CRC

HANDBOOK *of* WORLD FOOD LEGUMES: Nutritional Chemistry, Processing Technology, and Utilization

Volume II

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CRC PRESS

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CRC Press, Inc.
Boca Raton, Florida

Library of Congress Cataloging-in-Publication Data

Handbook of world food legumes.

Bibliography: p.
Includes index.
1. Legumes as food. I. Salunkhe, D. K.
II. Kadam, S. S.
TX558.L4H36 1989 664'.80565 88-37620
ISBN 0-8493-0554-3 (v. 1)

Direct all inquiries to CRC Press, Inc., 2000 Corporate Blvd., N.W., Boca Raton, Florida, 33431.

International Standard Book Number 0-8493-0554-3 (Volume I)
International Standard Book Number 0-8493-0555-1 (Volume II)
International Standard Book Number 0-8493-0556-X (Volume III)

Library of Congress Card Number 88-37620
Printed in the United States

PREFACE

The population explosion has created food shortages in several countries in Asia, Africa, and Latin America. The problem of unavailability of sufficient quantity and quality food has been further compounded due to natural calamities like flood, cyclone, and famine. The world population in 2000 A.D. is estimated to be more than 6 billion. The increases in population are expected to occur mostly in developing countries where resources for producing more food to match the demand of the growing population are limited. The scientific advancements in crop production have increased the yields of principal food crops. However, the impact of such increases is not apparent due to the increase in population in these countries. In recent years, there has been a rapid rise in prices of agricultural inputs such as fertilizers, insecticides, and pesticides. This has restricted producers to intensive farming in areas where the density of population is high and a major proportion of the population subsists below the poverty level.

There is a chronic protein deficiency in almost every developing country. A massive increase in vegetable protein supply in malnourished areas would present less difficult, less expensive, and more energy prospects than boosting the supply of animal proteins. Food legumes are leading candidates since they contain more protein than almost any plant products. The "Green Revolution" in developing countries has not increased the yield of food legumes. On the contrary, emphasis on cereals has often led to decreased legume production. Only a similar revolution in production of legumes can eliminate protein malnutrition in the immediate future. As the cost of animal protein sources such as meat, milk, eggs, and fish slowly increases, legume offers a way to bridge the problem of an enlarging protein gap in developing countries.

Food legumes form important sources in developing countries. These are used mostly as animal feed in developed countries. The "Green Revolution" in developing countries has a negative impact on the production of food legumes. With the exception of soybeans, there was a decline in production of most food legumes in the year 1983 as compared to the world production figures of 1973. This is due mainly to a decrease in area under these crops. The production of legumes is restricted mainly to developing countries where they are used as human food. These are the countries where the yields per hectare of legume crops are lowest. The availability of food legumes in these countries ranges from 14 to 54 g/d.

In addition to the seeds, legumes offer a variety of other edible products. Many immature pods are edible at 2 or 3 weeks before the fibers lignify and harden. At this stage, they are green and succulent and can be used as green vegetables. Although they have less production than mature seeds, they are rich in vitamins and soluble carbohydrates. The mature seeds are good sources of fiber, proteins, minerals, and vitamins. The relative proportion of essential amino acids is not as well balanced for human dietary requirements as it is in meat, milk, or fish. Most legume proteins are deficient in methionine. However, these proteins usually contain more than adequate levels of some of the nutritionally important amino acids (such as lysine) which is deficient in most cereals. The combination of cereals and legumes provide a good balance of amino acids since cereals supply adequate methionine.

Food legumes are known to contain several antinutritional factors such as trypsin inhibitors, chymotrypsin inhibitors, lectins, phytates, polyphenols, flatulence factors, and other antinutritional factors such as lathyrogen, goitrogen, etc. depending upon the type of legume. The available evidence suggests that most of these antinutrients can be eliminated or reduced significantly by processing. To eliminate toxins a widespread practice in the Orient is to treat legume seeds by fermentation, or by sprouting and cooking before consumption. These processes produce wholesome, edible products essentially free of toxic material. Some compounds in legume seeds interfere with digestion without being truly toxic. Such substances occur in many legumes. If they are not inactivated, they may inhibit enzymes that digest proteins or they may impede the absorption of amino acids from the digestive tract;

both processes cause protein to be wasted. Some legumes also contain certain compounds that cause flatulence and other (lectins) that agglutinate certain blood cells. Phytates and polyphenols are known to decrease the availability of proteins, vitamins, and minerals.

Food legumes are processed in a variety of ways. The common methods are canning, milling, cooking, germination, fermentation, roasting, puffing, and preparation of protein concentrates and isolates. It has been shown that processing helps to eliminate or reduce the level of toxic factors and improve the nutritional quality of food legumes. However, significant amounts of minerals and vitamins are lost during processing. Excessive heat processing affects amino acids and proteins resulting in nutritional quality loss. Hence, it is necessary to make certain that processing conditions reach and do not exceed the optimum level to eliminate the effects of various antinutrients. When proteins are extracted from food legumes, alkali and acid treatments are commonly employed. These treatments results in modification of amino acids and proteins which exerts adverse effects of nutritive value of proteins. Such processes requires careful manipulation to avoid possible losses in nutritional quality of food legumes.

The seeds of legumes are stored under improper storage conditions which result in the hard-to-cook phenomenon. Significant losses in quantity and quality occur due to insects, rodents, and microorganisms during storage. The control of these losses by employing improved storage technology can improve the supply of food legumes in many developing countries. Food legumes are utilized in the human diet in numerous ways. In developed countries, these are available as dry seeds, fried seeds, seeds canned in brine, or canned in brine with meat, and in mixed vegetables. In developing countries, several fermented and deep-fat-fried products are prepared from legumes. In these countries, food legume preparations are consumed in conjunction with certain cereals and/or dairy products. During processing, several desirable and certain undesirable changes occur in the food. In order to improve the utilization of food legumes in human nutrition, optimum processing conditions need to be worked out for various legume-based products.

In the recent past, numerous scientific reports have been published on nutritional composition, processing, and utilization of food legumes. Among the legumes, soybeans, peanuts, *Phaseolus* beans, and faba beans are most extensively studied. However, information on the above aspects of other legumes is very limited. This book is an attempt to compile our own research and tabulate data available on above aspects of commonly consumed food legumes in the world. We hope it will serve as a reference book for students, researchers, and professionals involved in nutrition, food science, and other related areas of science.

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S. S. Kadam

THE EDITORS

D. K. Salunkhe is a Professor of Nutrition and Food Sciences at Utah State University, Logan, Utah. Under his guidance, 80 postgraduate students received their M.Sc. or Ph.D. degrees. He has authored about 400 scientific papers, book chapters and reviews. Some of his articles received recognition and awards as outstanding articles in biological journals.

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Professor Salunkhe was Sigma Xi President, Utah State University Chapter; Fellow of Utah Academy of Sciences, Arts and Letters; Fellow of the Institute of Food Technologists; and Danforth Foundation Faculty Associate. He delivered the Utah State University 50th Faculty Honor Lecture "Food, Nutrition, and Health: Problems and Prospects", on the basis of his creative activities in research and graduate teaching.

Professor Salunkhe was Vice-Chancellor of Marathwada Agricultural University, Parbhani, and Mahatma Phule Agricultural University, Rahuri, in India during 1975 to 1976 and 1980 to 1986, respectively.

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ACKNOWLEDGMENTS

The editors of the *CRC Handbook of World Food Legumes: Nutritional Chemistry, Processing Technology, and Utilization* thank Sharon Morey, Coordinating Editor, and her associates of CRC Press, Inc. for their prompt attention, considerate cooperation, and skillful help in the preparation and see-through of the publication of the three volumes.

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COWPEA

J. K. Chavan, S. S. Kadam, and D. K. Salunkhe

INTRODUCTION

Cowpea (*Vigna unguiculata* [L.] Walp.) is mainly cultivated for its pods and seeds in the tropics and subtropics. It is an important food legume of Africa, Asia, and the Mediterranean.[1-3] The world cowpea production was 1.4 million metric tons (t) in 1979.[4] This is approximately 3% of the total world food legume production. Hence, it is considered to be a minor food legume. The botanical classification of cowpea and its subspecies has been reported by several investigators.[5-15] In African countries, cowpea is consumed as a boiled vegetable using fresh or rehydrated seeds, as an ingredient in soups, and as a paste in steamed and fried dishes.[2] In Nigeria, cowpea is commonly consumed in the form of fermented products. In India, it is mostly consumed as cooked green immature pods or cooked whole seeds in the form of curry with rice or other cereals. The young shoots and leaves are often consumed as spinach in fresh or dry form. In the U.S., immature seeds are used for canning. Attempts are being made to process and utilize the cowpea in fermented foods like *tempeh*, extruded products, and in a variety of bakery products.

PRODUCTION AND SEED STRUCTURE

Production

The world cowpea production was 1.0 to 1.1 million t in 1975[16], out of which Nigeria alone contributed over 80%, Upper Volta, 7.5%; Haiti, 3.5%; Senegal, 2.2%; and the U.S., 1.9%. In 1979, the world cowpea production increased to 1.46 million t of which Africa contributed 94%, North-Central America, 2.7%, Asia, 2.3%; and Europe, 0.9%.[4] The FAO discontinued reporting the production figures for cowpea since 1976. Although grown throughout the tropics and subtropics, it is mainly consumed as a staple in Africa and the Indian subcontinent.

Seed Structure

The dry mature seed is made up of cotyledons, germ, and seed coat with testa hilum. Stanton[5] classified seeds of four species of cowpea on the basis of seed coat types and seed index. The seed index ranged from 12.5 g/100 seeds for smaller seeds to 18 g/100 seeds for larger seeds. The seed coat color depends on the color of testa. The seeds vary markedly in size, shape, and color.[6] The seeds are 2 to 12 mm long, globular to kidney shaped, smooth or wrinkled, white, green, buff, red, brown, or black and variously speckled, mottled, blotched, or eyed. The 100-seed weight range from 10 to 25 g.[6] The seeds of commonly cultivated cowpea cultivars in India are kidney shaped, about 1 cm long, and variously colored, such as white with black eyes, solid brown, clay, black, and mottled.

CHEMICAL COMPOSITION

The chemical composition of cowpea seeds has been reported by several investigators (Table 1). The large variations in the content of nutrients can be due mainly to the genetic-background as well as the climate, fertilization, season, and agronomic practices. Cowpea seeds are a good source of proteins, minerals, and energy. The nutrient composition of various seed components is presented in Table 2. The cotyledons making up more than 87% of the seed weight contain most of the seed proteins (93%), fat (95%), ash (87%), N free

Table 1
PROXIMATE COMPOSITION OF COWPEAS[1,6,7,17,21,24,25,33,34,37]

Constituent	Range (%)
Crude protein (N × 6.25)	18.3—35.0
Crude fat	0.7— 3.5
Crude Fiber	2.7— 7.0
Ash	2.5— 4.9
N-free extract	55.7—76.4

Table 2
COMPOSITION OF SEED COMPONENTS OF COWPEAS[32]

Composition	Cotyledons	Seed coat	Embryo
Proportion (%)	87.23	10.64	2.12
Protein (%)	26.7	10.7	44.1
	(93)	(4)	(3)
Ether extract (%)	2.3	0.9	9.8
	(95)	(5)	(10)
Ash (%)	3.15	3.17	4.38
	(87)	(11)	(2.8)
Crude fiber (%)	0.3	25.8	1.6
	(14)	(87)	(1)
N-free extract (%)	67.6	59.4	40.1
	(88)	(9)	(1.2)
Phosphorus (mg/100 g)	496	89	829
	(94.2)	(2)	(3.8)
Calcium (mg/100 g)	165	853	368
	(59)	(33)	(3.2)
Iron (mg/100 g)	6.1	11.6	20.7
	(77)	(18)	(6.3)

Note: Figures in parentheses indicate percent distribution of the chemical constituent.

extract (88%), and minerals like calcium, phosphorus, and iron. The seed coat contains most of the seed fiber (87%). The embryo, although rich in proteins, fat, and minerals, contributes very little of these nutrients as it is a minor seed constituent.

Proteins

Protein Content

The protein content in cowpea is variable (Table 1). The reported values for protein content range from 18.3 to 35.0%. Similar variations in protein content of cowpea have also been reported by other investigators.[18,20,22,28,35] The values reported in the Grain Legume Improvement Programme 1972 Report of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria[23] range from 22 to 35%. These variations in protein content of cowpea are due to genetic and environmental factors.[24,36-39] The larger seeds are reported to exhibit less protein as compared to the smaller seeds.[30,40] Considerable genetic variability available with cowpea genotypes can be exploited to develop a high protein plant type through breeding.

Amino Acid Composition

Several investigators have reported the total or essential amino acid composition of cow-

Table 3
AMINO ACID COMPOSITION OF COWPEA MEAL AND PROTEINS[49]

Amino acid	Meal (%)	Proteins (g/16 g N)
Isoleucine	0.90	3.82
Leucine	1.65	7.04
Lysine	1.60	6.80
Methionine	0.27	1.17
Cystine	0.26	1.09
Phenylalanine	1.21	5.2
Tyrosine	0.61	2.61
Threonine	0.84	3.76
Tryptophan	0.25	1.09
Valine	1.06	4.53
Arginine	1.50	6.40
Histidine	0.76	3.26
Alanine	0.96	4.11
Aspartic acid	2.58	11.02
Glutamic acid	3.85	16.43
Glycine	0.88	3.74
Proline	0.91	3.10
Serine	1.00	4.29

Table 4
ESSENTIAL AMINO ACID COMPOSITION (g/16 g N) OF COWPEAS

	Ref.								FAO
Amino acid	**50**	**51**	**52**	**53**	**54**	**55**	**Range**	**Mean**	**reference pattern**
Lysine	6.7	6.8	7.0	6.8	6.2	5.6	5.6—7.0	6.5	5.5
Threonine	4.1	3.6	3.9	3.7	3.2	4.2	3.2—4.2	3.8	4.0
Valine	5.2	4.5	4.9	4.8	6.3	4.9	4.5—6.3	5.1	5.0
Leucine	7.4	7.0	7.8	7.6	7.5	7.1	7.0—7.8	7.4	7.0
Isoleucine	4.9	3.8	4.1	4.0	4.9	3.8	3.8—4.9	4.3	4.0
Methionine	1.3	1.2	1.1	1.0	1.0	1.4	1.0—1.4	1.2	3.5
Tryptophan	1.0	1.1	1.3	1.4	0.6	0.8	0.6—1.4	1.0	1.0
Phenylalanine	5.7	5.2	5.5	5.3	5.2	4.5	4.5—5.5	5.2	6.0

peas.[25,33-55] Considine[49] has recently summarized the amino acid composition of cowpea seed meal and proteins (Table 3). Like other legumes, the cowpea proteins are rich in glutamic acid, aspartic acid, and lysine. A few representative values of essential amino acids are summarized in Table 4. The FAO reference pattern for these amino acids is also given for comparison. It is clear that methionine is the first limiting amino acid in cowpea proteins. The amino acids such as threonine, phenylalanine, tryptophan, and valine are only marginally in an acceptable range in several cowpea cultivars. Like proteins, amino acid composition of cowpea is also variable. Application of sulfur to the cowpea crop has been found to increase the methionine content significantly.[56] Kachare[40] studied the methionine and tryptophan contents of several cowpea cultivars differing in protein content and found that both of these amino acids are negatively correlated with the protein content. Phillips[52] fractionated the cowpea seeds into cotyledons and seed coat meal and studied their essential amino acid composition (Table 5). All fractions were found to be rich in lysine and severely deficient

Table 5
ESSENTIAL AMINO ACID COMPOSITION OF COWPEA FRACTIONS[52]

Amino acid	Whole meal	Cotyledon	Seed coat	FAO reference pattern
Lysine	7.0	7.2	6.3	5.5
Methionine	1.1	1.2	0.9	3.5
Half-cystine	0.9	0.9	1.0	—
Threonine	3.9	3.9	3.5	4.0
Isoleucine	4.1	4.2	3.7	4.0
Leucine	7.8	8.0	6.5	7.0
Valine	4.9	5.0	4.6	5.0
Tyrosine	3.2	3.3	3.6	—
Phenylalanine	5.5	5.6	4.3	6.0
Tryptophan	1.3	1.2	1.1	1.0

Table 6
DISTRIBUTION OF PROTEINS IN DIFFERENT PROTEIN FRACTIONS[26,38,40,57-60]

Fraction	Range (%)
Albumins	2.5—14.8
Globulins	48.2—90.0
Prolamins	5.3—13.1
Glutelins	6.5—23.3

in sulfur amino acids. The differences in essential amino acid composition between cotyledon and seed coat fraction were minimal. This indicated that the removal of the hull does not change the essential amino acid composition of the cotyledon.

Fractionation and Characterization of Proteins

The proteins of cowpea seeds have been fractionated into albumins (water soluble), globulins (salt soluble), prolamins (alcohol soluble), and glutelins (acid/alkali soluble).[26,57-60] The relative proportion of various fractions in different cowpea cultivars vary markedly (Table 6). Azimov[26] reported that the globulins contribute 80 to 90% of the total proteins followed by glutelins (6.5 to 13.5%) and albumins (2.5 to 10%). Similar results have been reported by Boulter et al.[38] and Klimenko and Platsynda.[57] Klimenko and Vysokos[59] fractionated cowpea seed proteins by column gradient chromatography and observed that the globulin fraction contributes 73.3%, albumins, 14.8%; and glutelins, 11.9% of the total seed proteins. Tella and Ojehomon[60] used simple procedures for rapid extraction of storage proteins in eight cowpea cultivars. The range of values observed for different fractions were albumins, 18.8 to 30%; globulins, 20.5 to 38.5%; prolamins, 15.2 to 21.8% and glutelins, 19.6 to 37% of the total proteins. The recovery of protein ranged from 86.4 to 99.3%. The values observed for globulins were lower as compared to most of the other reports.

Kachare[40] fractionated the seed proteins of low and high protein cowpea cultivars using the procedure of Nagy et al.[61] The total globulin content (soluble in water plus 5% sodium chloride) ranged from 48 to 59% of the total seed proteins while the glutelins ranged from 15 to 23%, prolamins from 4 to 13%, and albumins from 12 to 13%. The protein recovery

Table 7
PROTEIN QUALITY PARAMETERS OF COWPEAS[19,25,29,31,51,55,75-79]

Parameter	Range
Chemical score	65—75
Essential amino acid index	77—84
Protein efficiency ratio	0.5—1.4
Protein digestibility	55—92
Biological value	45—72
Net protein utilization	35—53.3

was over 95% in low protein cultivars and 63 to 67% in high protein seeds. These reports indicate that the variations in the reported values of relative proportions of various fractions can be attributed to the genetic differences, methods of protein extraction and determination, and the protein content of the sample. This also indicates that an increase in protein content in certain cultivars is associated with an accumulation of proteins which are not soluble in the common solvents employed for extraction.

The albumins are richer in lysine, tryptophan, methionine, threonine, and valine than the globulins.[62] However, globulins are deficient in methionine.[25] This causes the overall deficiency of methionine in cowpea seed proteins. The correlation between the methionine and protein content is significantly negative.[40] Hence, an increase in methionine-rich protein fractions is more important than increasing the total protein content.[63,64]

Cowpea globulins have been fractionated and characterized for electrophoretic properties, structure, sedimentation value, and molecular weight.[65-73] Boulter et al.[25] reported that electrophoretic separation of cowpea globulins was influenced by the variety. The globulins were found to contain two anodic, one to two cathodic, and one stationary component. Klimenko and Platsynda[71] observed both quantitative and qualitative variability in electrophoretic components and globulins from different cowpea cultivars. Sefa-Dedeh and Stanley[73] observed four bands for water-soluble and acid-precipitated proteins on polyacrylamide gel electrophoresis. The sedimentation coefficients of the components were 3.1S, 8S, 12.7S, and 14.6S. The 8S component was found to be the major protein which corresponds to vicilin. These characteristics are more closely related to soybean globulins.

Protein Quality

The quality of dietary proteins is evaluated by bioassay methods such as protein efficiency ratio (PER), net protein utilization (NPU), relative nutritive value (RNV), biological value (BV), and true digestibility (TD), in addition to the chemical methods like essential amino acid index (EAAI), chemical score, and *in vitro* protein and starch digestibilities.[74-76] The values available in the literature for various protein quality parameters of cowpea exhibit a wide range (Table 7). This can be attributed to the genetic differences in the amino acid composition, nature of proteins, and the experimental conditions. Sivaraman and Menachery[79] reported that cowpea proteins promoted a significantly higher growth in albino rats than pigeonpea proteins. The PER of cowpea was found to be increased from 1.0 to 1.8 after addition of 0.3% methionine in the diet. Similarly, the supplementation of cowpea protein were 55 to 60, 45 to 48, and 50 to 51%, respectively. In general, the PER, BV, and TD of cowpeas are low, compared to that of egg or milk proteins. These can be partly improved by supplementing the cowpea meal with sulfur amino acids.

Carbohydrates

Cowpea seeds are a good source of dietary carbohydrates. The total carbohydrate content in cowpea ranges from 56 to 68% (Table 8). The starch is most abundant in cowpea

Table 8
CARBOHYDRATE COMPOSITION OF COWPEAS[84-89]

Carbohydrate	Range (%)
Total carbohydrates	56.0—68.0
Starch	31.5—48.0
Total sugars	6.0—13.0
Sucrose	1.8—3.1
Raffinose	0.4—1.2
Verbascose	0.6—3.1
Stachyose	2.0—3.6
Crude fiber	1.7—4.0

Table 9
LIPIDS AND FATTY ACIDS COMPOSITION OF COWPEAS[93]

Component	%
Total lipids	2.05
Neutral lipids	46.88
Phospholipids	36.82
Glycolipids	8.98
Saturated fatty acids	31.90
Palmitic acid	23.50
Stearic acid	5.60
Arachidic acid	0.60
Unsaturated fatty acids	68.10
Oleic acid	8.40
Linoleic acid	34.00
Linolenic acid	25.70

carbohydrates while the sugars represent only a small percentage. Among different sugars, sucrose is predominant in cowpea. Stachyose and verbascose are more predominant than raffinose.[81]

Cowpea seeds contain an appreciable amount of crude fiber. Cellulose is a major component in cowpea fiber. Longe[82] reported that glucose is the major sugar in cowpea hemicellulose. The dietary fiber of common Indian legumes has been implicated in lowering the blood cholesterol levels.[85-86] Since most seed fiber is concentrated in the seed coat, and cowpea is mainly consumed as cooked whole seeds, investigations on the hypocholesterolemic effects of cowpea fiber, if any, are essential. The *in vitro* and *in vivo* digestibilities of legume starches and their physiological effects on metabolism of other food components such as proteins and lipids have been studied by several investigators.[87-92] Such information on cowpea is, however, not available.

Lipids

Lipids constitute the minor component of cowpea seeds. The total lipid content in cowpeas range from 0.7 to 3.5% (Table 9). The neutral lipids form a major portion of total lipids followed by phospholipids and glycolipids.[93] Of the fatty acids, unsaturated fatty acids constitute more than two thirds of the total fatty acids. The linoleic, linolenic, and palmitic acids are the major fatty acids in cowpea lipids. The lipids, although low in quantity, play an important role in storage and processing of legumes because of their minerals, which cause a reduction in their bioavailability[94] and development of undesirable flavors.[95-97]

Minerals and Vitamins

The total ash content in cowpea ranges from 3.2 to 4.9% (Table 1). It is a good source of dietary minerals such as phosphorus, potassium, calcium, iron, copper, and zinc (Table 10). The cowpea seeds contain more phosphorus and potassium than several other common legume seeds.[35] The bioavailability of minerals is important as it is influenced by the interaction with other food constituents. The factors such as digestibility of cowpea meal, chemical forms of minerals, levels of other constituents, presence of mineral chelates, and processing methods influence the bioavailability.[96-98] Several investigators have studied the vitamin content in cowpea.[101-107] The cowpea seeds are a rich source of certain B-group vitamins such as thiamin, riboflavin, niacin, folic acid, and choline (Table 10). Although it contains carotene, it is generally considered to be low in vitamin A content.