Dry Edible Beans: Indigenous Staple and Healthy Cuisine

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Abstract

The common dry bean (*Phaseolus vulgaris* L.) is a diverse food resource of high nutritional value (protein, energy, fiber and vitamins and minerals) with broad social acceptance. This agricultural legume crop demonstrates global adaptability, genotypic and phenotypic diversity, and multiple means of preparation and dietary use. Numerous factors influence utilization, including: bean type and cultivar selection, cropping environment and systems, storage conditions and handling infrastructure, processing and final product preparation. Further, nutrient content and bio-availability are dramatically influenced by these conditions. Anti-nutritional factors (trypsin inhibitors, lectins and phytic acid) have long been recognized as concerns and require appropriate processing conditions to ameliorate adverse effects. Recently, beans have been cited for imparting specific positive health potentiating responses (hypocholesterolemic response, mitigation of diabetes and colonic cancer, and weight control) when properly positioned in the diet. This paper provides an overview of characteristics and protocols used to provide this global food staple as a valued dietary component. Enhanced dry bean utilization focused on improved dietary health is an opportunity within subsistent and developed diets.

Introduction

Background Terminology Associated with Legumes

Dry beans are distinctive among a diverse and broad class of legumes. Carolus Linnaeus (1707-1778) observed these plants and designated them as *Phaseolus vulgaris* L. in his classic descriptive genus and species taxonomy. The term “Legume” has a very well defined botanical classification of specific traits. However, it appears to have a broad connotation when used in commercial trade or by consumers. The following points are made to assist with an understanding of legume terminology.

Botanically, legumes are dicotyledonous (bi-valved) seeds of plants belonging to the family *Leguminosae*, which is one of the three largest families of flowering plants. *Leguminosae* contains about 600 genera with 13,000 species. The annual plants possess herbaceous stems with tri-foliolate leaves. The flowers are flat (butterfly or keel shaped) and develop seeds of various size, shape and color, which are produced in a single cavity pod.

Legume plants serve as hosts for nitrogen-fixing bacteria (R*hizobium*) through symbiotic colonization within the plant root nodules. Thus, legume crops are soil nutrient enhancers that build soil nitrogen levels. Typically, this is achieved through suitable crop rotations with non-nitrogen fixing cereal grains. It is to be noted that the historical inter-cropping of beans and maize (corn) observed since antiquity in native cultures has biological significance due to the soil nitrogen fixation capability of beans, which enhances corn yield. Although, the family *Graminae* comprised of grasses and cereal grains (e.g. wheat, maize, rice) are the most extensively used food plants and contribute the greatest levels of food energy globally, the food legumes or pulse crops provide the greatest level of protein and are particularly important in plant–based diets to compliment amino acids with resultant enhanced protein quality.

The terminology used for describing leguminous plant products is frequently complex and ambiguous. Key elements associated with dry bean and legume terminology are presented in Table I.

It is noteworthy that in the USDA's recently revised food pyramid the long-standing "legume" terminology was replaced with beans due, in part, to the general confusion regarding the term "legume." Several general observations may be considered in assessing American consumers' understandings or misunderstandings of the terminology "legumes". Examples of these consumer perceptions are presented in Table II:

This paper provides an overview of characteristics and protocols used to provide beans as a global food staple and as a valued-added dietary component. Enhanced dry bean utilization focused on improved dietary health is an opportunity within both subsistent and developed diets.

Dry Beans As A Diverse And Global Food Resource

The common dry bean (*Phaseolus vulgaris* L.) is of global agronomic and dietary importance. This agricultural legume crop demonstrates global adaptability, genotypic and phenotypic diversity, and undergoes multiple means of preparation and dietary use. Dry bean consumption patterns vary dramatically by geographic region and among cultures. Determinants include a broad spectrum of social interactions and traditions that discriminate among bean types (color, size and shape) and among means of preparation and end product use. These patterns of use have significant public health impact.

Dry beans (*Phaseolus vulgaris* L.) are cultivated throughout the world; however, it is commonly recognized that beans are a "new world crop" with distribution to Europe and Africa following Spanish and Portuguese explorations/conquests. Two distinct origins of domestication are located in Central and South America. These distinctions are made based on phaseolin protein patterns elucidated using electrophoresis. The centers of domestication are identified as Mesoamerican (ranging from the southern United States to Panama with primary focus in Mexico and Guatemala) and Andean (encompassing Columbia through Peru) and generally segregate the small seeded Mesoamerican beans and the large seeded Andean gene pools. Extensive bean gene pool arrays comprised of extremely diversified colors, sizes, and shapes are common in these regions and have been utilized in plant breeding programs for the development of the distinct modern commercial classes as follows: 1) white seed coat: navy, small white and great northern; 2) solid colored seed coat: black, kidney, small red, and pink; and 3) mottled (spotted) colored seed coat: pinto, cranberry and yelloweye.

The complex and long-standing differences in bean consumption habits, which are clearly exhibited among countries, regions or people groups within the same country can be explained, in part, by the following factors:

- **Food value**. Beans are universally recognized as wholesome and nutritious food. For example, the traditional use of beans and maize in blended dishes is deeply imbedded in Latin American cultures and transcends to other people groups. It is due in-part to the inherent complementation of amino acids resulting in a more complete protein food.

    - Health and wellness. It is noteworthy that consumers are increasingly selecting healthy and balanced diets proportionally higher in plant–based foodstuffs. Legumes have significant nutritional and health advantages for consumers.
    - Environmental sustainability. Advantages are associated with legume nitrogen fixation in soils. Bean cultivation has been associated with a positive impact on agriculture and the environment. Thus, real and perceived benefits for the cultivation of beans are increasingly supported by select groups of consumers.

- **Socio-economic demographics**. Generally, rural populations consume greater levels of legumes than the contrasting urban populations, because of the dependence on locally produced foods, which are commonly prepared in traditional manners. Peoples of subsistent or lower income levels, generally consume larger quantities of beans which furthers the stereotypic response "Beans are poor man's steak" that often stigmatizes and denigrates bean use and reduces expanded utilization.

    - Urbanization. It is likely that the evolution of increased bean consumption patterns will be impacted by further urbanization of the population, expanded access to processed foods and increased income levels.
    - Public health policy. Mitigation of chronic health issues resident within both rural subsistent and urbanized people groups remains the foremost rationale for establishing public policy focused, at minimum, on maintaining or preferably increasing the current bean consumption levels.

- **Culinary attributes**. Numerous culinary quality traits of beans contribute to acceptable use and are frequently underestimated in their influence. These include:

    - Accessibility. Local indigenous versus commercial production and open marketplace verse packaged procurement (on-site point of purchase quality assessment, frequency and quantity of purchase).
    - Storage. In-home storage and meal planning dynamics (stability, knowledge, water
    - Preparation. The extensive constraints associated with preparation and cooking (water and fuel availability, sanitation and time).
    - Quality. Characteristic palatability attributes such as appearance (color and integrity), texture (firmness and consistence), taste and flavor.

Utilization of Dry Beans as Indigenous Foods

In many developing regions, women provide an essential a central role focused to sustain the family's food security. This vital link cannot be underestimated and has been more formally recognized through Women-in-Development (WID) programs. These programs, established in many universities, promote teaching, research, and action on international development and global transformation as they affect women and gender relations. They serve as catalysts for the scholarly discussion of gender, development, and global change on a wide range of issues. Specifically WID has served to facilitate agricultural development and the utilization of beans in indigenous diets (Ferguson, 1994).

In African and Latin American countries where beans are staple foods, women and their children laboriously carry water vessels and wood for cooking fuel long distances, frequently in arid or mountainous terrain, to their village or rural homes. Traditional cooking of dry edible beans in these countries involves excessive expenditure of time and fuel. The development of appropriate preparation technologies for use at the household and village-level would facilitate processing and dietary availability of beans and other legumes. Valuable time could thus be devoted to more effective childcare or additional income-generating activities.

The integrative need for research that transcends traditional bean production limitations (germplasm, adaptation, yield and disease) and more fully addresses the social and cultural implications of improved food utilization has been imbedded within the USAID Bean/Cowpea Collaborative Research Support Program (CRSP). This comprehensive program has been highly acclaimed based on the transdisplinary approaches and the strong collaborative linkages established within regionally strategic host countries. A thorough review of these accomplishments has been presented (Graham P.H. et al. 2003).

Utilization of legumes in many regions still entails long and tedious preparations. Typically, beans are used in the native dry form and are marketed in open bulk displays. The consumer has traditional purchase criteria that include: appearance (color, gloss or sheen), size and shape (typical of the expected class) and overall quality (splits, defects, and debris) of the seed. The consumer is able to readily discriminate among bean lots to select appropriate levels of quality. Commonly, the concerns of purchasing "hard beans" or "old beans" are paramount. These aspects of quality have been thoroughly documented (Borget, 1992).

Beans are generally stored in the home (often in high security areas to avoid moisture and insect damage). Numerous special and unique methods of preparation are established within a given region or culture; however, beans are commonly soaked and cooked in an open pot of water (steel or ceramic) over a low heat fire. This provides for a long-term slow (up to eight hours) cooking process and yields a palatable and nutritious product.

The requirements for high quality water and sufficient wood fuel for cooking are major constraints.

Several traditional methods of bean preparation such as germination and fermentation in African and Asian countries have found wide acceptability. These methods produce highly specialized and culturally distinctive products and are recognized for improving bean digestibility and reducing anti-nutritional factors. Reddy et al. (1982a) indicated that legume-based fermented foods are very popular in Southeast Asia, the Near East, and parts of Africa and examined the production of various legume-based fermented foods and critically assesses their nutritional quality. These products form an appreciable part of daily diets of people as a main source of protein, calories, and certain vitamins. Preparation of legume-based fermented foods has remained, to some extent an art, and their nutritional quality has been of interest to both professionals and laymen. The fermentation process aids in improvement of the organoleptic quality of legumes and enhances nutritional quality. Davila et al. (2003) reviewed the use of germination and fermentation to improve the nutritional value of legumes, with particular reference to the generation of functional foods and functional ingredients. Germination and fermentation are presented as alternatives that are able to reduce or inactivate anti-nutritional factors in legumes, preserve and possibly enhance the content of isoflavones in legumes, and improve the potential of legumes as functional foods and as ingredients for use in functional foods.

The regions of highest bean consumption include all of Latin America, where legume consumption ranges from 1 kg/capita per year (Argentina) to 25 kg/capita per year (Nicaragua). Common beans dominate and account for 87 % of the total legume product consumption (Leterme and Muñoz, 2002). Sub-Saharan Africa utilizes a wide range of dry beans and other legume crops (cowpea). These are typically water cooked and eaten as porridge. The subcontinent of India uses the greatest quantity and most diversity of legume-based foods. These are characteristically prepared and processed in very specialized recipes and formats (Khader and Uebersax 1989). Throughout Southeast Asia, consumption of legumes is moderate and a great variety of species are produced and used as mature seeds and immature vegetative pods. Sprouted grains are consumed fresh or dehulled and roasted or ground for use in soups or side dishes.

Dry Edible Beans as Weaning Foods. The long-standing nutritional challenge to positively affect an infant’s transition from nursing to solid foods is complex and entails an array of socio-economic factors. The dynamic of the mother child relationship and the availability of appropriate foods are well documented in numerous cultures. The use of dry beans to enhance the protein and energy needs required for weaning periods has been extensively researched. Generally, digestibility and flatulence-producing components are important factors to consider when feeding legumes to children. Preliminary processing techniques include: 1) dehulling, 2) fine grinding, 3) roasting 4) germination and fermentation, and 5) prolonged cooking. These techniques have been found to increase digestibility, improve protein to energy ratio and reduce flatulence from beans. Further, high viscosity associated with bean pastes and gruels has been a deterrent to use in weaning foods. Pre-processing protocols (extractions, enzymatic digestions, fermentation, and germination) have been proposed to reduce starch and oligosaccharide content. These procedures have generally reduced viscosity, enhanced overall acceptability and improved digestibility (Uebersax and Occena, 1997). Thus, pre-processing (in-home or centrally within the local marketplace) may enhance potential for bean-based weaning foods.

A particular problem associated with use of bean cooking broth in weaning has been common in many subsistent cultures. In South and Central America and parts of central and eastern Africa, dry beans are commonly cooked without dehulling. These whole beans are unsuitable for infants and children. Thus, young children are served the broth or soup in which the beans have been cooked. This practice results in poor protein digestibility, diarrhea, and other gastrointestinal distresses and further acerbates protein digestibility as the liquid portion may contain high levels of polyphenolic compounds (tannins) extracted from the seed coats of colored beans during cooking (Aykroyd and Doughy, 1982; Lyimo et al. 1992).

A number of traditional weaning food mixtures can be prepared using pre-heated legumes and cereals. These products must incorporate calculated ratios of selected ingredients to optimize the nutritive value (characteristically designed for improved amino acid profiles), enhance preparation time and possess stable shelf-life and are designed for economical accessibility.

The Institute of Nutrition for Central America and Panama (INCAP) has conducted a well-recognized and comprehensive legume nutrition research program including much work on infant weaning foods. Numerous product formulations have been proposed and developed to provide nutritious, economic and culturally accepted foods (http://www.incap.org.gt/). India has been another focal point for infant legume research. The Central Food Technological Research Institute (CFTRI) in Mysore and the National Institute of Nutrition (NIN) in Hyderabad have developed a number of weaning foods/infant formulations using the cereal-legume blends as well as legume oil seed combinations. CFTRI has also developed various ready mixes that align with traditional cuisine such as: Muruku mix, Idly mix, Sambar mix, Dosa mix and Jelabee mix (Khader and Uebersax, 1989). Numerous studies have demonstrated the diversity of approaches taken to achieve suitable weaning food products. Drum-dried bean meals prepared from split beans, a low grade by-product of whole bean markets, demonstrated potential for pre-cooked, prolonged shelf-life weaning food formulations which can provide both protein and energy to the infants as well as offer preparation convenience (Occena et al. 1997). Mwikya et al (2001) evaluated sprouted kidney beans (up to 96 hours at 30°C) for inclusion into a weaning food formulation. During the sprouting period, starch content decreased; reducing and non-reducing sugars increased; tannins, trypsin inhibitor and phytates decreased; and in-vitro digestibility increased. Mensa-Wilmont et al (2001) developed six cereal/legume mixtures with the aid of computer-assisted optimization software. Three processing schemes (roasting, amylase digestion and extrusion cooking) were employed. Nutrient composition indicated that these blends were nutritionally adequate as weaning foods. Ghanaian mothers of weanling children evaluated sensory attributes of the formulations and found the convenience of a weaning food made from local staples processed on village/market scale to be very attractive. Mbithi-Mwikya et al (2000) studied the effects of sprouting, autoclaving and fermenting of kidney beans and finger millet during the processing of a weaning food. Sprouting resulted in a significant decrease in lysine in kidney beans. Autoclaving caused significant decreases in histidine, while fermentation significantly decreased phenylalanine and increased tryptophan in finger millet. Leucine to lysine ratio was significantly improved in finger millet by both sprouting and fermentation. Rodriguez-Burger et al (1998) developed a nutritious weaning food with the use of fermented black beans combined with rice. Raw beans were coarsely ground, soaked, cooked, fermented (up to 25 hours) and then homogenized to obtain a supernatant and a precipitate. Cooking improved protein digestibility and decreased the levels of lectin and trypsin inhibitor. The oligosaccharide content was reduced by fermentation. The weaning food product prepared using dry weight ingredients (27% fermented dry beans / 73% cooked rice) had an *in vitro* protein digestibility of 86% and a very low content of oligosaccharides.

Utilization of Dry Beans as Processed Foods in Developed Regions and Diets

A comprehensive assessment of strategies and procedures used for processing dry beans is prerequisite to improved utilization of dry beans. Implementation of a given protocol can be maximized through an understanding of the physical and chemical components, the inherent constraints and diversified processing techniques available to develop economically viable alternative and innovative products (Uebersax et al. 1991).

The typical means of presentation of bean–based products are sensitive to differences among various regions and countries. The appreciable differences in bean costs and availability may be attributed to significant differences in global supply chains. These differences may be particularly acute for specific commercial classes of beans. There is considerable opportunity to expand overall bean utilization by improving quality of products derived from non-traditional production areas and world trading partners such as China and Thailand. Canned products consistently dominate bean usage (based on individual frequencies of use data and total sales volume) compared with dry beans distributed in pre-packaged lots or bulk dispensing. Dry beans account for the greatest volume of legumes used in Europe; however, much variance among bean commercial classes is apparent by individual country. These differences are illustrated by predominate use of 'Navy beans' in the UK, preference for large white beans (Great Northern, White Kidney) in France and specialty use of colored beans (Cranberry and Dark Red Kidney) in Italy.

The per capita consumption of legume-based food products in the United States, Europe (encompassing the EU) and other industrialized economies has generally and consistently been substantially lower than that observed in other regions of the world. However, as an aggregate (with much internal variability) there has been an overall slight increase observed in recent years. Specific regional responses are noteworthy and illustrate this variability. Western European countries (e.g. Spain, France and the UK), account for about 60 % of the total bean consumption within the European Union (Schneider 2002). Total per capita dry bean consumption has increased gradually in the United States over the past two decades. Cooked bean consumption is recognized to be greatest in the southern and western areas of the country. About 55 percent of black beans, one of the fastest growing classes in terms of per capita use, are consumed in the southern region of the country. Although people of Hispanic origin represented approximately 11 percent of the population, they account for 33 percent of all cooked dry edible bean product consumption. Relative to their share of the population, low-income consumers consume substantially more navy, lima, and pinto beans than those consumed by mid or high income groups (Lucier et al. 2000).

The popularity of convenience items such as dehydrated, extruded, frozen and microwavable food products has provided a venue for the development of new bean products or bean formulations. Selected categories of dry bean-based products utilized in industrialized regions, typically with wide market distribution channels, are illustrated.

Canned Beans (beans in brine or specialty sauces). The canned bean market sector constitutes the greatest level of bean consumption in industrialized economies. Canned bean products are recognized for convenience and distinctive flavor while providing excellent consumer value. Common dry beans of numerous commercial classes are generally soaked (using various soaking procedures) to hydrate the seed, hot water blanched, filled into cans or jars and immediately covered with hot brine or sauce, hermetically sealed and thermally processed under steam pressure. The processing times and temperatures for canned beans generally exceed the minimum requirements necessary for commercial sterility. Thus, the process is an extended cook required to achieve the desired bean tenderness. "Pork and beans" are typically canned in a tomato sauce with a small portion (< 2%) of pork, added primarily for flavor. This characteristically simple product has wide acceptance throughout the United States. Canned baked beans requiring complex sauce formulations to achieve delicate flavor profiles are viewed as the premiere bean products. Further, specialty products such as canned "beans and franks" are popular. Lopez (1987) provides details of the canning procedures for dry bean products.

Packaged Dry Beans. Whole dry beans packaged in retail bags of individual commercial classes are suitable for in-home preparation. The need for pre-soaking (often overnight) and cooking has limited this format due to the required pre-meal planning (lead time) and the direct cooking time. Further, increased prevalence of value-added bean medley mixes (based on seed size and color) have received popular use for "homemade" soups.

Precooked Bean Products.

Pre-cooked and dehydrated bean flakes and powders. Fully-cooked dehydrated bean flakes, flours, and bean "crumbles" are commercially available. Formulated refried bean mixes are prepared for use in institutional food service systems and receive wide use. Instant pre-cooked bean powders prepared by soaking, cooking, slurrying and drum or spray drying of beans are feasible (Bakker, 1973; Occena et al., 1997).

Pasta-type products. Traditional pasta products have highly specialized product standards and characteristics however the incorporation of legumes ingredients have been attempted. Numerous commercial specialty products have been designed to enhance protein content and have been primarily marketed in natural food channels. Fortified spaghetti prepared from blends of legume composite flours or protein concentrates demonstrated higher levels of protein, ash and fiber compared to control spaghetti made from durum semolina. Spaghetti supplemented with up to 10% legume flours or protein concentrates was judged acceptable by a taste panel. A "beany taste" was reported for spaghetti containing 25% legume flours or concentrates (Kohnhorst et al., 1990). Noodles prepared with pinto bean flour substituted at 5, 10 and 20% levels were more tender and slightly darker; however, increased substitution levels resulted in decreased flavor and acceptability (Uebersax and Zabik, 1986).

Extruded products. Continuous thermal extrusion technology is widely available and provides much potential for preparation of bean products. The interaction of bean solids, added water and heat during high pressure mixing provides for hydration and cooking of beans prior to mass expulsion through a fixed die. The extruded cooked and pliable "ropes" may be further dried and dry milled to desired size specifications (Aguilera et al. 1984). Further, specific shapes and conformations may be achieved. It is noteworthy that extrusion systems may be used for highly industrial applications or as appropriate technology suitable for village/market level processing.

Specialized food ingredients (meals, flours, concentrates, powders & flakes). Specialized pre-processed food ingredients each possessing definitive and diversified functional properties have been prepared from dry edible beans. These products may include: 1) high protein, 2) high starch, and 3) high fiber fractions of varying concentrations (Guillon and Champ 2002). Clearly, caution must be taken to inactivate anti-nutritional factors for appropriate use in food products. These products may be used directly or as a component of formulated foods. High protein food ingredients can be produced as either flour fractions processed by pin milling & air classification, or as concentrates and isolates processed by alkali, salt and acid extraction with subsequent use of isoelectric precipitation or ultrafiltration (Uebersax et al. 1991). Dry roasting of beans prior to milling has been used to inactive anti-nutritional factors without hydration. Much research has been conducted to investigate the functionality of these high protein products to broaden their use in various foods. Chang and Satterlee (1979) produced bean protein concentrates containing 70% to 80 % protein by wet processing using water extraction techniques. Dry beans have been milled into whole flour and air-classified into high starch and high protein fractions (Kon et al., 1977; Aguilera et al., 1982). High protein flour fractions generally contain twice the original whole bean seed protein content. Air-classified high protein bean flour contains a residual starch, which offers some particularly desirable functional applications (Lee et al., 1983). Bean hulls are readily separated by cracking rolls and air aspiration and then milled into high a fiber fraction. Air classification of roasted beans produces high fiber, starch and protein fractions, each suitable as food ingredients in a variety of food products such as cookies, donuts, quick breads and leavened doughs (Uebersax and Zabik, 1986).

Quick cooking beans. Since preparation and cooking time remains a major constraint to bean utilization, numerous chemical and physical processing techniques have been proposed and /or initiated to alleviate this problem. The addition of phosphates to bean soaking/cooking water results in increased hydration yield and softer bean texture compared to standard procedures. The patented "quick cooking beans" process developed by the USDA utilize a vacuum-infiltration of salts to enhance hydration and to soften beans. This has been promoted as a means to reduce cooking time (approximately 15 minutes) and improve efficiency of bean preparation. This specific process has not received extensive commercial development due to the disadvantages of added salt and need for high-energy vacuum pumps.

Frozen beans. Partially or fully cooked beans marketed as individually-quick-frozen (IQF) or as a frozen block are suitable as institutional food ingredients or for direct retail distribution. Appropriate hydration and softening under low temperature cooking conditions prior to freezing provides products which are readily suitable for use in recipe based foods such as chili and acidified three-bean salad dishes. Products may possess a six-minute preparation time, either using microwave or stove top cooking. Bulk sales as a food ingredient to industrial food manufacturers or for direct use in foodservice appear to be expanding.

Factors That Influence Dry Bean Utilization

Numerous factors influence the use of dry edible beans including: bean type and cultivar selection, cropping environment and systems, storage conditions and handling infrastructure, processing and final product preparation.

Cropping Systems and Local Acceptance

In many parts of the developing world, the primary responsibility for bean and cowpea production resides with women and children. While women's role in agricultural activities vary by country and region, it is common for them to play a major role in seed selection, planting, cultivation, harvesting, storing, and processing and preparation. Beans are often intercropped with maize and squash in manners that follow the most rigid of traditional patterns. Annual seed carryover for planting is often burdened with plant diseases. Much progress has been realized where cooperative seed distribution and the use of improved cultivars have been employed. Bean selection and consumption patterns are often influenced by the physical characteristics of the seed. Factors such as seed color, size, and shape are often well established within a culture and are strong determinants affecting use. The USAID Bean/Cowpea CRSP has established an integrative approach to address production and utilization of beans for improved human health. (http://www.isp.msu.edu/crsp/index.html) Further, a detailed and descriptive series of informative papers review the diverse agronomic production practices and regional bean improvement research (Kelly, 1985-1988).

Storage and Handling Practices of Dry Beans

Dry beans are harvested upon physiological maturity and may be subsequently air dried to assure storage stability. Beans require a moisture content of less than 18% to remain stable during storage. Higher bean moisture contents result in intrinsic fungal spoilage (physiological heating, moisture migration with subsequent catastrophic quality failure) and significant product loss. Bean seed coats (testa) are subject to mechanical damage during dry handling. Thus, careful handling is warranted to avoid excessive seedcoat cracks and splits which are serious trade and consumer defects. Dry bean harvesting, handling and storage systems and infrastructure vary considerably from often-rudimentary processes in rural and subsistent environments to sophisticated commercial distribution systems common to global markets and urban settings. The quality changes may be manifested as flavor (mustiness, sour/bitter) and color (browning, darkening) defects, seed hydration defects and decreased digestibility. Globally, post harvest quality losses of dry beans are extensive and dramatically impact acceptability of use particularly by increasing the time and energy requirements for preparation and decreases in palatability and nutrient bio-availability.

Hard shell and hard-to-cook phenomenon (HTC). The storage-induced textural defects of cooked bean seeds are classified into two categories: (1) "hard shell" and (2) hard-to-cook (HTC). Legumes termed "hard shell" (or "hard seed") do not imbibe water sufficiently due to a relatively impermeable seed coat and are resultant of dry beans stored in a very low humidity atmosphere. These beans do not hydrate completely, and may remain undesirably hard even after extensive cooking or canning. This defect is commonly associated with arid climates. HTC legumes, however, may appear to absorb adequate water during soaking but will not soften sufficiently during a reasonable cooking time. HTC is typically developed under high temperature and high humidity storage environments (Reyes-Moreno and Paredes-Lopez 1993; Liu, 1995; Stanley and Aguilera, 1985). Thus, this is a major defect within tropical and sub-Saharan Africa as has been demonstrated in various cultivars of *Phaseolus* and *Vigna* as well as other legumes (Sefa-Dedeh et al., 1979). Recommendations to prevent storage loss of dry bean from hardening in tropical regions include: 1) beans should be stored at the lowest possible moisture content and 2) beans should be stored in a dry and cool environment (Mejia, 1980). The most important hypotheses that have been proposed to explain the cause of bean hardening are: (1) lipid oxidation and/or polymerization, (2) formation of insoluble pectates, (3) lignification of middle lamella, and (4) multiple mechanisms (Reyes-Moreno and Paredes-Lopez 1993; Jones and Boulter, 1983; Stanley and Aguilera, 1985; Bernal-Lugo et al., 1990; Liu et al., 1992). The cellular ultrastructure of the cell wall and cotyledon tissue has been shown to be significantly different between normal and hard beans. The most noticeable structural change caused by HTC defect is a failure of cotyledon cells to separate during cooking (Sefa-Dedeh et al., 1979 and Varriano-Marston and Jackson, 1981). Phenolic compounds have been associated with HTC. Srisuma et a1. (1989) demonstrated different degrees of HTC phenomenon in differentially stored navy beans. Storage induced HTC beans contained higher levels of hydroxycinnamic acids (especially ferulic acid) than the control beans. Large increases in free hydroxycinnamic acid content associated with increased hardening suggested a relationship between these two factors. HTC phenomenon has been postulated as an interaction of storage proteins with starch granules (Liu, K., 1997).

Preparation Procedures for Dry Beans

Preparation requirements and prolonged cooking times are major constraints to bean utilization. Research to address these limitations has been extensive and includes modifications to cooking, roasting (Lee et al 1991), germination and fermentation (Tabekhia and Luh 1980), extrusion cooking (Alonso et al. 2000), and dehydration (Bressani et al. 1977) procedures. The energy required and the total time associated with preparation of whole intact native beans on an individualized basis are clear impediments that may be partially alleviated through cooperative village level processing schemes.

Digestibility and Flatulence

It has been noted that individual bean consumption is generally limited by a series of constraints and that overall bean digestibility (protein, starch and fiber) and its impact on flatulence cannot be overlooked. Beans clearly provide sound potential for enhanced overall dietary health. However, it must be noted "much of what makes beans attractive in the health conscious market is attributed to their relatively limited digestibility and the subsequent formation of flatus." (Bennink 2002) Attempts to reduce the flatus forming components of beans may reduce their dietary potential for enhanced health benefits. Therefore, any discussion of the clearly demonstrated significant health benefits associated with bean fiber and resistant starch is particularly complex because of their direct contributions to flatulence. These are relevant areas of concern with both the nutritional and social implications. An overview of digestibility is provided within this paper to bring context to dry bean products as component of a healthy diet.

Limited Availability of Novel Products and Ingredients

The limitations to preparation of beans may be alleviated through the use of innovative products and prepared ingredients for the use in traditional and expanded recipes and cuisine. **C**ooperative research programs among universities, government agencies and industry must be outcome focused and aligned at the interface of food science and applied nutrition. Efforts must build on existing product knowledge and result in practical and thus implementable strategies.

Nutritional Value Of Dry Edible Beans

Composition and Digestibility of Bean Macro Constituents

Dry edible beans have consistently been noted for high nutritional value including: protein, energy, fiber and vitamins and minerals. Further, it is generally recognized that for food products to have significant nutritional impact there must be broad social acceptance. An obviously important component of deriving the nutritional value of beans is associated with the level of consumption in the diet.

The wealth of research conducted to assess the nutritional content and bio-availability has been extensively documented and has been reviewed () Key elements associated with the nutritional value of beans are focused on the importance of digestibility of proteins and carbohydrates (including starch and fiber). Further, the micronutrients, including iron, zinc and folic acid are of dietary health significance.

The digestion of starch and protein in dry legumes is lower than in cereal grains and many other foodstuffs. Factors contributing to decreased digestibility include: 1) increased dietary fiber intake; 2) intact cell walls which hinder penetration of the digestive enzymes to access the starch and protein; 3) residual lectin activity; 4) limited proteolysis of certain proteins; 5) incomplete hydration of the starch granule; and 6) amylose retrogradation.

Protein. The most commonly recognized nutrient of importance has consistently been protein. Typically, the crude protein content of beans ranges from 18-22% and is among the highest vegetable sources; however, it must be noted that the amino acid profiles limit the quality of bean protein. The "first limiting amino acid" is of most concern in assessing the nutritional value of a protein. Methionine, a sulfur containing amino acid, has always been shown to be the limiting amino acid in dry beans. Cereal grains such as wheat and corn, are limiting in lysine. Thus, these two protein sources are "complementary." Beans are thus used as a “complementary protein” for cereal grains particularly, rice and maize. The traditional food recipes (blends of beans and cereals) have profound influence within lesser-developed countries and among native cultures where beans are used as a vital dietary staple. Legume protein is generally less digestible than protein in grains and animal products. (Wolzak, A., R. Bressani and R. Gomez Brenes, 1981). The overall nutritional quality of storage proteins is defined by the product’s essential amino acid profile and bio-availability.

Starch. Legume starch is comprised of relatively high levels of linear amylose and less branched amylopectin than many cereal grains. The extent of starch hydration and swelling during soaking and cooking is important to end product quality. Digestion rate is affected by factors, which slow or prevent digestive enzymes from gaining access to the glycosidic bonds of starch. Substantial legume starch may reach the stomach and small intestine within intact cell walls. Thus, the fiber matrix of cell walls is a primary hindrance to starch digestion since amylase must penetrate the cell wall prior to amylolysis. Hydration state of the starch is an additional factor affecting digestion rate. Starch granules must be hydrated to be digested. Starch will imbibe water if sufficient energy is present to break the internal hydrogen bonds. Heating water provides the energy necessary to break the hydrogen bonds. Breakage of the hydrogen bonds chains allows the starch molecules to relax and the granule to swell. With continued swelling and hydration, the granule eventually loses its crystallinity and will begin to gelatinize at a critical heating temperature. Starch must be gelatinized to fully hydrate the starch and the degree of gelatinization may determine the rate of starch digestion. When beans are cooked, the starch is not fully hydrated and there are data, which suggest that, some of the starch still retains its bifringence (Hahn et al. 1977; Varriano-Marston, and DeOmana, 1979). It appears that more energy is required to break the bonds between starch chains in legume starch than in most other types of starch (Biliaderis et al 1981). Bean starch has a propensity to retrograde. The generally long chained amyloses present in beans have a high tendency to retrograde to crystalline matrices that resist enzymatic degradation (Biliaderis et al 1981). Retrograded amylose is indigestible within the small intestine (Englyst et al, 1987).

Dietary Fiber. Dietary fiber is comprised of the indigestible components of food fermented by microorganisms in the colon. Beans are high in total dietary fiber comprised of soluble and insoluble fractions. Herrera et al (1998) analyzed the soluble (SDF), insoluble (IDF) and total dietary fiber (TDF) in numerous raw and cooked legumes. Values for TDF in the raw legumes were 13.6% (chick peas) and 28.9% (white beans). In processed beans, values varied from 16.1% (yellow peas) and 27.0% (black beans). IDF was consistently greater than SDF. Anderson and Bridges (1988) present analytical results for a variety of legumes. Total Dietary Fiber (TDF) ranged from 10.2% for garbanzo beans to 34.0% for green beans. The soluble-fiber content as a percentage of TDF ranged from 10.4% for raw lentils to 49.1% for "pork and beans." Srisuma et al. (1991) studied cell wall (CW) materials of selected navy bean cultivars. Seed coat CW was rich in cellulosic structural polysaccharides (range 58.7-65.0%) and lignin (range 1.4-1.9%), whereas cotyledon CW was composed principally of matrix polysaccharides and was especially rich in a hot water soluble polymer (range 25.7-32.5%) and hemicelluose (14.6-19.2%). Cotyledon CW contained 11-14% protein, which was resistant to proteolysis and/or inaccessible to proteolytic enzymes. Gonzalez (2000) studied the effects of thermal treatment modifications on the content of Total Dietetic Fiber (TDF), Soluble Dietetic Fiber (SDF) and Insoluble Dietetic Fiber (IDF) in beans. The results indicate significant differences in the contents of TDF and its fractions, between the crude legumes and those subject to thermal treatment. Fleming and Reichert (1983) compared the effects of selected purified fibers to those derived from cereals or legume seeds. The cell-wall-fiber fraction of beans had little effect on feed consumption and growth. The cell-wall- fiber fraction reduced apparent protein digestibility and the hull fraction accelerated food passage relative to the fiber-free diet. Bourdon et al (2001) studied the effect of a test meal that contained dry beans as a source of dietary fiber on the acute hormone and lipid responses in men. It was concluded that adding beans to a meal to increase fiber content prolongs the postprandial presence of intestinally derived lipoproteins.

Dietary fiber interactions with proteins and minerals have been shown to reduce apparent bio-availability.

Fiber & protein digestibility. Gomes et al (1997) assessed the *in vitro* digestibility of bean proteins in relation to the interaction of amino acids with dietary fiber components. Digestibility of proteins associated with fiber fractions was found to be low and demonstrated to be related to the protein/cellulose ratio. Hughes et al (1996) investigated the ability of dietary fiber and tannins to lower protein utilization in dry beans. Tannins significantly reduced protein utilization. Soluble dietary fiber was primarily responsible for the reduction in protein digestibility that is commonly associated with dietary fiber in foods. Dietary fiber and tannins appear to contribute to the low nutritional value that is typical of bean protein. Acevedo et al (1994) studied the effect that the traditional cooking process of black beans has on the quantity and composition of soluble (SDF) and insoluble (IDF) dietary fiber of beans, as well as on its protein digestibility and protein quality. Protein digestibility and protein quality decreased from cooked to fried beans and was positively related to IDF.

Fiber & mineral binding. Garcia-Lopez (1985) assessed the influence of fiber on iron absorption. Neutral (NDF) and acid (ADF) detergent fiber obtained from cooked pinto beans was shown to bind Fe, Cu and Zn but not Mg. Binding depended on the concentration of the mineral. The ability of fiber to decrease Fe absorption appeared to depend on: fiber source; particle size and concentration; the presence of competing minerals; and the iron status of the animal.

Anti-Nutritional Factors And Bio-Availability

Seed storage and preparation conditions and inherent seed constituents dramatically influence digestibility and nutrient bioavailability of dry beans. Anti-nutritional factors (trypsin inhibitors, phytohemaglutinating compounds, commonly referred to as "lectins," and phytic acid) have long been recognized as concerns and require appropriate processing conditions to ameliorate adverse effects. These compounds are intrinsic to the bean and serve vital physiological processes during growth and development. These components may contribute acute and chronic adverse health effects and must be rendered inactive to assure nutrient adsorption and the expected health benefits derived from the consumption of beans. Additional factors affecting digestibility of various legumes include: saponins, protease inhibitors, lathyrogens, phytohaemagglutinins, favism, and cyanogenic glucosides as reported by Gupta (1987).

Protease Inhibitors (Trypsin Inhibitors)

It has been well understood that thermal inactivation of trypsin inhibitors is essential for use in animal and human food (Gomes et al. 1979; Genovese and Lajolo 1996). Birk (1996) discussed protein proteinase inhibitors as widely distributed in legumes. The Kunitz soybean trypsin inhibitor STI and the Bowman-Birk trypsinchymotrypsin inhibitor (BBI) have been characterized. The STI has been responsible for induction of the pancreatic enlargement. The BBI trypsin-chymotrypsin inhibitors from soybeans and from chickpeas inhibit insect midgut proteinases, supporting the hypothesis that proteinase inhibitors comprise the defense mechanism of the seed against insects. Of caution are the findings on the involvement of proteinase inhibitors, such as BBI, in prevention of tumorigenesis, suggesting a possible positive contribution of the active inhibitors to the nutritional or health value of legume seeds.

Phytohemagglutin (PHA) or "Lectins"

An important anti-nutrient is phytohemagglutinin (PHA), a heat-labile lectin known to depress the nutritional quality of dry beans (Thompson et al 1986). Lajolo and Genovese (2002) studied the nutritional significance of lectins and enzyme inhibitors from legumes with reference to: contents of enzyme inhibitors and lectins in legumes; nutritional and physiological effects; inactivation through processing; resistance to proteolysis; effects of chronic intake of low dietary levels; nutritional utilization of enzyme inhibitors and lectins; and possible useful biological activities of these compounds. Coffey et al. (1985, 1992 and 1993) used of two processes 1) extrusion and 2) cooking in a high pH medium, to achieve the inactivation of PHA. Extrusion was relatively ineffective in reducing the activity of PHA in whole red kidney or black beans. Extrusion was more effective but highly variable in reducing PHA activity of bean flours (25-80%). However, soaking and cooking beans at high pH was very effective, significantly reducing the activity of PHA and also reducing the time required to reach a palatable texture. Soaking and cooking dry beans at high pH also caused significant changes in the saline soluble protein extract as determined by gel electrophoresis. It was concluded that high pH cooking treatment could be useful in improving nutritional quality of dry beans.

Phytic acid

Reddy et al. (1982b) comprehensively reviewed phytate in legumes and includes: structure and chemistry of phytic acid; biological function; phytate content in legumes; and nutritional implications. Positive effects of processing procedures (i.e. cooking, germination, fermentation and breadmaking, soaking, autolysis and other processes) on phytates are discussed. Appropriate processing of cereals and legume seeds can reduce or eliminate appreciable amounts of phytic acid. Legumes contain relatively large amounts of phytic acid (Lolas and Markakis 1975). Phytic acid functions as a reserve material for phosphorus and typically accounts for 60-90% of the total seed phosphorus (Lolas et al., 1976). The metabolism of phytic acid during seed development and germination has been well established. Phytic acid serves several other important physiological functions, such as antioxidant protection during dormancy, storage of cations, and cell wall precursors. Phytic acid is undesirable because it readily chelates with metal ions as Ca, Mg, Zn, Cu, and Fe to form insoluble phytate salts (Crean and Haisman 1963). Such complexes are poorly absorbed from the intestine, resulting in reduced availability of these minerals.

Specific Positive Health Potentiating Responses

Recently, beans have been cited for imparting diverse positive health responses (hypocholesterolemic response, mitigation of diabetes and colonic cancer, and weight control) when properly positioned in the diet. As previously indicated, extensive research has been conducted to understand and improve the digestibility and bioavailability of bean nutrients particularly relevant to subsistent populations. However, within the world’s developed economies beans are increasingly noted for a variety of dietary health benefits. These benefits transcend the need for protein and energy and include concerns for risk reduction of a host of chronic diseases prevalent in western cultures. The increased incidences of cardiovascular health conditions and diabetes are noted concerns.

Research has demonstrated that increased consumption of dietary fiber and moderated starch digestion (resistant starch) that are available from dry beans possess specific physiological responses of health significance. These include documented hypocholesterolemic and hypoglycemic responses attributed to bean consumption. Kushi et al. (1999) states that there is growing evidence that cereals and legumes play important roles in the prevention of chronic diseases and that overall, the substantial epidemiological evidence of legumes in chronic diseases is very promising.

Hellendoorn (1976) reviewed the common diseases of civilization and their relation to lack of fiber in the diet; nutritional contribution of legumes; intestinal action following bean intake; and hypocholesterolemic effect of leguminous seeds. It was recommended that more dry beans and peas should be incorporated in the daily diet of people in the western counties due to stimulating action of fiber on peristalsis and the lowering effect on serum cholesterol. Further, extensive specific research studies and reviews on the health promoting aspects associated with bean consumption have been conducted. An overview of the health potentiating responses is summarized on selected topics:

Hypocholesterolemic Response

There is considerable evidence that foods high in water-soluble dietary fiber such as oats or bean products, and purified forms of water-soluble dietary fiber can reduce blood cholesterol (Kritchevsky, 2001; Anderson and Gustafson, 1988; Anderson et al 1999). The precise mechanism of action of the hypocholesterolemic effect of fiber has not been fully elucidated, however, proposed mechanisms may involve components of the following: 1) reduction of fat and energy intake; 2) reduction of cholesterol and fat absorption; 3) changes in endocrine response; 4) effects of colonic metabolites; 5) increased bile acid excretion.

The nutrient composition of dry beans makes them ideally suited to meet two major dietary recommendations for good health--increased intake of starches and complex carbohydrates and decreased consumption of fat. Dry beans supply protein, complex carbohydrate, fiber and essential vitamins and minerals to the diet, yet are low in fat and sodium and contain no cholesterol. Both protective and therapeutic effects of bean intake have been documented. Dry beans are an excellent way to increase dietary fiber consumption and most individuals can incorporate beans into their diet without difficulty if they do so gradually. Including dry beans in a health-promoting diet is especially important in meeting the major dietary recommendations to reduce risk of chronic diseases such as coronary heart disease, diabetes mellitus, obesity and cancer. (Geil PB, Anderson JW. 1994.)

Much of the clinical research associated with bean consumption has been conducted on hypercholesterolemic men (Anderson et al., 1984). Anderson and Chen (1982) reported that bean supplemented diets (115g dried beans/day; 50 g total and 20 g soluble fiber) were found to selectively lower atherogenic LDL cholesterol fractions while preserving anti-atherogenic HDL cholesterol levels. This effect probably relates to the high soluble storage polysaccharide content of legumes. Further, short chain fatty acid fermentation products of soluble fibers may attenuate hepatic cholesterol synthesis. The hypolipidemic effects of canned beans were also studied by in 10 hypercholesterolemic men. After 3 weeks on a canned-bean diet (122g daily; 24 g total and 7 g soluble fiber), serum cholesterol values averaged 13% lower and triglycerides values 12% lower than control values (Anderson et al., 1990). Daily consumption of 100-135g dried beans (dry measure) reduces serum cholesterol levels ~ 20% short-term, hypothetically reducing risk for CHD by 40% (Anderson et al., 1984). Smaller portions of 100-200g cooked or canned beans lower serum cholesterol ~12% short-term and 20-25% long-term (Anderson et al., 1984). Nutritional therapy combining HCF diets with bean supplementation is well tolerated and associated with no major side effects, except for reported increased flatulence.

Hypoglycemic Response of Beans Mitigates Diabetes

Legume starch is more slowly digested than starch from most other sources. The rate of *in-vivo* starch digestion is illustrated by the rise in blood glucose and insulin following the consumption of starch. The "glycemic index" (GI) has been developed to aid dietary treatment of diabetics (Jenkins et al. 1982). The glycemic index obviously reflects both gastric emptying and starch digestion rate. Low glycemic responses have been observed for legumes compared with other starchy foods such as bread, potato and certain breakfast cereals. Research designed to assess the low glycemic response attributed to consumption of bean products has been extensive and clearly demonstrates the positive impact associated with the slow release of glucose following ingestion (Jenkins et al.1983). Resistant starch present in cooked beans has been of particular interest (Higgins JA. 2004). Wolever et al. (1987) fed portions of five varieties of beans, both cooked and canned, to groups of diabetic patients, and found their glycemic indices to be lower than that of white bread (GI =100). They concluded that the canning process increased the glycemic effect of dried legumes. The effect of a meal prepared with pre-cooked instant bean flakes on glucose and insulin plasma levels was conducted. The elevation of glucose was markedly less during 2 hours following the ingestion of beans when compared to potatoes. The bean flake meal gave rise to only moderate elevation of plasma glucose and insulin levels (Tappy et. al., 1986).

In a study, volunteers took carbohydrate portions of eight varieties of dried legumes and 24 common foods. Both the mean peak rise in blood glucose concentration and mean area under the glucose curve of the subjects provided beans were at least 45% lower than those of subjects receiving the other foods. These results suggest a potentially valuable role for dried leguminous seeds in carbohydrate exchanges for individuals with impaired carbohydrate tolerance (Jenkins et. al. 1980).

Leathwood and Pollet (1988) studied slow release carbohydrates from ingested bean flakes on plasma glucose and satiety. After a meal containing potato, plasma glucose levels rose sharply, but fell below initial levels 2 to 3 hours later. In contrast, there was a low, sustained increase in blood glucose after consumption of bean puree. Consumption of bean puree delayed the return of hunger and decreased ratings for propensity to eat a tasty snack.

Colonic Cancer

There is increasing evidence that suggests an inverse relationship between bean consumption and colon cancer in humans. Therefore, increased direct research is warranted. Laboratory animal studies have demonstrated dramatic results in reducing incidence of chemically induced colonic cancer. Hughes et al. (1997) report that epidemiological studies show a low incidence of colon cancer in many Latin American countries where the consumption of dry beans (e.g., pinto) is high. Research using rats was conducted to test effects of dry beans on the inhibition of colon carcinogenesis. The carcinogen, azoxymethane (AOM), was used. This study demonstrated that dry beans contain anticarcinogenic compounds capable of inhibiting AOM-induced colon cancer in rats. However, the specific anticarcinogenic components within dry beans have not been identified, and it is unclear whether dietary fiber, phytochemicals or other components within dry beans are primarily responsible for the anticarcinogenic properties of beans. Additional, studies have determined that consumption of black beans and/or navy beans reduce colon carcinogenesis in rats. Rats were fed a modified AIN-93G diet (control) or diets containing 75% black beans or 75% navy beans for 4 wk, and then colon cancer was initiated by azoxymethane administration. It was concluded that eating black beans and navy beans significantly lowered colon cancer incidence and multiplicity. (Hangen and Bennink, 2002).

Weight Control

Weight control and weight management strategies involve highly complex physiological and psychological interactions. There is not a single food item that will have a sustained impact on weight control but rather a series of life-style and diet adjustments. However, beans have been noted to as a food that can contribute to weight management due to the relative low glycemic index, high resistant starch and high satiety level (Leathwood et.al.1988; Ludwig et al. 1999). Higgins (2004) discusses potential health benefits and metabolic effects of resistant starch consumption, including effects on: glucose and insulin responses (acute and chronic); lipid and cholesterol concentration; satiety; and fat oxidation and storage. The role of short chain fatty acids resulting from fermentation of resistant starch was also considered, as well as the potential use of resistant starch in weight loss and management diets.

Conclusions

The trends in the consumption of legume-based products are dynamic and can be readily influenced by public policy, educational strategies and industrial innovation. The evidence for health promoting aspects of legume-based foods is strong and should receive more attention by consumers.

The targeted use of food aid programs and assistance with procurement and distribution of dry beans and/or partially prepared ingredients (flours, powders, meals or extrudates) or fully prepared products (canned, precooked-dehydrated, extruded) will directly expand use in the most urgently needed populations. Utilization of prepared dry edible beans has consistently been advocated by both governmental and non-governmental organizations (NGO). These nutrition programs are particularly important to infants and children. Dry edible beans are also frequently considered for applications in regions experiencing sustained crop failure. The further use of beans as direct food aid and possible use in monetarization programs should be encouraged.

The integration and expansion of public and private sector research and educational support programs including publicity campaigns designed for culturally appropriate proclamations are warranted. Supportive behavior change strategies emphasizing the nutritional and health benefits of beans must be emphasized. The long term efforts and documented accomplishments associated with the USAID Bean/Cowpea CRSP projects and the more recent and immediate impact of the Bean Health Alliance (BHA) (www.beansforhealth.org) are to be commended and should be further sustained.

The food industry, in cooperation with public research programs (universities and centers) and other professional organizations, must focus efforts to incorporate dry beans and minor grain legumes into innovative products that are economically viable, readily accessible to consumers, convenient to use and of high culinary quality. The clearly recognized healthy attributes of beans deliverable in both subsistent and developed diets should be exploited for long-term improvement in positive health outcomes. The factors limiting the consumption of dry beans in industrial economics may in-part be attributable to an inadequate level of innovation for developing value-added products adapted to modern consumer needs for convenience while specifically linked to high quality eating experiences.

In developed countries of Europe and North America, beans are generally prepared by commercial food processing operations and consumed as canned beans in brine or sauce. The market and overall consumption of beans and formulated bean products are expected and to increase and to further segment as they are positioned as nutritionally rich and healthy foods. However, the development of high quality bean products in convenience foods categories such as dehydrated, frozen, and extruded formats remains an open opportunity.

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Table I: Terminology Used in Conjunction with Dry Bean and Legume Foods

- "Food legumes" (used for direct edible portions, such as beans) versus "Forage legumes" (used for crop rotation or animal feed such as clover or alfalfa).
- Legume is derived from the Latin term *Legumen* defining seeds harvested in pods.
- Legume seeds possessing low levels of lipids are frequently termed "pulses" and are derived from the Latin *puls* referring to pottage.
- "Legume" was used in early England to encompass all general vegetables in a manner similar to the current French terminology.
- "Leguminous comestible" is used to refer to a broad host of edible plant products which may include cereal grains and is thus not limited to the technical and botanical definition of legumes.
- "Grain legumes" is commonly used in literature associated with lesser developed regions and subsistence agriculture. (India commonly utilizes this terminology to describe a broad array of crops including: soya, chick peas, dry beans and lentils.) Grain legumes may be used as edible whole seeds or processed as dehusked-split cotyledons referred to as "dhal" or milled into flours and meals.
- Terminology used to refer to the common bean *Phaseolus vulgaris* varies by country include: haricot (French); kidney and navy (British); habas (Mexican); feijaos (Portuguese); frijoles (Spanish); fagiolo (Italian); bohnen (German).
- Various other common food legumes are frequently not distinguished from common dry beans including: soybean (*Glycine max.*); cowpea (*Vigna sinensis)*; fava bean / broad bean / horse bean (*Vicia faba*); garbanzo / chick pea (*Cicer arietinum)*; lima bean (*Phaseolus lunatus)*; peanuts (*Arachis hypogea*); and lentils (*Lens culinaris)*.
- Legumes may be consumed as products derived from in a wide variety of plant tissue including:
  - Herbaceous succulent tissue, commonly immature seeds in fleshy pods (e.g. string beans, snap beans, or "snowpeas")
  - Immature seeds removed from pods (e.g. garden peas)
  - Mature dry seeds (e.g. dry beans)
- "Dry shell beans," "field beans," "dry edible beans," and "common beans" are terms used for plants producing a wide spectrum of dry leguminous seeds.
- The United Nations Food and Agricultural Organization (FAO) generally uses the term "legume" to refer to all leguminous plants. The seeds are classified into groups according to the various lipid contents. Thus, "pulses" (low-fat: beans, lentils, chick peas) and leguminous oil seeds (high-fat: soy and peanuts) are widely accepted.
- The typical food legumes are annual plants; however perennial legume plants include shrubs and trees such as locusts (locust beans) and other woody species.
- Legumes presented in the genus *Phaseolus* contain only legumes of "new-world" botanical origin.
- Garden peas consumed as immature seeds or field peas consumed from the mature, dry state are readily distinguished at the stage of harvest. Green peas are commonly considered a "fresh" or "processed" vegetable whereas field peas are considered "pulses." Dried peas (terminology derived from Sanskrit, "pease") have a long history as a traditional legume food. However, fresh garden peas were only recently introduced through French cuisine during the reign of Louis XIV.

Table II. Selected Consumer Comments Regarding the General Knowledge of Legume Based Foods (Uebersax, 2002)

- “They are seeds but not cereal grains”
- “They are good for you”
- “They are protein foods”
- “They are bitter”
- “They replace meats”
- “They may complement cereal proteins to improve nutrition”
- “Soy is a legume”
- “You need some, but not much”
- “Peanut butter is a legume food”
- “Beans and rice go together”
- “They help the soil”
- “My culinary cookbook (French cuisine) calls them vegetables”
- “They are a poor man’s food”

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