75.

Moskowitz, H.R., Kapsalis, J.G., Cardello, A.V., Fishken, D., Maller, O. and Segars, R.A. 1979. Determining relationships among subjective, expert and consumer measures of texture. Food Technol. 10:87.

Moskowitz, H.R. and Sidel, J.L. 1971. Magnitude and hedonic scales of food acceptability. J. Food Sci. 36:677.

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

Noble, A.C. and Schmidt, J.O. 1981. Comparison of structured and unstructured category scales in the evaluation of sourness intensity. In "Flavor '81," P. Schreier (Ed.). Walter de Gruyter, Berlin.

Nordstrom, 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. 44:392.

Novais, A., Hanson, S.W., and Ryley, HJ. 1982. The texture of mashed potato in catering. I. The background. The contribution of hedonic texture to overall preference. Lebensm-Wiss. V. Technol. 15:295.

Pangborn, R.M. 1986. Sensory techniques of food analysis, Ch. 2 In "Food Analysis," D.W. Gruenwedel and J.R. Whitaker (Eds.) p.37. Marcel Dekker, Inc., New York, U.S.

Pangborn, R.M. and Dunkley, W.L. 1964. Application of sensory evaluation to the routine maintenance of product quality. Food Technol. 9:38.

Pearce, J. 1980. Sensory evaluation in research and development. Food Technol. 34(11):60.

Peryam, D.R. and Haynes, J.G. 1957. Prediction of soldiers' food preferences by laboratory methods. J. Appl. Psychol. 41:2.

Peryam, D.R. and Pilgrim, F.J. 1957. Hedonic scale method of measuring food preference. Food Technol. 11(9):9.

Peryam, D.R., Polemis, B.W., Kamen, J.M., Eindhoven, J. and Pilgram, F.J. 1960. Food preferences of men in the U.S. armed forces. OM Food and Container Institute.

Piggott, J.R. and Jardine, S.P. 1979. Descriptive sensory analysis of whiskey flavor. J. Inst. Brew. 85:82.

Piggott, J.R. and Canaway, P.R. Finding the word for it- methods and uses of descriptive sensory analysis. In "Flavor '81," P. Schreier (Ed.) W. de Gruyter, Berlin.

Piggott, J.R. 1982. Food preferences of some United Kingdom residents. J. Human Nutr. 33, 197-205.

Powers, J.J. 1981. Multivariate procedures in sensory research: scope and limitations. MBAA Technical Quarterly 18(1):11.

Powers, J.J. 1984. Current practices and application of descriptive methods. Ch. 7. In "Sensory Analysis of Foods," J.R. Piggot (Ed.), p. 179. Elsevier Applied Science Publishers, New York, NY.

Proctor, J.R. 1985. Navy bean cookability evaluation by modified Mattson Bean Cooker and by sensory panels. M.Sc. thesis, University of Manitoba, Winnipeg, Manitoba.

Proctor, J.P. and Watts, B.M. 1987. Effect of cultivar, growing location, moisture and phytate content on the cooking times of freshly harvested navy beans. Can. J. Plant Sci. 67:923.

Quast, D.C. and da Silva, 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.

Radtke, L.H. and Rodriguez, N.C. 1981. In house preference testing: an R and D resource. Food Technol. 35(11):67.

Rependa, M. and Sumner, A.K. 1983. Factors affecting the cooking quality of legumes. Unpublished report. College of Home Economics, Univ. of Saskatchewan, Saskatoon, Saskatchewan.

Rockland, L.B. and Metzler, E.A. 1967. Quick cooking lima and other dry beans. Food Technol. 21:344.

Saiao, K. 1976. Soybeans resistant to water absorption Cereal Foods World 21(4):168.

Sanford, K.A., Gullet, E.A., and Roth, V.J. 1988. Optimization of the sensory properties of frozen peas by principal component analysis and multiple regression. Can. Inst. Food Sci. Technol. J. 21:174.

SAS. 1985. "SAS User's Guide: basics and statistics". Version 5. Cary, NC.

Schutz, H.G. 1983. Multiple regression approach for optimization. Food Technol. 37(11):46.

Schutz, H.G. 1988. Product optimization techniques using consumer acceptance measures. Pre-Conference Workshop. 31st Annual CIFST Conference, Winnipeg, MB, May 29 - June 1.

Schutz, H.G. and Damrell, J.D. 1974. Prediction of hedonic ratings of rice by sensory analysis. J. Food Sci. 39:203.

Schutz, H.G., Damrell, J.D. and Locke, B.H. 1972. Predicting hedonic ratings of raw carrot texture by sensory analysis. J. Texture Studies. 3:227.

Sefa - Dedeh, S., Stanley, D.W., and Voisey, P.W. 1979. Effect of storage time and conditions on the hard to cook defect in cow peas (Vigna unguiculata). J. Food Sci. 44:790.

Sgarbieri, V.C. and Whitaker, J.R. 1982. Physical, chemical, and nutritional properties of common bean (Phaseolus) proteins. Adv. Food Res. 28:93.

Sidel, J.L., Stone, H., and Bloomquest, J. 1980. Use and misuse of sensory evaluation in research and quality control. J. Dairy Sci. 64:2296.

Silva, C.A.B., Bates, R.P., and Deng, J.C. 1981. Influence of soaking and cooking upon the softening and eating quality of black beans (Phaseolus vulgaris). J. Food Sci. 46:1716.

Stone, H. and Sidel, J.L. 1985. Descriptive analysis. Ch.6. In "Sensory Evaluation Practices," B. Schweigert and G. Stewart (Ed.) p.194. Academic Press INC. Orlando, Florida.

Stone, H., Sidel, J.L., and Bloomquest, J. 1980. Quantitative descriptive analysis. Cereal Foods World. 25(12):642.

Stungis, G.E. 1976. "Overview of Applied Multivariate Analysis," Correlating Senory Objective Measurements - New Methods for Answering Old Problems, ASTM STP 594, American Society for Testing and Materials, p. 81-96.

Swanson, B.G. 1985. Off flavors in dry bean products-background and prevention. In "Proceedings - Technical Conference on Dry Bean Research." The Food Processors Institute, Washington, D.C.

Szczesniak, A.S. 1963. Classification of textural characteristics. J. Food Sci. 23:385.

Toda, J., Wada, T., Yasumatsu, K. and Ishii, K. 1971. Application of principal component analysis to food texture measurements. J. Text. Stud. 2:207.

Uebersax, M.A. and Bedford, C.L. 1980. Navy bean processing: effect of storage and soaking methods on quality of canned beans. Agric. Exp. Sta. Res. Rep. 410. Michigan State University.

Van Herpen, D. 1983. Attitudes and preferences towards beans in Cali. Unpublished data. CIAT. Cali, Colombia.

Van Herpen, D. 1984. Measuring attitudes and preferences towards beans in Medellin. Unpublished data. CIAT. Cali, Colombia.

Varriano - Marston, E. and Jackson, G.M. 1981. Hard to cook pheneomenon in beans: structural changes during storage and imbibition. J. Food Sci. 46:1379.

Voisey, P.M. and Larmond, E. 1971a. Texture of baked beans - a comparison of several methods of measurement. J. Texture Studies. 2:96.

Voisey, P.W. and Larmond, E. 1971b. The effect of storage time before processing on baked bean texture. Engineering Research Service. No. 255. Research Branch, Agriculture Canada, Ottawa, Ontario.

Watts, B., Diamant, R., Elias, L., Rios, B., and Garcia, A. 1987. Consumer utilization and criteria for acceptability of raw and cooked beans in Guatemala. Final Report. International Development Research Centre. Ottawa, Canada.

Wu, L., Bargmann, R.E., and Powers, J. 1977. Factor analysis applied to wine descriptors. J. Food Sci. 42:944.

Yglesias, G.E. 1964. Estudio sobie el efecto de la densidad de siembra, habito de crecemiento, color y tamano del frijol en los ensayos de variedades. Publicacion No. 22. Inst. Interam. Cienc. Agric. Turrialba, Costa Rica. 22:39.

APPENDIX 1

Cuestionario
(Questionnaire)

I. Información General
(General Information)

1. Nombre del Agricultor: ______________________
(Farmer's name)

2. Localización del terreno: Municipio ______________
(Land's location) (Municipality)
Departamento ______________
(Province)

II. Manejo Agronómico
(Agronomical handling)

3. Origen de frijol que sembró:
(Origin of beans you grow) criollo ___ mejorado ___
(criollo) (improved)

4. Tipo de frijol: suelo ___ enredo ___
(Type of beans) (bush) (vine)

5. Variedad de frijol: ______________________
(Variety of bean)

6. Ultima fecha de siembra: mes ______________
(Last date of sowing) (month)
año ______________
(year)

7. Donde consiguió la semilla? ______________
(Where did you get the seed?)

8. Cantidad de semilla utilizada: ______________
(Amount of seed used)

9. Cuando empezó a usar esta semilla? ______________
(When did you start using that seed?)

10. Por que usó esta semilla?
(Why did you use that seed?)

____

11. Usa fertilizante? si ___ no ___
(Did you use fertilizer?) (yes) (no)

tipo de fertilizante: ______________
(type of fertilizer)

cuando lo utilizó? ______________
(when did you apply it?)

cuanto usó? ______________
(how much did you apply?)

III. COSECHA

12. En que fecha cosechó ese frijol? (When did you harvest those beans?)

mes (month) ______

ano (year) ______

13. Que hizo con el frijol que cosechó? (What did you do with the beans you harvested?)

utilizo para consumo (self consumption) ___

guarda (stored them) ___

vende (sold them) ___

14. Por qué le gusta consumir este frijol? (Why do you like to consume this kind of bean?)

______

15. Como era la calidad del frijol al momento de la cosecha? (How was the quality of these beans after harvesting?)

______

______

16. Que opinan las personas que lo compran, acerca de la calidad de su frijol? (What do the customers think about the beans you sell in terms of quality?)

______

______

17. Secó el frijol despues de arrancarlo y/o cosecharlo? (Did you dry the beans after harvest?)

si (yes) ___ no (no) ___

18. En el proceso de secado incluyó? (Which parts of the plant were included in the drying process?)

La planta completa (the whole plant) ___

vainas (pods) ___

grano (grains) ___

19. Donde secó? (Where were the beans dried?)

campo (field) ___

galera (barn) ___

otro (other) ___

20. Cuánto tiempo secó? ______ dias
(For how long did you dry the beans?) (days)

21. Guarda usted del frijol que cosecha? si ____ no ____
(Do you store beans after harvest?) (yes) (no)

22. Dónde lo guardo? ______________________________
(Where do you store them?)

23. Que recipiente utilizó? ______________________________
(In what type of container do you store the beans?)

24. Como guardó su frijol? limpio ____
(How did you store the beans?) (clean-just the seed) ____
con basura ____
(with pods) ____
en vaina ____
(in the pod) ____

25. Durante cuanto tiempo lo guardó? ________ meses
(For how long did you store the beans?) (months)

26. Agrego algun producto al guardarlo? si ____ no ____
(Did you add any product during storage?) (yes) (no)

27. Que producto agregó? ______________________________
(What did you add?)

28. Ha notado si su frijol cambio de calidad si ____ no ____
despues que ha estado guardado? (Have you
noticed any change in the quality of beans
you harvested after a period of storage?)

29. En qué características?
(Which characteristics were affected?)
se endurece ____
(increases hardness) ____
cambia sabor ____
(changes in flavor) ____
cambia textura ____
(changes in texture) ____

30. Que características tiene su frijol cuando esta cocido?
(Which characteristics do your beans have when cooked?)

____

____

____

Appendix 2

PHYSICAL TESTS*

I. SEED WEIGHT

A. Definition
Average weight of 100 beans expressed in grams.

B. Application
Any kind of dry beans

C. Instruments
Analytical scale at 0.1mg precision

D. Preparation of the samples
Randomly select 3 samples of 100 beans

E. Procedure
Weigh 100 beans

F. Calculations
Mean values and standard deviations of the three repetitions

Note: individual weight of 25 beans gives more information about variability within the sample than the weight from a group of 25 beans.

G. Reference values:

Average weight of common black beans (g)		
<0.193	=	small size seed
from 0.193 to 0.217	=	medium size seed
>0.217	=	large size seed

II. PERCENT SEED COAT

A. Definition
Weight of dry seed coat of 25 beans related to the weight of dry cotyledons and seed coat expressed as a percentage.

B. Application
Applicable to any kind of dry beans.

C. Instruments
- Analytical scale al 0.1mg precision
- Vacuum oven, calibrated to $60^{o}C$ and a pressure of 25mm of Hg.
- Desiccator containing chemical desiccant

D. Procedure
- Select a representative amount of beans from the sample to be analyzed.
- From the selected amount take 3 random samples of 25 beans each.
- Soak each sample overnight (16-18hrs) in luke warm water, using approximately 50 ml of water.
- Dry the beans with a paper towel and separate the seed coat from the cotyledon of each bean.
- Weigh the seed coats and cotyledons after cooling down in a dessicator.

E. Calculations

$$\% \text{ seed coat} = \frac{\text{Dry seed coat weight}}{\text{Whole bean weight}} \times 100$$

F. Reference values

< 8%	=	low content of seed coat
8.0 to 10%	=	medium content of seed coat
>10%	=	high content of seed coat

III. WATER ABSORPTION

A. Definition
Amount of water absorbed by the bean seed during certain period of time, expressed as a percentage of seed weight.

B. Application
Applicable to any kind of dry beans.

C. Instruments
Analytical scale with 0.1mg precision

D. Procedure
- Weight duplicate samples of 25 beans each
- Soak each sample in 75ml distilled luke warm water
- Every hour, during 8 hours, take the sample out of the soaking water. Dry the sample, weigh it and put it back in the soakiong water.

E. Calculations

$$\% \text{ water absorption} = \frac{W2 - W1}{W1} \times 100$$

Note: 4h water absorption is an adequate measurement to differentiate among cultivars.

F. Reference values

Beans with tough seed coat = less than 80% water absorption
Beans with tender seed coat= more than 80% water absorption

* (INCAP, 1986).

Appendix 3

Boleta con escalas hedonicas de 9 puntos para evaluar aceptabilidad de frijol negro

Nombre:

Fecha:

EVALUACION DE ACEPTABILIDAD DE

INSTRUCCIONES: A continuacion se presentan cinco muestras de frijol. Evaluarlas siguiendo el orden que le aparece en su boleta. las siguientes muestras, e indique cuanto le gustan o disguistan, chequeando la descripcion que usted considere mas apropiada en cada escala.

Codigo	Codigo	Codigo	Codigo	Codigo
---Gusta muchisimo	---Gusta muchisimo	---Gusta muchisimo	---Gusta muchisimo	---Gusta muchisimo
---Gusta mucho	---Gusta mucho	---Gusta mucho	---Gusta mucho	---Gusta mucho
---Guast moderadamente	---Gusta moderadamente	---Gusta moderadamente	---Gusta moderadamente	---Gusta moderadamente
---Gusta ligeramente	---Gusta ligeramente	---Gusta ligeramente	---Gusta ligeramente	---Gusta ligeramente
---No gusta ni disgusta	---No gusta ni disgusta	---No gusta ni disgusta	---No gusta ni disgusta	---No gusta ni disgusta
---Disgusta ligeramente	---Disgusta ligeramente	---Disgusta ligeramente	---Disgusta ligeramente	---Disgusta ligeramente
---Disgusta moderadamente	---Disgusta moderadamente	---Disgusta moderadamente	---Disgusta moderadamente	---Disgusta moderadamente
---Disgusta mucho	---Disgusta mucho	---Disgusta mucho	---Disgusta mucho	---Disgusta mucho
---Disgusta muchisimo	---Disgusta muchisimo	---Disgusta muchisimo	---Disgusta muchisimo	---Disgusta muchisimo
<u>Comentario</u>	<u>Comentario</u>	<u>Comentario</u>	<u>Comentario</u>	<u>Comentario</u>

Appendix 4

END POINT STANDARDS FOR DESCRIPTIVE ANALYSIS SCALES

CHARACTERISTIC	END POINT STANDARDS
1. Darkness of color	Dark: Bush P beans (Tamazulapa 1981) cooked for 3.5h. Light: Bush I beans from Jutiapa cooked for 1.5h.
2. Degree of splitting	Photographs with 100% and 0% split beans.
3. Beany flavor	Strong: Bush N bean from Jalapa cooked for 2h15′ and soaked overnight in its broth. Weak: no reference
4. Beany aftertaste	Strong: no reference Weak: no reference
5. Bitterness	Bitter: caffeine solution 0.003M Not bitter: No reference
6. Particle size	Large: Precooked bean flour milled through a #20 mesh screen and sifted on sieve >35 mesh screen. Slurry 2:1 water:flour. Small: Precooked bean flour milled through mesh #20 and sifted on sieve >100 mesh screen. Slurry 3:1 water:flour.
7. Hardness	Hard: Bush P bean (Tamazulapa 1981) cooked for 3h. Not hard: Plain processed cheese "Apericube" La Vache Quirit. 1/2 cube per person.
8. Cohesiveness	Cohesive: plain processed cheese "Apericube" La Vache Quirit. 1/2 cube per person. Not cohesive: Graham crackers 2-1cm^3 cube per person.
9. Chewiness	Chewy: No reference Not chewy: No reference

Appendix 4 continued.....

10. Seed coat toughness	Tough: Navy beans "Chapin" cooked for 1h50′ Tender: No reference

Appendix 4

REFERENCIAS REPRESENTANTES DE EXTREMOS DE ESCALAS USADAS EN ANALISIS DESCRIPTIVO

CARACTERISTICA	REFERENCIA
1. Oscuridad de color	Oscuro: Frijol de suelo "P" (Tamazulapa 1981) cocido por 3.5h. Claro: Frijol de suelo "I" de Jutiapa, cocido por 1.5h.
2. Proporcion de granos reventados	Fotografias con 100% y 0% granos reventados.
3. Sabor a Frijol	Intenso: Frijol de suelo "N" de Jalapa, cocido por 2h 15min y remojado en su caldo durante una noche. Suave: No se uso referencia
4. Sabor residual a frijol	Intenso: No se uso referencia. Suave: No se uso referencia.
5. Sabor amargo	Amargo: solucion de cafeina 0.003M. No amargo: No se uso referencia.
6. Tamano de particula	Granuloso: Harina de frijol, precocida, molida en mesh #20 y tamizada en tamiz >35. Mezcla 2:1 agua:harina. Fino: Harina de frijol, precocida, molida en mesh #20 y tamizada en tamiz >100. Mezcla 3:1 agua:harina.
7. Dureza	Duro: Frijol de suelo "P" (Tamazulapa 1981) cocido por 3h. Suave: Queso procesado "Apericube",La Vache Quirit. 1/2 cubito por persona.

8.	Cohesividad	Cohesivo: Queso procesado "Apericube", La Vache Quirit. 1/2 cubito por persona. No cohesivo: Galletas Graham, 2 cubitos de 1cm c/u por persona.
9.	Masticabilidad	No se uso referencia
10.	Dureza de cascara	Dura: Frijol blanco marca "Chapin", cocido por 1h 50 min. Suave: No se uso referencia.

Appendix 5

General instructions for evaluation of appearance, flavor and texture of black beans

Darkness of color:	Establish if the color the sample is closer to the white or to the black (dark brown). Open the petri dish, compare the sample with the standard and evaluate the intensity of darkness of color.
Degree of splitting:	Estimate the percentage of split beans in each sample (do not count them). Include only the beans that have the cotyledon broken in the middle.
Beany flavor:	Evaluate the intensity of beany flavor, which is different from mild or bland. Place 3 beans in your mouth, chew them and evaluate this characteristic.
Beany aftertaste:	Swallow the sample used for the above evaluation (beany flavor) and evaluate the intensity of aftertaste which is left in the mouth after the sample is swallowed.
Bitterness:	Place 3 beans in your mouth, chew them, move them towards the back of your tongue. Evaluate the presence of bitterness in each sample.
Hardness:	Bite down once with the molar teeth on the sample of beans (2 beans) and evaluate the force required to penetrate the sample.
Particle size:	Chew the sample (2 beans) for 2-3 chews between the molar teeth, and then rub the cotyledon between the tongue and palate and assess the size of the particles which are most apparent.
Cohesiveness:	Chew the sample (2 beans) for 2 chews between the molar teeth. Then evaluate how easy the beans break apart in smaller particles.

Appendix 5 continued...

Skin toughness:	Separate the skin from the cotyledon by biting the beans (2 beans) between the molar teeth and rubbing the cotyledon out between the tongue and palate. Then evaluate the force required to bite through the skin with the front teeth.
Chewiness:	Place a sample of beans (2 beans) in your mouth and chew at a constant rate (1 chew per second), counting the number of chews until the sample is ready for swallowing.

Appendix 5

INSTRUCCIONES GENERALES PARA EVALUACION APARIENCIA, SABOR Y TEXTURA DE FRIJOL NEGRO

Oscuridad de Color	Establecer si el color de la muestra esta cerca del blanco o negro (cafe oscuro). Destapar la caja, comparar con el estandar y evaluar la intensidad de color oscuro.
Granos Reventados	De acuerdo a su criterio, estime el porcentaje de granos reventados en la muestra (no los cuente). Incluye solo aquellos granos que tienen el cotiledon rajado transversalmente.
Sabor a Frijol	Ponga una muestra de 3 granos en su boca, mastiquelos y evalue la intensidad de sabor (a frijol) que es diferente de blando o insipido.
Sabor Residual a Frijol	Trague la muestra que utilizo en la evaluacion anterior y evalue la intensidad de sabor residual que queda despues de tragar la muestra.
Sabor Amargo	Ponga una muestra de frijol (3) en su boca, mastiquelos, muevalos hacia la parte posterior de la lengua y evalue la presencia de sabor amargo.
Dureza	Ponga una muestra de 2 frijols en su boca, mastiquelos una sola vez con las mueslas y evalue la fuerza requerida para penetrar la muestra.
Tamano de Particula	Ponga 2 frijoles en la boca, mastiquelos con las muelas (2 o 3 veces), sobe el cotiledon entre la lengua y el paladar y estime el tamano de particulas que sobresale.

Dureza de cascara	Separe la cascara del cotiledon mordiendo con las muelas una muestra de 2 granos, saque el cotiledon de la cascara, llevandolos a la lengua, pase la cascara ya sola a la parte de adelante, evalue la fuerza requerida para partie la cascara mordiendo con los dientes incisivos (del frente).
Cohesividad	Tome una muestra de 2 granos de frijol, mastique 2 veces y evalue la facilidad con que las particulas se disgregan.
Masticabilidad	Ponga una muestra de frijol (2) en su boca y mastiquelo a una velocidad constante (1 masticadas por segundo), cuente el numero de masticadas hasta que la muestra este lista para tragarse.

Appendix 6

Nombre ____________________

Fecha ____________________

ANALISIS DESCRIPTIVO DE FRIJOL NEGRO
EVALUACION DE APARIENCIA

ORDEN DE EVALUACION: ______ ______ ______ ______ ______

OSCURIDAD DE COLOR

R

Claro oscuro

% GRANOS REVENTADOS

R

0% 10 20 30 40 50 60 70 80 90 100%

Appendix 6 continued ...

EVALUACION DE SABOR Y TEXTURA

Orden de EVALUACION ______ ______ ______ ______ ______

INTENSIDAD DE SABOR
A FRIJOL

R

Suave

fuerte

SABOR RESIDUAL
A FRIJOL

R

Suave

fuerte

DUREZA

R

No duro

extremadamente
duro

TAMANO DE PARTICULA

R

FINA

GRUESA

COHESIVIDAD
DEL COTILEDON

R

no cohesivo

extremadamente
cohesivo

Appendix 6 continued ...

DUREZA DE CASCARA

R

Suave Dura

NUMERO DE MASTICADAS

R

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

AMARGO

R

No amargo Extremadamente amargo

COMENTARIOS

Appendix 7

ANOVA F-VALUES FOR PANELIST EFFECT ON EVALUATIONS OF THE BLIND CONTROL SAMPLE

Characteristics	F-value
Darkness of color	3.45[a]
Degree of splitting	5.65[a]
Beany flavor	3.42[a]
Beany aftertaste	3.74[a]
Bitterness	6.47[a]
Particle size	3.73[a]
Hardness	3.07[b]
Cohesiveness	3.40[a]
Seed coat toughness	3.85[a]
Chewiness	19.61[a]

[a]significant at $p<0.001$
[b]significant at $p<0.01$

Appendix 7 continued......

ANOVA F-VALUES FOR SESSION EFFECT ON EVALUATIONS OF THE BLIND CONTROL SAMPLE

Characteristics	F-value
Darkness of color	2.75[b]
Degree of splitting	0.86
Beany flavor	1.79
Beany aftertaste	1.61
Bitterness	0.41
Particle size	1.26
Hardness	0.69
Cohesiveness	1.03
Seed coat toughness	1.39
Chewiness	0.20

[b]significant at $p<0.01$