# Legume Quality Factors Affecting Processing and Utilization

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**Abstract.** *Much of the plant breeding work on the quality of legumes has been directed towards improving their nutritional quality, notably to increasing protein content, and improving their amino-acid pattern, and the balance and reduction of such anti-nutrient factors such as trypsin-inhibitors and haemaglutinins Relatively less attention has been paid to quality factors that affect the processing and utilization of legumes This paper briefly reviews and highlights recent work on the processing quality of legumes, in order to provide pointers to future objectives and strategies in legume improvement programs as they specifically apply to ICRISAT mandate crops*

*Quality factors affecting cooking time and cookability are major determinants of utilization and processing potential Some of these, such as water absorption, hydration starch gelatinization, and the effect of processing treatments on these characteristics are reviewed Postharvest and storage-quality changes in legumes, which cause the hard-to-cook phenomenon and the mechanisms involved, are discussed to illustrate the importance of good storage conditions*

*Available processing technologies, such as germination, fermentation, and protein isolation/concentration, as well as newer applications of groundnut and chickpea in such novel foods as beverages and pasta products, are examined in relation to grain and food quality requirements*

## Introduction

Most plant breeding work related to the food quality of legumes has in the past been directed towards improving their nutritional quality, notably increasing the protein content, and improving the amino-acid pattern, and balance and reduction of antinutrient factors such as trypsin-inhibitors and heamagluttinins (Bliss 1973, Kelly 1971, Dickson and Hackler 1973, Jeswani et al. 1970)

Relatively less attention has been paid to quality factors that affect processing, utilization, and consumer acceptance of legumes This paper briefly reviews and highlights more

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recent work on the processing quality of legumes to serve as pointers to future strategies in grain legume improvement and utilization The review will include work on legumes other than the specific ICRISAT mandate legumes, to illustrate areas of relevant research and investigations with likely applications to the mandate crops chickpea, pigeonpea, and groundnut Some selected processing technologies will be discussed to indicate the scope and potential of expanding and diversifying the utilization of these crops

## Cookability

Cookability, as applied to legume seeds, has been defined as 'the conditions by which they achieve a degree of tenderness during cooking, acceptable to the consumer' In most countries, legumes are commonly prepared for traditional consumption by soaking for varying periods and then boiling A characteristic property of nearly all dried legumes is the long cooking time of 3-4 h required to attain the required degree of softness and palatability ('doneness') In high altitude regions, such as the highland plateau of Africa, cooking time is even further increased

In the semi-arid regions, with shortages of energy resources, notably fuelwood for food preparation, cooking time and cookability are important criteria for domestic utilization

Traditional processing methods and pretreatments designed to reduce cooking time include soaking in water for periods of up to 24 h, and the use of traditional softening agents, such as '*Magadi*' soda in eastern Africa

Water absorption is an important determinant of the rate of hydration and of cooking properties Water absorption is to some extent determined by heredity, but it is also influenced by environmental factors, such as agronomic and storage conditions Starch and protein are the major components involved in the hydration process, while seed anatomy and cellular structure are just as important Agbo (1982) demonstrated significant differences in processed food quality between two dry bean strains of the same genotype that differed only in a single gene for seed-coat color This monogenic difference affected the water uptake and starch gelatinization characteristics

Initial moisture content, seed-coat thickness, texture and permeability, and storage temperature have been shown to affect water uptake in cowpea (Sefa-Dedeh and Stanley 1979, Moscoso 1981) and dry kidney bean In several species of legumes, a good correlation between phytic-acid content and cookability have been observed (Kon 1968, Kumar et al 1978, Mattson et al 1950) The mechanism proposed is that phytic acid chelates calcium, reduces the formation of calcium-pectic complexes responsible for hard texture, and exhibits a texture-softening effect

## Hard-to-Cook (HTC) Phenomenon

Long storage periods under tropical conditions result in HTC This phenomenon has been reported in several species of legumes including cowpea and red kidney bean (Jackson and Varriano-Marsten 1981, Sefa-Dedeh et al 1979) HTC results from deterioration during storage and reduced water absorption (hard shell) and cookability of cotyledons (Sclerema), accompanied by deleterious changes in texture and flavor Mejia (1979) reported a significant correlation between an increase in tannin content and hardness, attributable to temperature- and humidity-dependent changes in condensed tannins, and continued development of tannin from low-molecular mass nontannin material The loss of cookability of dry kidney bean in storage has been related to the reduction in phytic acid phosphorus, and changes in the ratio of monovalent to divalent cations in soaked bean The reduction in phytic acid and monovalent cations results in lower solubilization of pectic substances through chelation and ion exchange during cooking (Moscoso et al 1984)

HTC is overcome by the use of salt solution for soaking the legumes Salt alters the configuration and conformation of native proteins, thus increasing their solubility, reducing steric hindrance, and exposing more peptide bonds to hydrolysis Salts also break the hydrogen bonds between protein and condensed tannins Salt reduces the calcium- and magnesium-mediated interactions between phytic acid and protein and between minerals and pectin, altering the microstructure of black bean, making them more porous and permitting easier penetration of heat and water (Sievwright and Shipe 1986) Rockland and Metzler (1967) observed that soaking dry bean in food-grade salt reduced HTC

The foregoing review and discussion illustrates the need to consider and evaluate the following quality factors, as indices to evaluate the processing quality of chickpea and pigeonpea

- Seed coat thickness and permeability
- Tannins and phytic acid
- HTC
- Starch gelatinization

There is inadequate information on quality aspects of these legumes and research efforts in these areas are indicated

## Processing Technologies and Products

Fermented legume products have been prepared and consumed in the Orient for centuries Many fermented soybean foods, such as *miso natto* and *tempeh* are consumed as traditional foods, but have also been commercialized in Japan, Thailand, and Indonesia.

*Tempeh*, the product of a legume fermentation based on a fungal organism, *Rhizopus oligosporus*, is of special interest as a supplement to vegetarian diets, because of its nutritional and flavor characteristics (described as meaty, nutty, and chicken-like). Robinson and Kao (1974) have developed a *tempeh* from chickpea and faba bean, and work on a pigeonpea *tempeh* is in progress in Indonesia. A shelf-stable, palatable, and nutritious *tempeh* was developed from red kidney bean (Gomez and Kothary 1979), which effectively reduced cooking time from 3-4 h to 20 min, and produced a ready-to-eat *tempeh* in a 48 h incubation period. The pilot-scale flow chart of this process is shown in Figure 1 and the following details and features of this process merit special attention.

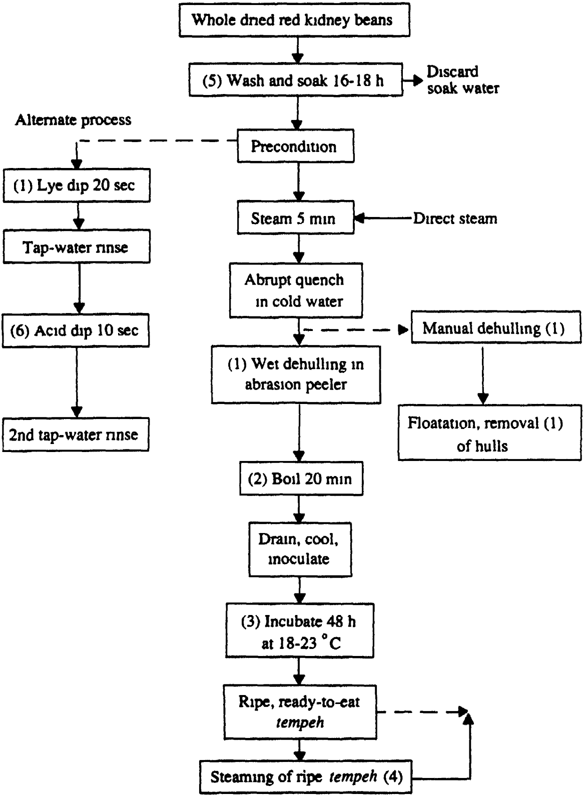


**Figure 1. Flowchart for pilot-scale process for red kidney bean *tempeh* production. (Gomez and Kothary 1979).**

- Dehulling was found to be essential for adequate penetration and growth of the fungal mycelia. Therefore dehulling pretreatment step by alternative chemical (lye) treatment or physical treatment involving quick steaming and cold-water quench, or mechanical or manual dehulling should be considered.
- Optimization of prefermentation boiling conditions to (a) sterilize the bean mass, and (b) achieve sufficient starch gelatinization within the cotyledons to soften the starch granules but not to cause their expansion, as otherwise this would fill the interspaces between cotyledons and inhibit the growth and penetration of the mycelia within the bean mass
- Ambient temperature incubation for 48 h to avoid costly heating/incubating equipment
- Steaming of ripe *tempeh* to arrest further mold growth (and sporulation) and to pasteurize the product prior to storage 'as is or oven/sun drying to a shelf-stable moisture content
- Prevent migration of hull color into cotyledons by (a) presoaking to leach out water-soluble pigments, and by (b) dehulling
- pH values as low as 4 5 were not inhibitory to mold growth

The following quality factors are important criteria for the production of legume *tempeh*

- Ease of dehulling and thickness of the testa
- Testa color and migration behavior of pigments into cotyledons
- Water absorbed
- Amylose content and gelatinization temperature of starch

## Germination

Several studies document the improvement in nutritional quality of grain legumes effected by germination Sprouted legumes, such as mung bean, are widely consumed as fresh and canned products, and are known to have significant nutritional advantages over non-sprouted grain, such as increase in Vitamin C content and decrease in antinutrient factors Germination of other legumes is, however, not yet widely practised on a traditional or commercial scale While flavor and functional and nutritional improvements in malted cereals have been exploited in the commercial production of beer, food, and flavor malts, comparatively little work has been carried out in the utilization of germinated legumes

Mosha and Svanberg (1983) observed an important property of sprouted cereals, i e , the reduction in dietary bulk accompanying the reduction in viscosity of germinated cereal-water mixtures This property was used to advantage to increase the nutrient density of cereal-based weaning foods Marero et al (1988) have recently applied the same principle to prepare blends of cereal legume germinated flours to prepare a protein-supplemented weaning food of high nutrient density and digestibility Blends of 70% cereal (rough rice and maize) and 30% legumes (mung bean and cowpea) were found to provide over 1/3 of the dietary requirements of protein and calories for weaning-age children.

## Soaking Pregermination

Soaking, as a pretreatment or pregermination step, has received limited attention as a process Many studies report only on the net effects of soaking and germination Since this is a simple no-cost technology applicable at the domestic level, it is worthwhile investigating more extensively the effect of soaking on quality changes in legumes Soaking is widely practised on a domestic scale as a pretreatment for wet dehulling and grinding, based on the obvious physical benefits of swelling, water uptake, and resultant softening and loosening of seed coats The hydration process however also brings about the mobilization of enzyme systems, and a differential analysis of only the soaking process could assist in identifying the benefits and advantages of soaking as a pretreatment for boiling, or for preparation of wet-ground, dried legume flours

In an experimental study on Bambara groundnut, (Gomez, unpublished) for example, a significant reduction in trypsin-inhibitor (TI) activity and phytic acid was noted in the 24-h soak period, TI remained stable over the following 5-day germination period, while phytic acid continued to decrease (Table 1) Similarly, concentration of most amino acids was higher at the 24-h soak time than at germination (Table 2) These results indicate a need to evaluate soaking as a process more fully for its physical, biochemical, and functional quality changes

## Beverages

The viscosity-reducing property of germinated chickpea has also found application in the production of a legume beverage A chickpea-based chocolate beverage was developed in Mexico to increase local consumption of chickpea, since most of the chickpea grown is exported However the product's high viscosity made it unacceptable (Fernandez de Tonella et al 1981) The beverage from germinated chickpea showed decreased viscosity and improved consistency when compared to a control formulated from nongerminated chickpea, attributable mainly to a 15% reduction in starch (Fernandez de Tonella and Berry 1987)

At the Central Food Technological Food Research Institute (CFTRI) in India, a high-protein drink known as Miltone was prepared from groundnut-protein isolate (Chandrasekhara et al 1971) In the Philippines, a country dependent on imports of milk and dairy products, a nondairy milk substitute has been produced using nondefatted or partially defatted groundnut using low-cost technology (Rubico et al 1987) (Fig 2) Though groundnut milk preparations have been studied extensively (Schmidt and Bates 1976, Beuchat and Nail 1978, Encarnacion and Rillo 1982), process and product optimization is still to be achieved with respect to flavor, texture, emulsion stability, and shelf life Defects, such as 'chalkiness' and suspension-stability problems, causing 'creaming' or 'layering', have still to be overcome

| Table 1. Changes in phytic acid and trypsin inhibitor units (TIU) because of soaking and germination | | |
|---|---|---|
| Soaking time | Phytic acid unit (mg 100 $g^{-1}$) | TIU (mg $^{-1}$) |
| 0 h | 1095 | 29 7 |
| 8 h | 881 2 | 21 9 |
| 12 h | | 19 4 |
| 24 h | 806 2 | 16 9 |
| Days after germination | | |
| Day 1 | 806 2 | |
| Day 2 | 731 5 | |
| Day 4 | 637 5 | |
| Day 5 | 562 5 | 16 2 |

Table 2 Amino-acid composition of Bambara groundnut dry soaked and germinated g (16 g N)[1]

| | Treatment | | |
|---|---|---|---|
| Amino acid | Dry | Soaked | Germinated |
| Lysine | 6 0 | 15 1 | 9 7 |
| Histidine | 3 5 | 7 6 | 5 5 |
| Arginine | 6 7 | 13 3 | 8 6 |
| Aspartic acid | 14 3 | 19 5 | 14 3 |
| Threonine | 4 5 | 5 2 | 4 2 |
| Serine | 5 6 | 6 0 | 4 7 |
| Glutamic acid | 21 9 | 29 5 | 23 4 |
| Proline | 5 8 | 6 3 | 6 1 |
| Glycine | 4 7 | 6 7 | 5 2 |
| Alanine | 5 3 | 8 6 | 6 6 |
| Valine | 4 8 | 10 2 | 8 2 |
| Methionine | 1 7 | 1 1 | 0 8 |
| Isoleucine | 5 2 | 8 6 | 5 8 |
| Leucine | 8 9 | 14 4 | 10 9 |
| Tyrosine | 2 4 | 1 2 | 0 9 |
| Phenylalanine | 6 6 | 10 5 | 8 7 |

# Canning

A canned pigeonpea product was attempted by Sammy (1971), but problems of color changes and color migration into the canning medium were encountered The processing of green pigeonpea, however has not been reported and is likely to cause fewer problems of color stability and migration since seed coat is lighter during earlier stages of growth Similar attempts at processing green Bambara groundnut in brine solution gave a highly acceptable canned product Some of the more important quality requirements in relation to canning are summarized as follows

- Integrity and reduced tendency to split, break, or disintegrate on autoclaving
- Texture retention

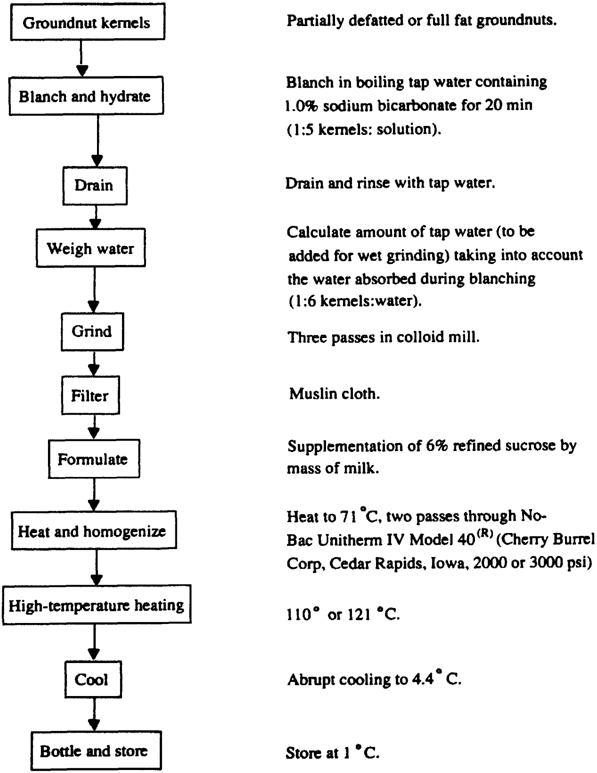


**Figure 2. Flowchart for preparation of groundnut beverages.**

Source: Rubico et al. 1987.

- Reduced release of starch from starch-protein matrix of cotyledons to canning medium
- Color stability, i e , minimum color change (fading, browning) and minimum color migration to canning medium
- Starch hydration and gelatinization properties

## Gluten-free (GF) Pasta Products

Pasta and noodle products are popular foods in southeast Asia A mung-bean noodle and vermicelli product is produced commercially in Thailand In wheat-containing pasta products, the gluten surrounds the starch granules and its viscoelasticity restricts starch swelling, confers cohesion, and prevents leaching during cooking In GF-pasta products, the starch must provide the network For this purpose high amylose genotypes are preferred where the high-amylose starch functions in a manner similar to the gluten, providing cohesiveness and integrity, and preventing leaching during cooking Mestres et al (1988) working on mung-bean noodles observed that the gluten network is replaced in the GF product by a ramified three-dimensional network of short segments linked to one another by junction zones The structure and strength of these junction zones is attributable to amylose crystallites, of melting point exceeding 100°C The starch gelatinization characteristics of high-amylose genotypes need to be evaluated for pasta-type products

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