Dry Beans and Pulses Production,
Processing and Nutrition
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Preface

The common beans and pulses are diverse food resources of high nutritional value (protein, energy, fiber, and vitamins and minerals) with broad social acceptance. These legume crops demonstrate global adaptability, genotypic and phenotypic diversity and multiple means of preparation and dietary use. Beans and pulses are produced in regions as diverse as Latin America, Africa, Asia and North America. However, these food crops have not been afforded their due importance to a scale similar to some other crops such as wheat, corn, rice or soybean.

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 bioavailability are dramatically influenced by these conditions. In recent years, beans and pulses have been cited for imparting specific positive health potentiating responses, such as hypocholesteremic response, mitigation of diabetes and colorectal cancer, and weight control. Enhanced dry bean utilization focused on improved dietary health is an opportunity within both subsistent and developed populations.

This book provides a contemporary source of information that brings together current knowledge and practices in the value chain of bean/pulse production, processing, and nutrition. This work provides an in-depth coverage on a wide variety of pertinent topics: breeding, postharvest technologies, composition, processing technologies, food safety, quality, nutrition, and significance to human health. An experienced team of over 25 contributors from North America, Asia and Africa has written 15 chapters, divided into three sections. These contributors come from a field of diverse disciplines, including crop sciences, food science and technology, food biochemistry, food engineering, nutritional sciences and culinology.

Part I of the book—“Overview, production and postharvest technologies of beans and pulses”—contains chapters on global production and consumption; breeding and production technologies; market classes and physical and physiological characteristics; and postharvest storage quality, packaging and distribution. Part II—“Composition, value-added processing and quality”—has eight chapters: composition of processed beans/pulses; hydration, blanching, and thermal processing; canning and canned products; extrusion processing and products; processing of flours and fractions; cowpea processing and products; utilization of beans and pulses in Africa; and common pulses, including chickpea, lentil, mungbean, black gram, pigeon pea and Indian vetch. The last part—“Culinology, nutrition and significance in human health”—has three chapters: culinary perspective of beans and pulses; nutrition and human health benefits; and chemistry and implications of antinutritional factors. This value-chain approach to the topics covered is a distinctive feature of this book.
The editors acknowledge many individuals for their support from conception through final development of this book. Foremost is our sincere thanks and gratitude to all authors for their contributions and for bearing with us during the review and finalization process of their chapters. We are grateful to our family members for their understanding and support enabling us to complete this work. We dedicate this work to the worthy contributions of the numerous researchers and students throughout the world for their decades-long devoted efforts to improve the quality and utilization of dry beans and pulses.

*Muhammad Siddiq*

*Mark A. Uebersax*
Part I
Overview, Production and Postharvest Technologies
1 Dry Beans and Pulses Production and Consumption—An Overview

Muhammad Siddiq and Mark A. Uebersax

INTRODUCTION

Legumes (dry beans and pulses) occupy an important place in human nutrition, especially among the low-income groups of people in developing countries. They are a good source of protein (significantly higher than that of cereals), dietary fiber, starch (Osorio-Diaz et al. 2003), minerals and vitamins (Kutos et al. 2002). They are a staple food and low-cost source of protein in developing countries where protein energy malnutrition (PEM) is prevalent (Van Heerden and Schonfeldt 2004). Many reports claim that inclusion of legumes in the daily diet has many beneficial physiological effects in controlling and preventing various metabolic diseases such as diabetes mellitus, coronary heart disease and colon cancer (Tharanathan and Mahadevamma 2003). Further, legumes belong to the group that elicits the lowest blood glucose response and contains considerable amount of phenolic compounds. The role of legumes as therapeutic agents in the diets of people suffering from metabolic disorders has gained significant interest in recent years.

Legume crops demonstrate global adaptability, genotypic and phenotypic diversity, and multiple means of preparation and dietary use (see Fig. 1.1 for a selection of common dry
beans and pulses). 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 bioavailability are dramatically influenced by these conditions. Antinutritional factors (trypsin inhibitors, lectins and phytic acid) have long been recognized as concerns and require appropriate processing conditions to ameliorate adverse effects. However, it is noted that some of the antinutrients may have therapeutic value (e.g., tannins, phenolics). In recent years, beans have been cited for imparting specific positive health potentiating responses (hypercholesteremic response, mitigation of diabetes and colorectal cancer, and weight control) when properly positioned in the diet.

The general consensus of recent opinion on healthy eating habits favors an increase in the proportion of legume-based polymeric plant carbohydrates, including starch (particularly, resistant starch) in the diet. In the growing phase of urbanization in developing countries, ready-to-eat foods are beginning to play a major role in food consumption patterns, and moreover, traditional methods of preparation are generally labor and time intensive and certainly unsuitable for urban settings where time is very often a major constraint (Njintang et al. 2001).

The common bean (Phaseolus vulgaris L.) is considered the most widely grown among more than 30 Phaseolus species described in the literature. It has undergone wide produc-
tion distribution from its origins in Mexico, Central America, and the Andean region of South America, has extensive domestication and cultivation, and has been utilized in a variety of food preparations (Hidalgo 1988). Scientific (genus and species) and common names for various food legumes are:

- *Phaseolus vulgaris* L. (common bean, field bean, haricot)
- *Vigna unguiculata* L. (cowpea, black-eyed pea, crowder pea)
- *Cicer arietinum* L. (chickpea, garbanzo, Bengal gram, gram, Chana)
- *Lens culinaris* Medik. (lentil, Masur)
- *Vigna aureus* (mung bean, green gram, golden gram)
- *Cajanus cajan* L. Millsp. (pigeon pea, Congo pea, red gram, Angola pea, yellow dhal)
- *Phaseolus lunatus* L. (lima bean, butter bean)
- *Vicia faba* L. (broad bean, faba bean, horse bean)
- *Vigna aconitifolia* Jacq. (moth bean, mat bean)
- *Pisum arvense sativum* L. (common or garden pea, pois, arveja, Alaska pea, muttar)
- *Glycine max* (L.) Merr. (soybean, soya, haba soya)

Enhanced dry bean utilization focused on improved dietary health is an opportunity within subsistence and developed diets. This chapter provides an overview the important aspects of dry beans and pulses production, postharvest handling and storage, value-added processing and products, nutritional significance, and health benefits.

**History and origin**

Beans may be called “the food of the ancients,” with literature recording the cultivation of beans, lupins and lentils in the Nile Valley dating as early as 2000 BC. Beans have played a part in the superstitions, the politics and the warfare of ancient peoples. Magistrates were elected in Greece and Rome by the casting of beans into helmets. Certain kinds have been credited with medicinal value (Hardenburg 1927). Various forms still serve as the principal source of protein food for the vast populations in the countries bordering the Mediterranean Sea and the Indian Ocean.

*Phaseolus* beans are recognized as an exclusive New World crop of American origin despite their wide distribution worldwide. It is now generally accepted that all the species of the genus *Phaseolus* originated in Mexico, Guatemala, and the high Andes based on the wide genetic diversity of the cultivated and wild species that exists in the region (Evans 1976).

The early Europeans, first in the New England states of the United States, then generations later in the upper Midwest (Great Lakes region), found that the white pea bean and many other dry beans provided a fine staple for their own subsistence diet. The settlers possessed many considerable possibilities in growing dry beans that the native Indians apparently never exploited. They traded their excess production to non-bean growing neighbors for goods, services, or cash. The Iroquois Indians grew this small, round pea bean (Indian bean) with corn and squash (the “three sisters” cropping system); this bean later became known as the “navy bean” because of the large demand that developed for this bean for naval and marine food supply purposes.
PRODUCTION AND TRADE

Dry beans are grown widely in different regions of the world. The significance of dry beans and pulses is made clear by the wide distribution of their production and consumption in the diverse regions of the world, as summarized below:

- **East Asia**: China, Cambodia, Indonesia, Japan, Republic of Korea, Myanmar, Philippines, Thailand, Vietnam
- **South Asia**: Bangladesh, India, Nepal, Pakistan, Sri Lanka
- **West Asia/Middle East**: Iran, Israel, Jordan, Lebanon, Saudi Arabia, Turkey, Yemen
- **North America**: USA, Mexico, Canada
- **Central America and Caribbean**: Costa Rica, Cuba, Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Nicaragua, Panama
- **South America**: Argentina, Bolivia, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay, Venezuela
- **Europe**: Albania, Austria, Benelux, Bulgaria, France, Germany, Greece, Hungary, Ireland, Italy, Poland, Portugal, Romania, Spain, Sweden, United Kingdom, Russian Federation
- **East Africa**: Burundi, Ethiopia, Kenya, Rwanda, Somalia, Sudan, Tanzania, Uganda, Zaire
- **West Africa**: Algeria, Egypt, Morocco, Tunisia
- **South Africa**: Angola, Lesotho, Madagascar, Malawi, Republic of South Africa, Swaziland, Zimbabwe

Global production and trade

The world production of dry beans was 23.2 million metric tons (MT) in 2010, which represented an increase of almost 70% as compared to that in 1980 (Fig. 1.2). From 1980 to 2000, dry production increased by 3.9 million MT; however, a significantly higher increase (5.6 million MT) was reported in only the 10-year period from 2000 to 2010. The area under dry beans cultivation increased only by 14% during the past three decades and has ranged between 23.83 million hectares (2000) and 28.83 million hectares (2007). These figures illustrate that most of the production increases during the past three decades were achieved through genetic improvements and applying good agricultural practices (GAPs) than through increases in area under cultivation. Most regions of the world have seen significant increases in production during past three decades: Africa (145%), Asia (36%), and the Americas (North, Central and South) (49%); only Europe saw a decrease of about 35% (FAO 2011).

The total world production of pulses (chickpeas, lentils, lupins, pigeon peas, vetches, and other minor pulses) in 2010 was 24.3 million MT, which was more than double than that in 1980. It is noted that while the pulses production increased by 53% in 10 years (1980–90), it has advanced at a slower rate (32%) from 1990 to 2010. The area under pulse cultivation increased by 23% from 21.5 million hectares to 26.5 million hectares; however, during the 1990–2010 period, cultivation area for pulses has not changed significantly, as exhibited by only a 5.6% increase.

The fava/cowpea world production was 10.6 million MT in 2010, which was more than three times as much as compared to 1980. While the fava/cowpea production ranged between 3.4 million MT and 5.7 million MT during 1980–90, it increased by about 86%
Fig. 1.2. Area under cultivation (lines) and world production (bars) of dry beans, pulses and fava/cowpea (1980–2010). Dry beans data include pinto, navy, kidney, lima, black, Great Northern; pulses data include chickpeas, lentils, lupins, pigeon peas, vetches, and other minor pulses.
from 1990 to 2010. The area under fava/cowpea cultivation experienced similar growth from 1.2 million hectares in 1980 to 5.6 million hectares in 2010. In contrast to dry beans, the boost in fava/cowpea world production appeared to be related mainly to the increases in the cultivated area.

India, Brazil, Myanmar, China, and the United States were the top five dry beans-producing countries, with a production of 4,870,000 MT; 3,202,150 MT; 3,029,800 MT; 1,539,500 MT; and 1,442,470 MT, respectively, in 2010 (Table 1.1); combined, these five countries contributed over 50% of the total world production.

Nigeria and Niger were the major cowpea producers, accounting for 73% of the total world production. India ranked first among chickpea producers (with almost 70% of world share), followed by Australia and Pakistan. The cowpea production in the USA has been rather limited until recent years, with 2010 production at 65,570 MT. Lentil production is led by Canada, followed by India and Turkey; Canada’s share of total lentil production in the world was 42%. India, Ethiopia, and Australia were the leading countries producing pigeon pea, vetches, and lupins, respectively; India also led in other minor pulses production (Table 1.1).

The major dry bean exporting and importing countries are listed in Table 1.2. China was the lead exporter, followed by Myanmar and the United States whereas India was the top-most importer, followed by Mexico and the United States. Pulses and cowpeas are also traded in the world market; however, accurate data are not available since the FAO does not report figures for pulses and cowpeas.

### Table 1.1. Leading dry beans and pulses producing countries in 2010 (metric tons)

<table>
<thead>
<tr>
<th>Dry Beans</th>
<th>Cowpeas</th>
<th>Chickpea</th>
<th>Lentils</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>4,870,000</td>
<td>Nigeria</td>
<td>2,242,800</td>
</tr>
<tr>
<td>Brazil</td>
<td>3,202,150</td>
<td>Niger</td>
<td>1,800,900</td>
</tr>
<tr>
<td>Myanmar</td>
<td>3,029,800</td>
<td>Burkina Faso</td>
<td>432,400</td>
</tr>
<tr>
<td>China</td>
<td>1,539,500</td>
<td>Myanmar</td>
<td>169,900</td>
</tr>
<tr>
<td>USA</td>
<td>1,442,470</td>
<td>Cameroon</td>
<td>135,000</td>
</tr>
<tr>
<td>Mexico</td>
<td>1,156,250</td>
<td>Mali</td>
<td>109,500</td>
</tr>
<tr>
<td>Tanzania</td>
<td>950,000</td>
<td>Tanzania</td>
<td>90,000</td>
</tr>
<tr>
<td>Uganda</td>
<td>460,000</td>
<td>Uganda</td>
<td>85,000</td>
</tr>
<tr>
<td>Kenya</td>
<td>390,598</td>
<td>Malawi</td>
<td>80,100</td>
</tr>
<tr>
<td>Argentina</td>
<td>338,120</td>
<td>Kenya</td>
<td>72,274</td>
</tr>
<tr>
<td>World Total¹</td>
<td>23,230,034</td>
<td>World Total¹</td>
<td>5,540,903</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pigeon pea</th>
<th>Vetches</th>
<th>Lupin</th>
<th>Other Pulses</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>2,460,000</td>
<td>Ethiopia</td>
<td>202,700</td>
</tr>
<tr>
<td>Myanmar</td>
<td>724,200</td>
<td>Turkey</td>
<td>121,676</td>
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<tr>
<td>Malawi</td>
<td>182,900</td>
<td>Mexico</td>
<td>98,400</td>
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<tr>
<td>Kenya</td>
<td>103,324</td>
<td>Russian Fed.</td>
<td>59,030</td>
</tr>
<tr>
<td>Uganda</td>
<td>93,000</td>
<td>Spain</td>
<td>45,600</td>
</tr>
<tr>
<td>Tanzania</td>
<td>55,000</td>
<td>Belarus</td>
<td>39,070</td>
</tr>
<tr>
<td>Dominican Rep.</td>
<td>25,070</td>
<td>Serbia</td>
<td>33,115</td>
</tr>
<tr>
<td>Nepal</td>
<td>18,647</td>
<td>Ukraine</td>
<td>33,100</td>
</tr>
<tr>
<td>Congo</td>
<td>5,901</td>
<td>Syria</td>
<td>14,600</td>
</tr>
<tr>
<td>Haiti</td>
<td>2,400</td>
<td>Italy</td>
<td>9,200</td>
</tr>
<tr>
<td>World Total¹</td>
<td>3,680,314</td>
<td>World Total¹</td>
<td>704,362</td>
</tr>
</tbody>
</table>

¹Including all other countries not listed
Source: FAO (2011)
not report such data on these commodities. It is noted that the countries that are both exporters and importers of dry beans (e.g., the United States and the United Kingdom) are frequently exporting and importing different types of beans.

### US production and trade

North Dakota and Michigan were the two leading dry bean producing states (Table 1.3); together, these two states represented about 50% of total US production with a 36.1% and 13.3% share, respectively. Michigan traditionally was the leading dry bean producing state; however, North Dakota has been the leader for over a decade. The total US production of dry beans was 1.45 million MT in 2010, which is lower than that reported for 1990 (1.64 million MT). Pinto and navy beans are the two leading classes of dry beans produced in the United States (Fig. 1.3). The 2010 black bean production was about three times more than in 1980. Black beans were the only bean class that has seen such a tremendous growth. Garbanzo beans (chickpeas) production, which was only about 3,000 MT in 1980, has shown a tremendous growth in recent years, with 2010 figures as 87,952 MT.
Fig. 1.3. Different classes of dry beans produced in the United States for selected years during 1980–2010. Source: USDA-ERS (2011a).

During the same period (1980–2010), lentil production also increased significantly from about 98,000 MT to 392,670 MT. Cowpeas are the only other pulse crop of commercial significance in the United States, with 65,570 MT in 2010.

CONSUMPTION TRENDS OF DRY BEANS

The regions of highest bean consumption include all of Latin America, where legume consumption ranges from 1 kg (2.2 lbs) per capita per year (Argentina) to 25 kg (55 lbs) per capita per year (Nicaragua); common beans dominate and account for 87% of the total legume products consumed (Leterme and Muñoz 2002).

Since 1960, the per capita consumption of dry beans in the United States has ranged from a high of 8.96 lbs to 5.40 lbs, with a recent figure of 6.10 lbs in 2009 (Fig. 1.4) (USDA-ERS 2011a). Cooked bean consumption is recognized to be greatest in the southern and western areas of the country. About 55% 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% of the population, they account for 33% 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).

Dry beans are not a staple in the United States, and per capita consumption had been declining since mid-1960s. This decline in bean consumption was directly related to
changes in consumers’ food preferences. Rising incomes, urbanization, single adult household structure and the increase in the number of women in the labor force have adversely affected bean consumption. Most consumer preferences are shifting in favor of convenience foods and commodities, which require reduced food preparation time. Traditionally, dry bean products did not lend themselves to these emerging trends in consumer choices; however, recent advances in complex formulations and complete baked beans recipes have been innovative and greatly improved the convenience and high quality acceptability.

The per capita consumption of legume-based food products in the United States, Europe [encompassing the European Union (EU)] and other industrialized economies has generally and consistently been substantially lower than that observed in other regions of the world (Schneider 2002).

**DRIY BEANS AND PULSES AS A DIVERSE FOOD RESOURCE**

The common dry bean and associated legumes (pulses) are of global agronomic and dietary importance. These agricultural crops demonstrate global adaptability, genotypic and phenotypic diversity, and undergo 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 (Uebersax 2006).

The numerous culinary quality traits of beans contribute to their acceptable use but are frequently underestimated in their influence. These include: (1) accessibility and storage—local indigenous versus commercial production and open marketplace versus packaged procurement (on-site point of purchase quality assessment, frequency and quantity of purchase); (2) in-home storage and meal planning dynamics (stability, knowledge, water availability); (3) preparation and quality—the extensive constraints associated with preparation and cooking (water and fuel availability, sanitation, and time); and (4) characteristic

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**Fig. 1.4.** US per capita consumption of total dry beans for selected years since 1960. Source: Adapted from USDA-ERS (2011b).
palatability attributes such as texture and integrity, texture (firmness and consistence), and taste and flavor (Uebersax 2006).

The use of dry beans and pulses may be considered from either a traditional or a value-added perspective. In traditional households, dry beans are cooked, fried, or baked to be in soups, eaten as vegetables, or combined with other protein foods to make a main dish. Commercially, beans have commonly been packaged in dry-pack form intended for home preparation and also processed by canning in brine or tomato-based sauce.

**Traditional utilization**

Utilization of legumes in many regions still entails long and tedious preparations. Generally, 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, since these beans take a longer time to cook and lack desired quality attributes after cooking (Borget 1992).

Beans and maize in blended dishes are deeply imbedded throughout Latin American cultures and transcend to other groups of people. It is due in part to the inherent complementation of amino acids, resulting in a more complete protein food. 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 forms (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 legume seeds are consumed fresh or dehulled and roasted or ground for use in soups or side dishes (Aykroyd and Doughty 1982).

In many developing regions, women provide a central role focused on sustaining the family’s food security. 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.

**Value-added processing and products**

Beans typically require dry cleaning and sorting, gentle handling to assure a minimum degree of mechanical damage, and soaking and blanching prior to filling and thermal processing. The popularity of convenience foods such as dehydrated, extruded, frozen and microwavable food products has provided a venue for the development of new bean products or bean formulations (Fig. 1.5). Selected categories of dry-bean-based products utilized in industrialized regions, typically with wide market distribution channels, include packaged dry beans, canned beans (beans in brine or specialty sauces), precooked bean products (precooked and dehydrated bean flakes and powders), extruded and pasta-type products, specialized food ingredients (meals, flours, concentrates, powders and flakes), quick-cooking beans, and frozen beans. In developed nations, canned products consistently
dominate bean usage (based on individual frequencies of use data and total sales volume) compared with dry beans distributed in prepackaged retail offerings or through direct bulk dispensing.

**NUTRITIONAL AND HEALTH CONSIDERATIONS**

The characteristics that make beans and pulses a good food value are: (1) health and wellness. It is noteworthy that consumers are increasingly selecting healthy and balanced diets proportionally higher in plant-based foods. Legumes have significant nutritional and health advantages for consumers since they are high in protein and dietary fiber and very low in fat; and (2) environmental sustainability. Advantages are associated with legume nitrogen fixation in soils. Legumes cultivation has been associated with a positive impact on agriculture and the environment (Uebersax 2006). 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. People of subsistence or lower income levels generally consume larger quantities of beans, which furthers the stereotypical response “beans are a poor man’s steak” that often stigmatizes and denigrates bean use and reduces expanded utilization.

**Nutritional profile**

Legumes (dry beans and pulses) are a good source of protein, dietary fiber, starch (Osorio-Diaz et al. 2003), minerals and vitamins (Kutos et al. 2002). Table 1.4 shows a compositional comparison of dry beans with major cereal grain crops. In comparison to these cereal
grains, beans are relatively high in proteins and dietary fiber while low in fat and have relatively reduced carbohydrates.

### Health significance

Legumes belong to the group of foods that elicits the lowest blood glucose response and contains considerable amounts of phenolic compounds. The role of legumes as therapeutic agents in the diets of persons suffering from metabolic disorders has gained some research interest (Shehata et al. 1988). In the general opinion on healthy eating habits, an increase in the proportion of legume-based polymeric plant carbohydrates, including starch, is recommended in the diet. In the growing phase of urbanization in developing countries, ready-to-eat foods play a major role in the food consumption pattern, and moreover, traditional methods of preparation are generally labor and time intensive and certainly unsuitable for urban settings where time is very often a major constraint (Njintang et al. 2001).

Recently, heightened consumer awareness has led to the promotion of less saturated fat, cholesterol, sugar and salt in the diet and the preference for complex carbohydrates such as fiber. No single food outside of the context of the total diet should be recommended exclusively; however, dry beans can be promoted as a healthy food, being nutrient dense and an excellent source of dietary fiber (Table 1.5). Figure 1.6 shows the comparative nutritional benefits of dry beans versus cereal grains. Protein quality is generally not a nutritional concern for consumers who have mixed diets containing both vegetable and animal proteins.

A diet high in beans can potentially reduce the risk of developing a chronic disease (Wu et al. 2004). Chronic diseases are conditions that typically take many years (10 to 30 years) to develop and include certain types of cancers, type 2 diabetes mellitus, heart disease, and other diseases of the blood system. These diseases are the most common causes of death in the United States and many other parts of the world (Geil and Anderson 1994; Hangen and Bennink 2002). The inclusion of dry beans and other legumes in the daily diet has many beneficial effects in controlling and preventing various metabolic diseases such as diabetes mellitus, coronary heart disease and colon cancer (Dilis and Trichopoulou 2009; Flight and Cliffton 2006; Raju and Mehta 2009).

Antioxidants (chemicals that eliminate free radicals) are found to be very high in many types of beans. Wu et al. (2004) investigated the oxygen radical absorbance capacity (ORAC) of over 100 common foods consumed in the United States. Their data showed that red kidney beans had the highest total antioxidant capacity per serving size.
Table 1.5. Composition of selected dry beans and pulses (per 100 g)

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Pinto Bean</th>
<th>Navy Bean</th>
<th>Black Bean</th>
<th>Red Kidney Bean</th>
<th>Cowpea</th>
<th>Chickpea</th>
<th>Lentil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximate:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>g</td>
<td>11.33</td>
<td>12.10</td>
<td>11.02</td>
<td>11.75</td>
<td>11.05</td>
<td>11.53</td>
<td>10.40</td>
</tr>
<tr>
<td>Energy</td>
<td>Kcal</td>
<td>347</td>
<td>337</td>
<td>341</td>
<td>337</td>
<td>343</td>
<td>364</td>
<td>353</td>
</tr>
<tr>
<td>Protein</td>
<td>g</td>
<td>21.42</td>
<td>22.33</td>
<td>21.60</td>
<td>22.53</td>
<td>23.85</td>
<td>19.30</td>
<td>25.80</td>
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<tr>
<td>Total lipid (fat)</td>
<td>g</td>
<td>1.23</td>
<td>1.50</td>
<td>1.42</td>
<td>1.06</td>
<td>2.07</td>
<td>6.04</td>
<td>1.06</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>g</td>
<td>62.55</td>
<td>60.75</td>
<td>62.36</td>
<td>61.29</td>
<td>59.64</td>
<td>60.65</td>
<td>60.08</td>
</tr>
<tr>
<td>Fiber, total dietary</td>
<td>g</td>
<td>15.5</td>
<td>24.4</td>
<td>15.5</td>
<td>15.2</td>
<td>10.7</td>
<td>17.4</td>
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<td>Sugars, total</td>
<td>g</td>
<td>2.11</td>
<td>3.88</td>
<td>2.12</td>
<td>2.10</td>
<td>–</td>
<td>10.70</td>
<td>2.03</td>
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<td>Minerals:</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium</td>
<td>mg</td>
<td>113</td>
<td>176</td>
<td>123</td>
<td>171</td>
<td>83</td>
<td>333</td>
<td>115</td>
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<tr>
<td>Iron</td>
<td>mg</td>
<td>5.07</td>
<td>175</td>
<td>5.02</td>
<td>5.02</td>
<td>6.69</td>
<td>9.95</td>
<td>6.24</td>
</tr>
<tr>
<td>Magnesium</td>
<td>mg</td>
<td>176</td>
<td>352</td>
<td>171</td>
<td>407</td>
<td>138</td>
<td>438</td>
<td>175</td>
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<tr>
<td>Phosphorus</td>
<td>mg</td>
<td>411</td>
<td>407</td>
<td>352</td>
<td>352</td>
<td>406</td>
<td>366</td>
<td>451</td>
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<tr>
<td>Potassium</td>
<td>mg</td>
<td>1393</td>
<td>1359</td>
<td>1185</td>
<td>1483</td>
<td>1375</td>
<td>875</td>
<td>955</td>
</tr>
<tr>
<td>Sodium</td>
<td>mg</td>
<td>12</td>
<td>12</td>
<td>5</td>
<td>5</td>
<td>12</td>
<td>58</td>
<td>24</td>
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<tr>
<td>Zinc</td>
<td>mg</td>
<td>2.28</td>
<td>3.65</td>
<td>3.65</td>
<td>3.65</td>
<td>2.79</td>
<td>6.61</td>
<td>3.43</td>
</tr>
<tr>
<td>Vitamins:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin C</td>
<td>mg</td>
<td>6.3</td>
<td>–</td>
<td>0</td>
<td>4.5</td>
<td>1.5</td>
<td>4.0</td>
<td>4.4</td>
</tr>
<tr>
<td>Thiamin</td>
<td>mg</td>
<td>0.713</td>
<td>0.775</td>
<td>0.900</td>
<td>0.608</td>
<td>0.680</td>
<td>0.477</td>
<td>0.873</td>
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<tr>
<td>Riboflavin</td>
<td>mg</td>
<td>0.212</td>
<td>0.164</td>
<td>0.193</td>
<td>0.215</td>
<td>0.170</td>
<td>0.212</td>
<td>0.211</td>
</tr>
<tr>
<td>Niacin</td>
<td>mg</td>
<td>1.174</td>
<td>2.188</td>
<td>1.955</td>
<td>2.110</td>
<td>2.795</td>
<td>1.541</td>
<td>2.605</td>
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<tr>
<td>Vitamin B-6</td>
<td>mg</td>
<td>0.474</td>
<td>0.428</td>
<td>0.286</td>
<td>0.397</td>
<td>0.361</td>
<td>0.535</td>
<td>0.540</td>
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<tr>
<td>Folate</td>
<td>µg</td>
<td>525</td>
<td>364</td>
<td>444</td>
<td>394</td>
<td>639</td>
<td>557</td>
<td>479</td>
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<tr>
<td>Vitamin A</td>
<td>IU</td>
<td>0</td>
<td>0</td>
<td>17</td>
<td>0</td>
<td>33</td>
<td>67</td>
<td>39</td>
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<tr>
<td>Vitamin E</td>
<td>mg</td>
<td>0.21</td>
<td>0.02</td>
<td>0.21</td>
<td>0.21</td>
<td>–</td>
<td>0.82</td>
<td>0.49</td>
</tr>
<tr>
<td>Vitamin K</td>
<td>µg</td>
<td>5.6</td>
<td>2.5</td>
<td>5.6</td>
<td>5.6</td>
<td>–</td>
<td>9</td>
<td>5</td>
</tr>
</tbody>
</table>

1Total ascorbic acid
2Dietary folate equiv.
3As α-tocopherol
4As phylloquinone
Source: USDA (2012)

Fig. 1.6. Nutritional benefits of dry beans versus cereal grains (data for cereal grains are an average of wheat, corn, sorghum and oat).
Source: Adapted from USDA (2012).
as compared to all other foods, including many fruits and vegetables. Among all the foods analyzed in that USDA study, dry beans (small red, red kidney, pinto, and black beans) were found to have high levels of antioxidants. Generally, anthocyanin-rich fruits, such as blueberries and plums, are associated with having high antioxidant content; however, the above three types of beans were found to have higher antioxidant capacity than even blueberries. It is noted that the ORAC data for dry beans are for uncooked seeds; cooking or canning can result in significant loss of antioxidant capacity. Nevertheless, since dry beans cost significantly less than antioxidant-rich fruits and can be stored for months without quality deterioration, they represent an excellent healthy choice, especially for low-income groups and in developing countries.

The potential protective effects of dry beans in disease prevention, such as against cancer, may not be entirely due only to dietary fiber but also to phenolics and other non-nutritive compounds (Oomah et al. 2006), as polyphenols from dry beans can act as antioxidants, hindering the formation of free radicals (Boateng et al. 2008). In addition, legumes belong to the food group that elicits the lowest blood glucose response. The general consensus on healthy eating habits favors an increase in the proportion of legume-based polymeric plant carbohydrates including starch in the diet. The role of legumes as a therapeutic agent in the diets of persons suffering from metabolic disorders has been reported in the literature (Pittaway et al. 2008; Shehata et al. 1988). The large amount of water-soluble fiber is particularly effective in lowering cholesterol in the blood, whereas the water-insoluble fiber provides bulk, pushing food through the digestive system at a faster rate. Common beans are low in sodium (Augustin and Klein 1989; Buttriss and Stokes 2008); this could be a healthy food choice for persons on low-sodium diet. Regular consumption of dry beans in the United States, where obesity is on the rise, has been suggested to significantly improve the diet quality (Mitchell et al. 2009).

**Beans and pulses use in weaning foods**

Malnutrition in children contributes to more than 75% of the deaths due to infectious disease and significantly retards childhood growth (Pelletier et al. 1995). Therefore, providing adequate nutrition during early childhood is of supreme importance for infants’ health (Dahiya and Kapoor 1994). Nutritionally balanced weaning food must provide all the essential nutrients, both macro (protein, carbohydrates and fats) and micro (vitamins and minerals) to meet infants’ dietary needs. Weaning food is frequently derived from a mixture of multiple food sources specifically formulated to achieve a balanced nutritional profile for infants. Generally, plant-based foods are used to meet the protein needs of infants and preschool children (Chau et al. 1998; Simango 1997).

Weaning foods should be selected on the basis of taste, variable consistency, acceptability and, more importantly, essential nutrients. Initially, weaning foods can be prepared as a fluid gruel, which is soft, cooked and mashed to a thin consistency and given once a day. Later, a thicker gruel, which is cooked and mashed to a soft and thick consistency, should be given more often (Barrell and Rowland 1980). A systematic approach during the weaning process can be very helpful to support a steady growth and body tissue development in infants. Feeding practices are strongly associated with child growth (Prentice 1994; Fu et al. 2000) and better feeding practices are more important especially for children of lower socioeconomic status (Ruel and Menon 2002).

Beans and pulses—due to their nutrient-dense nature—serve as an important base for weaning foods. To augment the protein quality of bean-based weaning foods and to over-
come the problem of antinutritional factors, numerous diverse strategies have been proposed, including cereal-legume protein complementation (Hernandez et al. 1995). However, digestibility and flatulence-producing components may restrict their broad-scale utilization when feeding legumes to children. The use of appropriate preparation techniques (such as soaking/cooking, dehulling, fine grinding, roasting whole beans, germination and fermentation) has been found to improve digestibility and reduce flatus from beans and pulses (Sarkar et al. 1997; Donangelo et al. 1995). With regard to developing countries, there are problems associated with feeding young children broth or soup in which the beans have been cooked. This practice is appropriately discouraged as it results in poor protein digestibility, diarrhea and other gastrointestinal distresses, and further acerbates protein digestibility because the liquid portion may contain high levels of polyphenolic compounds (tannins) extracted from the seed coats of colored beans during cooking.

The Institute of Nutrition for Central America and Panama (INCAP, Guatemala), the Central Food Technological Research Institute (CFTRI, India) and the National Institute of Nutrition (NIN, India) have developed a number of traditional weaning food mixtures that can be prepared using preheated legumes and cereals. Drum-dried bean meals prepared can be potentially used for precooked, prolonged shelf-life weaning food formulations that can provide both protein and energy to infants as well as offer preparation convenience for mothers (Occena et al. 1997). The United Nations’ WHO/FAO has detailed guidelines for preparation and use of weaning foods. Further, numerous US public and private sector groups (e.g., USDA, USAID, Gates Foundation) have made significant impact in developing weaning food mixes and guidelines.

**Constraints to beans and pulses utilization**

A number of factors limit legume utilization, including the long soaking and cooking times necessary to adequately soften the beans, loss of valuable nutrients during bean preparation, low levels of the sulfur amino acids, low digestibility of unheated proteins, presence of antinutrients (e.g., lectins, trypsin inhibitors), a high level of phytic acid, various flatulence factors, and hard shell and hard-to-cook (HTC) defects that many develop during dry bean storage (Alonso et al. 2000; Lajolo and Genovese 2002; Uebersax et al. 1989, 1991).

Typically, dry beans are harvested in the mature, dry stage and stored until processed. Chemical changes that occur during adverse storage conditions may result in the development of the HTC phenomenon. Numerous factors influence the quality of the final dry bean product. These include cultivar, seed source, agronomic conditions, handling and storage of the dry product, and processing procedures during cooking or canning. Quality changes in dry beans during cooking and processing are associated with their inherent physical components and chemical constituents (Hosfield and Uebersax 1980; Uebersax et al. 1991). It must be noted that cooking and processing techniques improve palatability, digestibility, and bioavailability through cellular separation and inactivation of antinutritional components.

A comprehensive assessment of strategies and procedures used for processing dry beans is a prerequisite to improved utilization of dry beans. Implementation of a given protocol can be maximized through an understanding of the physical and chemical components, and the inherent constraints and diversified processing techniques available to develop economically viable alternative and innovative products (Uebersax et al. 1991). Improved utilization of dry beans can be maximized through an understanding of how physical and chemical components function and react under given process conditions. Variability in the
physicochemical composition of dry beans occurs, which warrants research and quality control programs directed toward providing a consistent product possessing the characteristics of acceptable flavor, bright color, attractive appearance, uniform texture and high nutritional quality.

**BEANS AND PULSES IN WORLD FOOD SECURITY**

Global food security continues to be a worldwide concern. Beans and pulses contribute significantly to world food supplies and food intake. The importance of agricultural research for crop improvement and enhanced utilization of dry beans and pulses is evident through the scale and diversity of programs. Under CGIAR (Consultative Group on International Agriculture Research), there are a number of research centers focusing on dry beans and pulses, e.g., the International Center for Tropical Agriculture (CIAT, Cali, Columbia), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT, Hyderabad, India), the International Center for Agricultural Research in the Dry Areas (ICARDA, Aleppo, Syria) and the International Institute of Tropical Agriculture (IITA, Ibadan, Nigeria). According to CGIAR (2011), “impressive gains have been made with improved common beans, developed with farmer participation through regional networks in East, Central and Southern Africa, e.g., a 30–50% yield increase from 1995 to 2010. This improved bean production, while strengthening household food and nutrition security, also provides women with surplus grain to sell in local markets.”

In the United States, the USAID (Agency for International Development) has long played a role in the dry beans and pulses improvement programs globally. Significant impact has been achieved through the Collaborative Research Support Program (CRSP) efforts on dry beans, cowpeas, and pulses. Current research foci are: increasing pulse productivity through genetic improvement, increasing pulse productivity through integrated crop management, increasing pulse utilization for improved nutrition and health, and strengthening pulse value chains (USAID 2012). The Pulse CRSP contributes to economic growth and food and nutrition security through knowledge and technology generation that strengthens pulse (e.g., bean, cowpea, pigeon pea, etc.) value chains and enhances the capacity and sustainability of agricultural research institutions that serve pulse sectors in developing countries in Africa and Latin America. Overall, the Pulse CRSP supports over 30 projects in about 20 countries; Fig. 1.7 shows the geographical distribution of these projects (USAID 2012).

In addition, numerous other countries through their international development agencies emphasize and support similar research programs on beans and pulses improvement. Selected agencies include the Australian Agency for International Development (AusAID), the Canadian International Development Agency (CIDA), the International Development Research Centre (IDRC, Canada), the German Agency for International Cooperation (GIZ), the Japan International Cooperation Agency (JICA), the Swedish International Development Cooperation Agency (SIDA), and the Department for International Development (DFID, United Kingdom).

Dry beans are an important component of US foreign food aid programs. The USAID lists the following beans and pulses as eligible for food aid programs in selected developing countries: black, Great Northern, kidney (dark and light), navy, pink, pinto, small red, garbanzo (chickpeas), lentils, peas (green, split green, and yellow). The targeted use of food aid programs and assistance with procurement and distribution of dry beans and/or