# GROUNDNUT

## Post-harvest Operations

INPhO - Post-harvest Compendium

Food and Agriculture Organization of the United Nations

# GROUNDNUT: Post-harvest Operations

**Organization:** National Research Centre for Groundnut (**ICAR**) **(www.icar.org.in)**
**Authors:** P.C. Nautiyal, Ph.D. **(nautiyal@nrcg.guj.nic.in or pnaut@ad1.vsnl.nic.in)**
**Edited by AGSI/FAO:** Danilo Mejia, PhD (Technical), Beverly Lewis (Language & Style),
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## Preface

Groundnuts especially those produced in the developing countries have been used traditionally since the origin of humanity. It is rich in oil and protein and has a high-energy value. Developing countries account for nearly 95 percent of world production. Asia accounts for about 70 percent of this amount where the major producers India and China together represent over two-thirds of global output. Other important producers are Nigeria, Senegal, Sudan and Argentina. In most of the developing countries kernels are used for oil extraction, food and as an ingredient in confectionery products. Following extraction, the residual cake is processed largely for animal feed, but is also used for human consumption. The quality attributes that are important for end uses of groundnut vary among the developed and developing countries. Groundnuts are mainly processed for oil in several developing countries. Even though it is a good protein source, the cake obtained after oil extraction is not utilized to the best advantage. Production of aflatoxin due to the invasion of the fungus *Aspergillus flavus* to groundnut pod/kernel is a serious problem in the trade of groundnuts in the international market, which has seriously hampered the export business of the developing countries. Therefore, these countries can no longer rely on monoculture in order to support their growing economies.

Under current conditions, crop dependency has made producers vulnerable to losses because of the lower prices paid for the pods and kernels. It is, therefore, imperative for them to diversify their production and create added value through processing thereby reducing risks and opening new local and export markets. There is a necessity to investigate new opportunities for the use of groundnut as food and confectionery items. Most of the developing countries have poor drying and storage facilities. Under these conditions the seed loses its quality and viability in storage rapidly. The purpose of this publication is to discuss the importance of the post-production system in developing countries and to suggest suitable curing, drying, storage and processing technologies. Advised methods are especially meant for the smallholder farmers and the most diversified uses of groundnut in confectionery items.

## 1. Introduction

Groundnut, or peanut, is commonly called the poor man's nut. Today it is an important oilseed and food crop. This plant is native to South America and has never been found uncultivated. The botanical name for groundnut, Arachis *hypogaea* Linn., is derived from two Greek words, *Arachis* meaning a legume and *hypogaea* meaning below ground, referring to the formation of pods in the soil. Groundnut is an upright or prostrate annual plant. It is generally distributed in the tropical, sub-tropical and warm temperate zones. Ethnological studies of the major Indian tribes of South America document the widespread culture of groundnut and provide indirect evidence for its domestication long before the Spanish Conquest. When the Spaniards returned to Europe they took groundnuts with them. Later traders were responsible for spreading the groundnut to Asia and Africa where it is now is grown between the latitudes 40°N and 40°S (Pattee and Young, 1982).

### 1.1 Economic and social impact of groundnut

China and India together are the world's leading groundnut producers accounting for nearly 60 percent of the production and 52 percent of the crop area. India cultivates about 7.74 million hectares and produces 7.61 million tonnes of groundnut with the productivity level of 991.8 kg ha-1. South Africa is the major producer in Africa, while in Latin America almost one half of the total groundnut produced in that region may be credited to Argentina. Among

the developing countries Egypt has the highest productivity and capacity to produce groundnuts (Table 1).
In most of the developing countries, the productivity levels are lower than in the United States of America, mainly due to a number of production constraints such as i.) the cultivation of the crop on marginal lands under rainfed conditions; ii.) Occurrence of frequent drought stress due to vagaries of monsoon; and iii.) higher incidence of disease and pest attacks; iv.) low input-use and v.) factors related to socio-economic infrastructure.

**Table 1. Groundnut (in-shell) area, yield and production in various developing countries in Africa, Asia and Latin America during the last decade.**

| Countries | Area (000 ha) | Yield (t ha-1) | Production (000 t) |
|---|---|---|---|
| Africa | | | |
| Nigeria | 1 798 | 1.1 | 1 917 |
| Sudan | 960 | 0.69 | 663 |
| Senegal | 829 | 0.83 | 684 |
| Mozambique | 279 | 0.39 | 109 |
| Niger | 207 | 0.37 | 83 |
| Uganda | 191 | 0.73 | 141 |
| Zimbabwe | 181 | 0.50 | 95 |
| Mali | 174 | 0.90 | 155 |
| Tanzania | 113 | 0.62 | 70 |
| Egypt | 38 | 2.70 | 107 |
| Asia | | | |
| China | 3 658 | 2.6 | 9 737 |
| India | 7 740 | 0.98 | 7 609 |
| Indonesia | 661 | 1.70 | 1 159 |
| Myanmar | 493 | 1.0 | 506 |
| Vietnam | 239 | 1.20 | 302 |

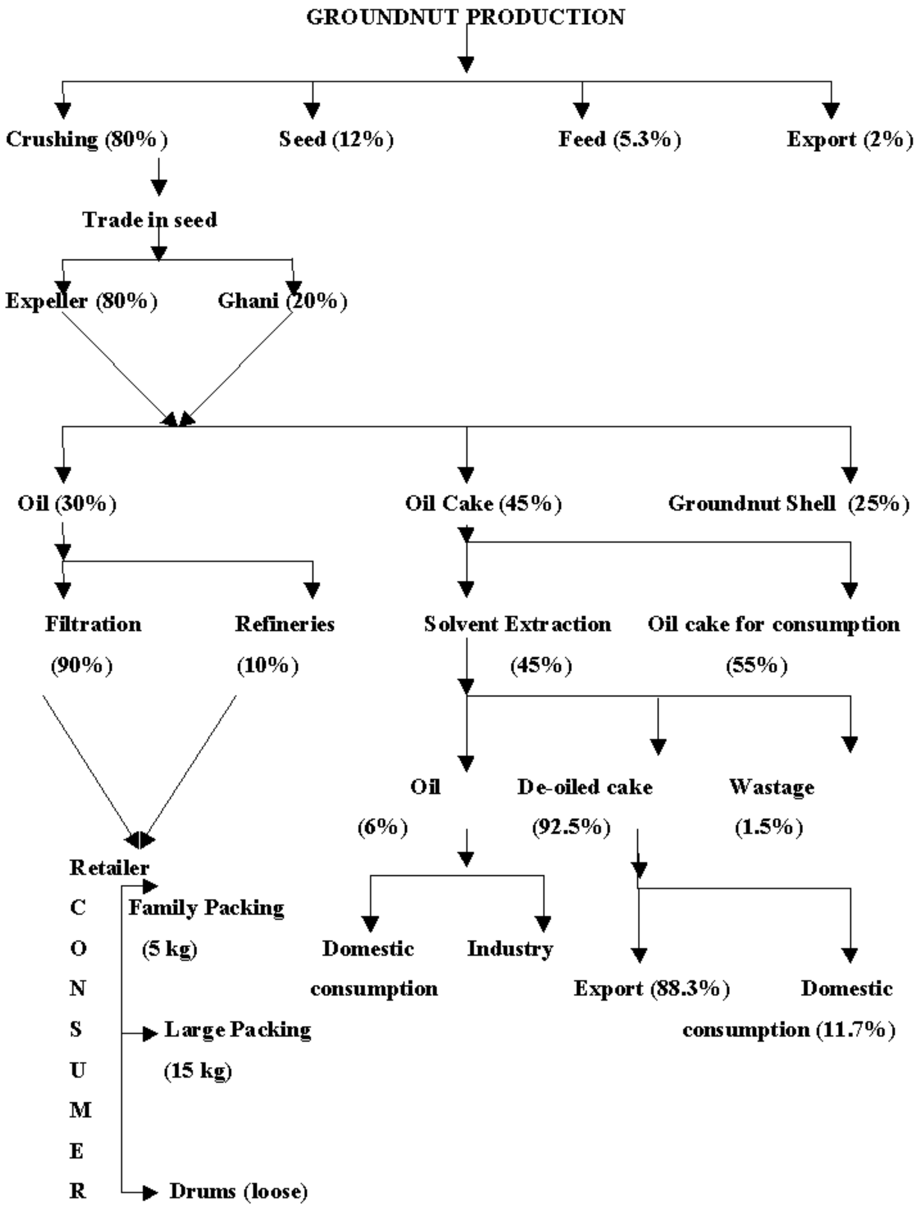
| Countries | Area (000 ha) | Yield (t ha-1) | Production (000 t) |
|---|---|---|---|
| Thailand | 97 | 1.50 | 143 |
| Pakistan | 98 | 1.0 | 99 |
| Turkey | 30 | 2.4 | 75 |
| Syria | 13 | 2.2 | 28 |
| Latin America and Caribbean | | | |
| Argentina | 214 | 2.2 | 464 |
| Brazil | 93 | 1.7 | 164 |
| Mexico | 82 | 1.3 | 112 |
| Paraguay | 32 | 1.0 | 35 |

Source: FAOSTAT, database 1990 to 1998, each figure is average for the period from 1990 to 2000

Especially in the developing countries, groundnut has to play an important role both as oil and food crop. For example in India about 10 kg groundnut per capita are available for domestic consumption. Fat and oil consumption averages less than 5 kg per capita per year. It has been estimated that in the year 2000, approximately 34 million Mt of groundnuts were produced worldwider of which 15 million Mt were produced in China, 6 million Mt in India, 2 million Mt in Nigeria, 1.5 million Mt in United States of America and the rest mostly in other countries. Protein calorie malnutrition (PCM) is a serious problem in the developing world. It is ironic that PCM exist in areas where most of the groundnut is produced. Assuming the level of production of 34 million Mt of groundnut in year 2000, there would be about 6.26 million metric tonnes of groundnut proteins (after correcting for the kernel yield). Thus there should be about 2.6 to 2.8 g of groundnut protein available per capita per day in the world. This translates into approximately 5.5 percent of the total protein requirements of the world. The obvious reason for low consumption of groundnut protein in India is that out of 6 million Mt of groundnuts produced every year, 80 percent are utilized for oil extraction, 12 percent for seed purpose, 2 percent for export and the remaining for edible purposes. The protein rich cake resulting from oil extraction is fed to the animals as protein supplement. The groundnut utilization system in India is shown in Figure 1. The system remains more or less similar in most of the developing countries, with the exception of South Africa.

Similarly in other developing countries, most of the groundnuts are used for extraction of oil for domestic consumption and export. For example, Sudan accounted for 17 percent of the world groundnut export trade. Groundnuts are important component of Nigerian diet and about 5 percent of the estimated 58.9 g of crude protein available per head per day, is contributed by groundnut (Abulu, 1978). In most of the developing countries it provides high-quality cooking oil and is an important source of protein for both human and animal diet and also provides much needed foreign exchange by exporting the kernels and cake. In the literature, groundnut role as cash crop is found to completely dominates its role as subsistent food crop. In spite of groundnut importance to diets in many developing countries and the increasing emphasis on food self-sufficiency, studies on domestic groundnut consumption are especially non-existent.

**Figure 1: Groundnut utilization system in India.(Source: Srivastava, 1988)**



Countries like South Africa, India, China and Egypt have good potential to utilize the opportunity to export groundnuts or groundnut products to the developed countries. They can earn valuable foreign exchange to improve their economic conditions. In the international market demand for groundnut products is determined by several factors. The primary factor in Africa has been population growth. In Asia, demand has grown due to a combination of population growth, increase in per capita income and urbanization. Expansion of urban areas signals higher incomes, higher opportunity cost of time and therefore greater demand for convenience foods. Groundnut production and consumption in the period up to 2010 is likely to shift progressively more to developing countries. This boost will be seen in all regions with most rapid growth in Asia. Per capita consumption will grow sharply in Asia, slowly in sub-Saharan Africa and will decline in Latin America. Utilization will continue to shift away from groundnut oil towards groundnut meal, especially confectionery products (Freeman et al., 1999).

## 1.2 World trade

Over half of the groundnut harvested worldwide is crushed for oil and a substantial quantity of groundnut produced in developing countries is traded in domestic markets. International trade of groundnuts is mainly in the form of in shell (pods), shelled (kernels) and meal (cake). A large trade of confectionery groundnut is also booming in the international market. The major country export groundnut in shell and shelled is shown in the following table (Table 2). Developed countries like UK, Holland, Germany, France, Canada and Japan account for 65 percent of world groundnut demand. However, the major suppliers of groundnut are the United States of America, China and Argentina. The international price of groundnuts is generally decided by the crop size and quality in United States of America. The fortunes for the Indian groundnut (shelled) export are bright and it may likely to emerge as a major supplier of raw and processed groundnut mainly because of its large production base. The production price of groundnut in India is competitive globally. The market price is only 16 percent above the producer price. Except for India and United States of America the price ratio is above 40 percent in the leading exporting countries (Rama Rao *et al.*, 2000). Though India is the largest producer of groundnut in the world, its share in the worldwide edible groundnut market is insignificant.

**Table 2. Major exporting countries of groundnut in-shell, shelled, cake and their values.**

| Countries | Groundnut in-shell | | Groundnut shelled | |
|---|---|---|---|---|
| | Export (Mt) | Value (1000 $) | Export (Mt) | Value (1000 $) |
| China | 49 078 | 30 849 | 289 213 | 202 412 |
| India | 4 394 | 2 303 | 86 494 | 50 276 |
| Argentina | 75 | 39 | 16 068 | 115 541 |
| South Africa | 4 378 | 3 370 | 25 406 | 16 722 |
| Netherlands | 6 089 | 5 564 | 81 335 | 79 868 |
| Indonesia | 1 992 | 1 874 | 206 | 110 |
| Brazil | 2 100 | 1 679 | 558 | 440 |
| Sudan | 144 | 73 | 7 170 | 3 666 |
| Senegal | 120 | 79 | 9 823 | 5 324 |
| Myanmar | 55 | 20 | 130 | 132 |
| Nigeria | 18 | 15 | 1 277 | 624 |

**Source: FAOSTAT, database 1990 to 1998. Values are the average for the year 1990 to 1999.**

Developing countries account for about 90 percent of export trade in groundnut meal. In 1995 to 1997 India ranked first by exporting about 50 percent of groundnut cake in the world followed by another 35 percent of world exports contributed by the Sudan, Senegal, Argentina and the Netherlands. France, Thailand and Indonesia account for more than 65 percent of groundnut cake import. In the 1990s, imports increased sharply in developing countries including Indonesia, Thailand, Malaysia and China, due to demand for meal from the growing livestock sector (FAO, 1999).

International trade in confectionery groundnut grew steadily from the late 1970s to the mid 1990s. Most of the increase in export share was concentrated in Asia, particularly in China, Vietnam and India, which together currently account for almost half of the world exports. Export shares increased slightly in Latin America and Caribbean due primarily to increased shipment from Argentina, which now accounts for 13 percent of the world export. In contrast, export shares from Africa declined by about one-third between the late 1970s and mid 1990s (Freeman, et al., 1999).

Groundnut oil is thinly traded in international markets, because the major producers like China, India and the United States of America consume substantial amounts in their domestic markets. This national use reduces the quantities available for export. In the 1960s and 1970s groundnut oil was the major item traded as edible groundnut trade was negligible. Since that period, the reverse has occurred. Edible groundnuts dominate world groundnut trade while groundnut oil is of minor importance. The export trade of oil in developing countries is concentrated in Senegal and the Sudan.

In the 21st century groundnut trade may change as a result of General Agreement on Tariffs and Trade (GATT) negotiations. Under the GATT agreements producer and consumer subsidies as well as trade restrictions must be eliminated or at least reduced. For example, the United States of America maintains import restrictions on groundnuts. A GATT agreement could eliminate import restrictions and open the United States of America's domestic groundnut market to other countries. India has a self-sufficiency policy for vegetable oil, of which groundnut is a major component. In addition, India has producer subsidies, as do many other countries. Under GATT agreement, these markets would be opened up and costs of production could change. The global groundnut trade estimated at about 0.70 million tonnes per annum is likely to reach 0.85 million tonnes in the next few years (Rama Rao et al., 2000).

## 1.3 Primary products

Groundnut oil has traditionally been a significant dietary component in several countries in Western Africa. In some countries like Nigeria, Gambia and Senegal, oil extraction has been important rural cottage industry for many years. Industrial processing of oil from groundnuts exists in many countries like, India, Sudan, Senegal, Nigeria and Gambia. Oil extraction at the village level is still quite common throughout the developing countries. The major groundnut oil and cake producing countries are shown in Table 3. Groundnut oil is generally used as a cooking medium and it may be processed into different products. For instance, it is hydrogenated to make *vanaspati* or vegetable ghee. After oil extraction, groundnut cake is obtained as a by-product. In general, the resultant cake contains about 43 to 65 percent protein and 6 to 20 percent fat plus some B-group vitamins depending upon the method of extraction. Incidentally, NASA of the United States of America has selected groundnut as a possible food for the Advanced Life Support system for extended space missions.

**Table 3. Five major developing countries producing cake (Mt 000) and groundnut oil (Mt 000).**

| Country | Year | | | | | |
|---|---|---|---|---|---|---|
| | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
| **Groundnut Oil** | | | | | | |
| China | 1 585 | 1 646 | 1 592 | 1 750 | 1 740 | 1 644 |
| India | 1 859 | 2 123 | 1 725 | 1 675 | 1 050 | 1 175 |
| Argentina | 48 | 60 | 52 | 85 | 72 | 60 |
| Brazil | 21 | 23 | 19 | 26 | 24 | 24 |
| Indonesia | 33 | 32 | 31 | 26 | 27 | 27 |
| **Groundnut Cake** | | | | | | |
| China | 2 078 | 2 158 | 2 087 | 2 293 | 2 281 | 2 154 |
| India | 2 216 | 2 511 | 2 065 | 2 110 | 1 286 | 1 449 |
| Argentina | 71 | 90 | 93 | 139 | 123 | 84 |
| Brazil | 29 | 30 | 25 | 34 | 32 | 32 |
| Indonesia | 29 | 29 | 28 | 24 | 24 | 24 |

**Source: FAOSTAT database 1990 to 1998.**

Roasting groundnut with 1 to 4 percent salt is a very common practice throughout the world.It is utilized in various forms including roasted, boiled, raw, ground or paste. Out of the several million tonnes of groundnut produced in the world each year, hulls represent about 25 percent of the total mass produced and is utilized mainly in cattle and poultry feed. The haulms are important as livestock fodder, especially in dry season in the semi-arid tropics.

## 1.4 Secondary and derived products

Among prominent cultivated crops in the developing countries, groundnut is unique because the plant and its produce have a wide range of uses in the daily life of the people as well as in the various industries. The roots of the plant help to enrich the soil and the vines serve as excellent fodder for cattle. The nuts, in addition to being the most consequential source of edible oil, are useful in numerous other ways. When the cake is powdered and extracted in solvent, it yields defatted groundnut meal. Thus the crop has gained great popularity, based on its all-around usefulness and the financial returns it brings to the grower.

Slightly over half of the groundnut production is crushed into oil for human consumption or industrial uses. Protein meal, a by-product of crushing, is an ingredient in livestock feeds. Groundnut is also consumed directly and is used in processed food and snacks. Approximately one-third of world production is used in the confectionery products. Utilization of oil, meal and confectionery groundnuts are all increasing concurrent with a gradual shift away from oil and meal into confectionery use. In many groundnut-producing countries, several products and by-products are processed and consumed locally as a few are exported too. Among the by-products traded in the international market are peanut butter and roasted groundnuts. Today, technologies exist for several value-added products from groundnut with very simple locally available materials. Their procdures are quite easy to follow. The groundnut-based products derived from these technologies may be consumed by the farming family or sold in the domestic market. These products may add value to groundnut and enable the farming family to earn additional income.

## 1.5 Requirements for export and quality assurance

### 1.5.1 Export requirements

The quality attributes defined by the final end products made from groundnut vary among the developed and developing countries. Groundnut is mainly used for making peanut butter and consumed roasted or in confectioneries in developed countries. Meanwhile, in several developing countries it is mainly processed for its oil. Most developing countries have not given much attention to the quality. They are obliged to meet the quality parameters fixed by the importer countries for the international trade of groundnut kernels and cake. For example, the general guidelines for the quality of groundnut pods and kernels formulated by the Natural Resources Institute of the United Kingdom Ministry for Overseas Development are: pod colour and type, size, pod texture, cleanliness, freedom from damage and absence of blind nuts; for in-shells and,

grading for size or count, shape, ease of blanching, skin colour and conditions; resistance to splitting, moisture content, cleanliness, oil content and flavour; for kernels.

Quality guidelines specify that the groundnut lots must be free from aflatoxin contamination. This is the most important consideration for export quality today. Aflatoxins are the toxic metabolites produced by some strains of fungi of the *Aspergillus flavus* group. Users may demand certain additional attributes, requirements and salient technical specifications. A large groundnut-processing factory makes its purchase based upon:

Size/grade: for medium runners graded between 83 mm and 71 mm slot screens a count size of 155 to 170 kernels 100 $g^{-1}$.

Aflatoxin: Five parts per billion maximum, however; recently European Union has modified the aflatoxin $B_1$ limit to 2-µg $kg^{-1}$ for the consumption of groundnuts by human beings.

Moisture: between 6 to 8 percent (determination by air oven drying of ground samples at 130°C for 2 h)

Oil quality: the acid value of cold pressed oil from kernels shall not exceed 1.5, while the peroxidase value shall normally be zero and shall not exceed 1.0 mille equivalents $kg^{-1}$.

Edibility: groundnut shall be free form pathogenic organism (e.g. *Salmonella*, *Escherichia coli*) and also free from insect infestation, live or dead and viable eggs.

There are certain other conditions regarding odour and flavour, splits, damaged kernels and unshelled groundnuts, foreign matter and discoloured/mouldy nuts.

#### 1.5.2 Inspection and diversion of aflatoxin contaminated lots

To ensure that groundnut utilized for food or feed contain less than 20 ppb aflatoxin, various agencies in developing countries, for example IOPEA in India and the AGC in Africa, are regulating the export quality of groundnuts and groundnut products.

#### 1.5.3 AGC agreement with the FAO

At the 18th Session of the FAO Intergovernmental Group on Oilseeds, Oil and Fats, 20 to 24 February 1984, in Rome, the AGC was part of the delegation, which discussed the proposed modifications to the EEC Directives regarding tolerance limits of undesirable substances (especially aflatoxin $B_1$) in cattle feed. After detailed discussion, the group finally declared that "all legislative regulatory measures in this field should necessarily be based on data which can be verified through reliable means, in order to prevent any unjust harm to the concern parties and to the liberty of international standardization of norms so the Joint Committee FAO/OMS of the "Codex Alimentarius" could fix aflatoxin limits which are internationally recognized, uniform and reasonable. Considering the significance of the aflatoxins, several countries including the FAO (Codex Alimentarious Committee) have set the tolerance limits for groundnuts and its extractions. India and the United States of America have set 20 μg $kg^{-1}$ of seed meant for human consumption as tolerance limit. As of the year 2000, European Union has formulated the following limits of aflatoxins for various categories of groundnuts (Table. 4).

**Table 4. Tolerance limits for aflatoxins as set by European Union.**

| Purpose | Tolerance limit (μg $kg^{-1}$) | |
|---|---|---|
| | $B_1$ | $B_1 + G_1 + B_2 + G_2$ |
| Groundnut for direct consumption | 2 | 4 |
| Groundnut for further processing | 5 | 10 |
| Milk and milk products | 0.05 | - |

The key attributes for the export of groundnuts are piece count referring to the number of seeds per ounce, aflatoxins and physical properties such as brokens and admixtures. The seed size expressed as piece counts is crucial to determine commodity value. Until now, there have been no limits for the pesticide residues in the seed and cake. The increasing interest in healthy eating has initiated the concept of organic farming in developing countries. Groundnuts grown without synthetic pesticides and fertilizers would fetch a premium.

#### 1.5.4 Aflatoxin limits fixed by importer countries

Many groundnut-importing countries have placed limits on the levels of aflatoxins permissible in groundnuts and groundnut products (Table 5). Countries depending on export of aflatoxin-susceptible commodities e.g. groundnuts are obliged to establish export limits that meet importers' requirements. This leads to economic loss, if the requirements are unnecessarily strict. Where a local food is also an export item, exportation of the most wholesome food may lead to local consumption of more contaminated foods. In part, this augments the risk of toxic effects in the indigenous population.

**Table 5. Maximum possible levels of aflatoxin in imported groundnut for human consumption and livestock and poultry feeds.**

| Country | Aflatoxin type | Maximum permissible level (ng $g^{-1}$), 1995 | |
|---|---|---|---|
| | | Foodstuffs | Livestock feed |
| Belgium | $B_1$ | 5 | 20 |
| France | $B_1$ | 1 | 20 |
| Germany | $B_1$ | 2 | 20 |
| Ireland | $B_1$ | 5 | 20 |
| Italy | $B_1$ | 5 | 20 |
| The Netherlands | $B_1$ | 0 | 20 |
| Sweden | $B_1$, $B_2$, $G_1$, $G_2$ | 5 | 10 |
| UK | $B_1$, $B_2$, $G_1$, $G_2$ | 4 | 20 |
| USA | $B_1$, $B_2$, $G_1$, $G_2$ | 20 | 20 |

Source: Freeman et al. 1999, ICRISAT

## 1.6 Consumer preferences

Groundnut quality and consumers preference may be judged by the following parameters:
Flavour: The flavour of the roasted groundnut plays important role in its acceptance by consumers and other users. Flavour also plays an important role in the acceptability of groundnut products such as peanut butter. Samples of several high yielding genotypes showed that their flavour quality needs improvements. A method of evaluating the cooking quality of groundnuts by boiling them in shell has been standardized at ICRISAT (ICRISAT, Report 1990). More than 300 compounds have been detected in roasted groundnut. Sugars in groundnut also play an important role as precursors in the production of the typical roasted groundnut flavour. Thus it is important to standardize the test used to evaluate the acceptability of roasted groundnut by conducting sensory evaluation and relating the findings to the presence or absence of various volatile compounds and the concentrations in which they are present. Studies indicate that hexanal concentration is one of the eight compounds that gives an objectionable flavour to groundnut and correlated with a professional flavour profile panellists' evaluation. Characterization of flavour compound by gas chromatography would enable breeders to identify those cultivars that have a good flavour profile for further development (Ahmed and Young, 1982).
Texture: Crunchy and crisp are textural attributes that are important and desirable sensory qualities of groundnuts. Crisp food is one that is firm (stiff) and snaps easily when deformed emitting a crunchy/crackly sound. Based on consumer study, crispness has been reported to

be the most versatile single texture parameter. A number of instruments have been developed for measuring mechanical properties of nuts, which can be related to texture of the kernels.
Sensory quality: Mechanical force and work usually have strong inverse correlation with sensory crispness and crunchiness scores. Sensory evaluation of texture in foods belongs to the domain of psychology known as psychophysics. Psychophysics directly concerns the correlation of sensory experience with physical measures. Two measure classification of sensory tests are: i.) affective and ii.) analytical. Affective tests are used to evaluate preference and/or acceptance of products. This method; however, cannot provide a proportional relationship between sensory scores and physical measures. Analytical tests are used for quantification of sensory characteristics. Evaluating the textural quality of groundnuts, sensory panellist can either bite or chew those groundnut kernels. The physical property differences between row, blanched and oil roasted groundnuts was distinguished best by a compression test (Vivar and Brennan, 1980). When groundnuts are exposed to high relative humidity environment they absorb moisture and become soggy, the consumers do not prefer such products.
Colour: Colour of raw groundnut kernels is attributed to both the testa and the oil. Tannins and catechol-type compounds are responsible for imparting the colour to the testa. The colour of cotyledons is due primarily to the oil colour present in the cells of the cotyledons. The measure carotenoid pigments present in oil are β-carotene and lutein. Maximum concentration of these pigments occurs in the immature kernels i.e. 60 µg of β-carotene and 138 µg of lutein per litre of oil and diminishes as the groundnut advance to maturity. Consumer preference is light coloured groundnut oil. The characteristic colour of roasted groundnut is due primarily to the sugar-amino acid reactions with subsequent production of melanins. Caramelization of sugars may contribute to brown coloration of roasted groundnut. Consumers reject soft or mushy roasted groundnuts even though they exhibit attractive colour and good flavour (Hodge, 1953).
Indian groundnut is very popular in the international market for the table purpose, due to its characteristic natural flavour, nutty taste and crunchy texture and also has relatively longer shelf-life. Therefore, with the growing consumer taste the world over for organic food with natural flavour, Indian groundnut has better export opportunity. Consumption of groundnuts as nuts and in the manufacture of peanut butter is based on the use of roasted groundnut kernels. Roasting time has a significant influence on the strength of the odour and flavour. Raw and roasted groundnuts should be free of foreign material, unadulterated with toxic or noxious substances such as pesticides and microorganisms. The Food and Drug Administration (1969) issued guidelines for food manufacturers who produce wholesome food items including groundnuts and groundnut products. The "Official Methods of AOAC" gives methods (36.020 to 36.024) for the determination of adulterants in food.

## 2. Post-Production Operations

Groundnuts especially those produced in the developing countries have been used traditionally since the origin of humanity. It is rich in oil and protein and has a high-energy value. Developing countries account for nearly 95 percent of world production. Asia accounts for about 70 percent of this amount where the major producers India and China together represent over two-thirds of global output. Other important producers are Nigeria, Senegal, Sudan and Argentina. In most of the developing countries kernels are used for oil extraction, food and as an ingredient in confectionery products. Following extraction, the residual cake is processed largely for animal feed, but is also used for human consumption. The quality attributes that are important for end uses of groundnut vary among the developed and developing countries. Groundnuts are mainly processed for oil in several developing countries. Even though it is a good protein source, the cake obtained after oil extraction is not utilized to the best advantage. Production of aflatoxin due to the invasion of the fungus *Aspergillus flavus* to groundnut pod/kernel is a serious problem in the trade of groundnuts in the international market, which has seriously hampered the export business of the developing countries. Therefore, these countries can no longer rely on monoculture in order to support their growing economies.

Under current conditions, crop dependency has made producers vulnerable to losses because of the lower prices paid for the pods and kernels. It is, therefore, imperative for them to diversify their production and create added value through processing thereby reducing risks and opening new local and export markets. There is a necessity to investigate new opportunities for the use of groundnut as food and confectionery items. Most of the developing countries have poor drying and storage facilities. Under these conditions the seed loses its quality and viability in storage rapidly. The purpose of this publication is to discuss the importance of the post-production system in developing countries and to suggest suitable curing, drying, storage and processing technologies. Advised methods are especially meant for the smallholder farmers and the most diversified uses of groundnut in confectionery items.

## 2.1 Pre-harvest operations

The tools and equipment fabricated locally by farm families themselves or by rural artisans mainly perform post-harvest processing of groundnuts in the traditional manner. Commercial machinery is normally manufactured in urban factories or overseas. The introduction of commercial machinery signals a decline in demand for the products of rural artisans. This potentially diverts cashflow away from the rural economy. As well, it will probably increase the drain on the country's scarce supply of foreign exchange for imported machines, spare parts and fuels. Please see Figure 2. In many cases, suitable machines could be made locally by the use of simple machines, tools and welding equipment.

**Figure 2: Artisan fabricating a thresher in a local market.**

Training of rural artisans, upgrading of technology in rural workshops, provision of credit plus other support services may encourage local manufacture of necessary machines. Small-scale farmers regard the groundnut as a very labour-intensive and high-risk crop. The high labour allocated for weeding, harvesting, drying, threshing and shelling makes the crop economically unattractive to the younger generation of farmers. Research is needed to provide the farmers with better implements. Farm operations comparable to digging or harvesting, curing, drying, shelling, grading and storage are must be suitably modified to reduce the quantitative and qualitative harvest and post-harvest losses.

The basic idea used to develop a crop management strategy is to provide an environment that allows maximum yield with reduced risk of losses, proper use of pesticides and other petrochemicals and minimal environmental contamination. In short, a successful plant health management strategy must include management of all the following:

1. Physiological and environmental disorders,
2. Weeds,
3. Pre-harvest and post-harvest insects,
4. Viral diseases and foliar pathogens,
5. Soil borne fungal pathogens, nematodes and mycotoxin producing fungi.

To be practicable at the farm level, plant health management strategies must be integrated as a package approach. Some guidelines for the cultivation of groundnut are mentioned below.

1. Fields may be selected with suitable type of soil, as the groundnut grows best in deep, well-drained soils with a sandy or very loose surface layer. Most soil rubbed between the index finger and thumb should not ribbon out but should fall apart easily. An exception to this rule is Gujarat (India) where most groundnut is grown in heavy, black-calcareous soils. Therefore, farmers practice adding sand or gravel or *moram* into the furrows before sowing once in 3 to 4 years to make the soils friable.
2. Groundnut crop rotation with other crops, such as sorghum, maize, cotton, pigeon pea and castor is beneficial in several ways: i.) more effective use of residual soil fertility; ii.) improved efficiency in controlling certain weeds; and iii.) reductions in soil borne disease and nematode problems.
3. Conventional primary and secondary tillage operations may be performed to control diseases and weeds and to operate a seedbed for planting.
4. Sowing may be performed with high-quality seed in well-prepared, moist seedbed. Groundnut seeds are generally planted at a depth of 4 to 5 cm. The spacing between row-to-row and plant-to-plant varies with the type of groundnut sown. After sowing in moist soil, water uptake is the first phase in returning the dry seed to active growth. For rapid emergence, soil temperature above 21°C is needed. The optimum temperature for the most rapid germination and seedling development is about 30°C.
5. Temperature is a major environmental factor that determines the rate of crop development. Temperatures above 35°C inhibit the growth of groundnut.
6. Moisture-deficit during vegetative phase is beneficial to increase water use efficiency. Because of the complex interactions between the soil and plant water status, the atmospheric conditions that influence both of these and the critical timings of water application need considerable research at various agro-ecological regions.
7. Length of crop growing season required for the four different types of groundnut varies widely, but it takes Virginia and runner groundnut, in general, 1 to 6 weeks longer to mature than Valencia and Spanish groundnut.

**Figure 3: Groundnut pod, inside shell and kernal colouration determines the right maturity stage. Dark tan colour inside the shell indicates maturity.**

Groundnut pod development takes place in the soil making it difficult to correctly judge the maturity of the crop. Farmers are obliged to have considerable experience and great vigilance to carry out the harvesting operations efficiently without much loss of quality and yields. A proper time to commence the harvest is when a good number of pods are fully developed and are fairly intact. This condition is normally achieved when the vine begins to turn yellow and leaf shedding starts. The actual maturity of the pod is determined when they attain normal size with prominent veins, the inside of the shell turns dark and the kernels reach maximum growth accompanied by good colouration of the seed coat.
A fully mature pod can often be difficult to spilt open with the

pressure of the fingers. Meanwhile an immature pod can be split easily revealing the white inside surface of the pod which appears also to be spongy in texture. These criteria may help in assessing the correct stage of the harvest of groundnut crop. Harvesting at the proper time ensures that a high percentage of mature pods remain on the plants and the maximum number of pods has attained their greatest weight or physiological maturity (Figure 3). Delay in maturation may also occur because of late-season drought stress. Long periods of rain immediately prior to harvest may result in both yield loss and deterioration of quality of groundnuts. Several methods have been described for determining the maturity of the groundnut crop i.e. shell-out maturity and hull-scrap maturity testing methods. The prevailing attitude among the groundnut production specialist is that the hull-scrap method is not accurate for Virginia and Spanish types groundnut and may predict a harvest time that is too early. Following are the tips of the shell-out maturity testing method:

1. Select five to ten plants from representative areas of the field.
2. Pick off all combine-harvestable pods i.e. soft; watery pods that shrivel in windrows should not be used.
3. Break open each pod to examine internal hull and seed coat colour.
4. Place pods with tan to black internal hull colour and pink to dark pink seed coat colour together as mature pods.
5. Calculate the percentage of mature pods: percent mature pods =[number of mature pods/(number of mature pods + number of immature pods)] x 100.
6. Mature pod percentage for approximate harvest time: runner, 70 to 80 percent; Virginia, 60 to 65 percent; Spanish, 75 to 80 percent.
7. Other considerations:

- If leaf spot or other diseases are problem in the field, do not delay harvest.
- If there is a weather forecast that would delay the harvest, this must be taken into account.
- Harvest must be done when sufficient labour and adequate equipment are available.
- Failure of peg strength and well-filled pods with pink seed coat indicate maturity in large-seeded Virginia type. Signs of weakening peg strength indicate immediate need for harvest if excessive losses are to be avoided. Check groundnut crop closely as the average number of days to maturity approaches.

Seed-hull ratio and shelling percentage as indicator of groundnut maturity:

The seed-hull ratio as an index of groundnut maturity was first proposed by Pattee, et al. (1977) and is obtained by dividing the mass of the seed by the mass of hull (shell). The ratio may be determined on the basis of fresh as well as dry seed mass. Shelling percentage is the proportion of the mass of the seed in a given mass of seed in a given mass of pods. It is usually measured on the basis of dry mass. Shelling percentage is an important attribute in the evaluation of varieties and in trade transactions, which involve unshelled groundnut. Troeger, et al. (1976) were apparently the first to use the seedpod ratio as a maturity indicator for individual pods.

The mathematical relations of this method are given below:

Seed-pod ratio (SPR) = seed mass (S) / Pod mass (P)

= S/P-S x (P/P-S)-1

= seed-hull ratio (SHR)/ Pod-hull ratio PHR)(1)

PHR = P/P-S

= 1 + S/P-S

=1+ SHR(2)

Substituting (2) in (1), we get

SPR = SHR/(1 + SHR)(3)

Multiplying both sides by 100, equation (3) can be restated as:

Shelling percentage =100 [seed-hull ratio/ (1 + seed-hull ratio)]

Similarly:

Hull-pod ratio (HPR) = 1-SPR(4)

And,

SHR = S/P-S

= S/P x (P-S/P)-1

= SPR/HPR(5)

Substituting (4) in (5), we get

SHR = SPR/ (1-SPR)(6)

Multiplying and dividing the right hand side by 100, equation (6) can written as:

Seed-hull ratio = shelling percentage/(100-shelling percentage).

**Table 6. Groundnut cultivars and elite germplasm being used in various developing countries for their useful traits.**

| Name of cultivars /germplasm accession | Country of Origin or Affiliation | Characteristics and remarks |
|---|---|---|
| CG 7 | ICRISAT | High yielding confectionery type, longer self-life |
| ICGV 86325 | India | Released jointly by ICAR and ICRISAT for rainy season cultivation |
| BARD 92 [ICGS (E) 56] | Pakistan | High yielding released by the Pakistan Agriculture Research Council. |
| 1.Stella (ICGV- SM 85 048) 2. Veronica (ICGV-SM 86715) | Mauritius | High yielding released by Mauritius Sugar Industry Research Institute. |
| ICGV 91004 | ICRISAT | Higher and balanced pod yields in relation to fodder yield across the locations. |
| ICGS 76, ICGS 44 | ICRISAT | Drought tolerant and high yielding cultivars |
| Kadiri 3, J 11, TAG 24, | India | High yielding and usually taken as National checks. |
| ICG 7625 and 5856 | ICRISAT | High oil content |
| ICG 5369 and 5856 | ICRISAT | High O/L ratio |
| ICGV 87123 | ICRISAT | High P/S ratio |
| ICGV 86552 | ICRISAT | Resistant to insects and pests, bud necrosis disease, tolerant of end-season drought. |
| ICGV 86606 | ICRISAT | Foliar disease resistant |
| ICGV 86398 and 86393 | ICRISAT | Pest resistant |
| ICGV 87480 | ICRISAT | High yielding and short-duration |
| ICGV 91278 | ICRISAT | Resistant to seed infection by Aspergillus flavus |
| ICGV 87350 | ICRISAT | Foliar disease resistant |
| ICGS (E) 56 (ICGV 86015) | ICRISAT | A short duration variety |
| NRCG 1800 (ICG 2530) | India | Resistance to ash-weevil and root knot nematode. |
| NRCG 8440 (ICG 3563) | India | Tolerant to iron-deficiency chlorosis |

| Name of cultivars /germplasm accession | Country of Origin or Affiliation | Characteristics and remarks |
|---|---|---|
| NRCG 664 (NCAc 17090) | Peru | High peg strength |
| NRCG 609 (ICG 3404) | Argentina | Salinity and drought tolerance |
| NRCG 2615 (ICG 1587) | India | Cold tolerance and resistance to Spodoptera litura |
| Chico (ICG 476) | - | Short-duration |
| TAG 24 | India | High harvest index (HI) |
| ICG 86031 | - | Higher water use efficiency (WUE) |
| TKG 19 A | India (BARC) | High shelling percentage (68 to 70%) |
| CSMG 84-1 | India | High yielding and rust resistant Virginia runner |
| GG 20 | India | High yielding semi-spreading variety |
| Luhia 15 | China | High-yielding, small-seeded with O/L ratio 1.31 |
| Birsa Bold 1 | India | Promising new confectionery variety |
| BR 1 | Brazil | High yielding cultivar seed yield 1.3 t ha-1. |
| NCAc 343 | ICRISAT | Multiple insect pest resistance |

(P=polyunsaturated and s= saturated acids)

It is evident that shelling percentage could also be used as an index of maturity in addition to seed-hull ratio (Abdul and Ahmadi, 1994).

Promising cultivars: Some promising cultivars and elite groundnut germplasm being used in the developing countries were shown in Table 6.

## 2.2 Harvesting

From the literature it appears that in the developing countries, crop harvesting equipment available with the smallholder farmers have changed very little over the years. The search for more efficient, cost-effective ways of harvesting and threshing the crop is significant because of the extreme labour intensity of these tasks. For example, up to 40 percent of the total labour required to grow this crop is expended in harvesting operations. At peak harvest periods labour shortages often occur, even in regions that normally have surplus labour available. This can either lead to higher costs of production or reduced yields. Several factors other than capital costs affect decisions on using harvesting and threshing equipment. The size of the farm in physical and economic terms influences the scale of machinery and the appropriate investment. If only a small amount of work is undertaken each season, then the capital cost per unit of work done may be so high that a machine may not be economical compared to alternative methods. Trade-offs can be avoided where multi-farm equipment use is possible, but this approach requires a high degree of organization and cooperation, especially when timely harvesting is critical.

**Figure 4: Manual harvesting and lifting of Spanish type of groundnut by hired labourers.**

Harvesting usually consists of a series of operations comprising digging, lifting, windrowing, stocking and threshing. Some of these tasks can be combined or eliminated depending on the system applied. Among the field operations concerned with groundnut cultivation, harvesting is the most laborious and costly endeavour. The actual method of harvest employed depends upon the type of groundnut grown.

In bunch types, pod development is confined to the base of the plant and the pegs carrying the pods into the soil are thick and strong. Almost all the pods are recovered with the plants when they are pulled out of the soil (Figure 4). The bunch type of groundnut is mostly harvested by pulling out the plants with manual labour in India. The diversity of the labour employed to harvest the crop depends on the location. For instance male labourers are used in Tamil Nadu and in Gujarat both male and female labourers are employed. Usually 12 to 14 labourers can harvest one-hectare area of groundnut crop in one day.

Harvesting may sometimes become a problem especially when the crop has passed the stage of full maturity and the soil has hardened. In this case, it is customary to lift the plants by loosening the soil either by working a hand hoe, a plough or a blade harrow along the plant rows. If after lifting the crop manually it is observed that a good percentage of the pods have been left in the soil, the same implements may be used to pick the leftover pods. In the latter case, additional labour will be required. In the case of the spreading type, the process of up-rooting the crop from the soil is a rather difficult operation as pod formation takes place all along the creeping branches of the plant. The pegs are comparatively thinner and more delicate. In Figure 5. a blade type digger is harvesting a runner type of groundnut (Figure 5).

**Figure 5: Groundnut harvesting by a blade type digger being operated by bullocks and tractor.**

As compared to manual uprooting, the performance of the bullock-drawn digger is satisfactory and economical. The digger lifts groundnut plants from a depth of 10 to 12 cm. Several models are available in the markets to be operated either by the animal draught or by the power tiller drive (3 to 6 hp). The capacity of various diggers ranges from 1.2 ha h-1 (animal drawn) to 1.5 ha h-1 (power tiller).

Harvesting bottlenecks in the less-developed regions are commonly caused by the logistics of lifting plants from the ground. This task is the most mechanized operation in developed countries and replaces the hard manual labour of digging. Many models of ploughs or digger blades can be used to up-root one or several rows. The design depends on whether the digger is animal operated or mechanically powered. It is essential that the blade or ploughshare be set deep enough to cut below all the pods, but not so deep as to increase draughts unnecessarily. Slow speeds and additional implements are preferable to higher speeds with fewer tools, especially when kernels are produced for table consumption. The gain in yield, quality and final price offsets the additional digging costs. Harvesting techniques can also affect milling quality of groundnuts. Sweeps or fingers may be necessary on the digging blades to ensure that the plants are left well to one side of the opened furrow and not covered with soil. Where it is necessary to combine several rows of plants into one, this operation must be carried out soon after lifting as practicable or pod loss can occur. Raking early in the day when plants are moist reduces this danger.

In certain areas, the vines are uprooted with country ploughs and the vines and pods are picked by manual labour (Figure 6). The pods left over in the soil are picked by hand. Groundnut diggers drawn by a pair of bullocks or by tractor are available in market. The bullock-drawn groundnut digger can harvest groundnut crops over an area of 0.75 hectares in 8 hours.
Some farmers use conventional 76 inch blades attached to cultivator frame to dig groundnut. A tractor-mounted digger-shaker-windrower is available in the Indian market. This equipment saves the loss of pods and reduces the cost of harvesting.

**Figure 6: Manual lifting of groundnut vines.**

## 2.3 Threshing

**Stripping**

Stripping of pods is performed manually by the small farmers (Figure 7) or by the strippers. There are two type of groundnut strippers, the drum type and comb type.

**Figure 7: The women-farmers and hired female labours are doing manual stripping of groundnut pods. In the background bullocks are also enjoying the freshly harvested crop.**

The description of the drum type stripper developed at Zonal Research Centre, Tamil Nadu Agricultural University, Coimbator. Drum type strippers consist of a hollow drum formed by two metal discs at the ends, connected on the periphery of 5 1/2 inch M.S. rods inserted inside and covered by thick and soft rubber tubes. This drum is mounted on pedestal bearings and is free to rotate. It is fixed on a framework at a conventional height so that the operator can stand and beat the root portion of handful of plants over the rubber-covered roads of the revolving drum.

To avoid scattering of pods, a hood frame is also provided. The roof as well as the three sides, i.e. other than the operator's side is covered with a canvas or gunny bag. One man can carry the unit. A comb type groundnut stripper is used for stripping the pods from the wet groundnut vines. This has been developed at Zonal Research Centre, Tamil Nadu Agricultural University, Coimbator. The unit consists of a square frame of four vertical-standards with a strip of expanded metal fixed on to each of its side in the form of a comb. The stripping of the pod is accomplished by drawing a handful of vines across the comb with slight force. The structure facilitates use by four persons simultaneously.

Stripping of pods from the vines is done by several methods. In bunch type the plants are stacked in heaps with the pod end exposed. Please see Figure 8 and 9.

**Figure 8: Comb type groundnut stripper. Source: NDDB**

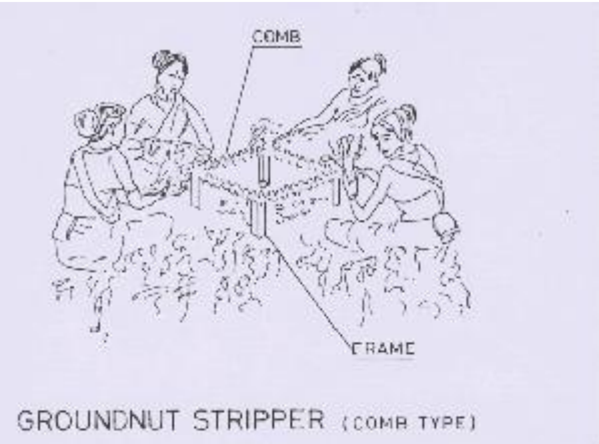
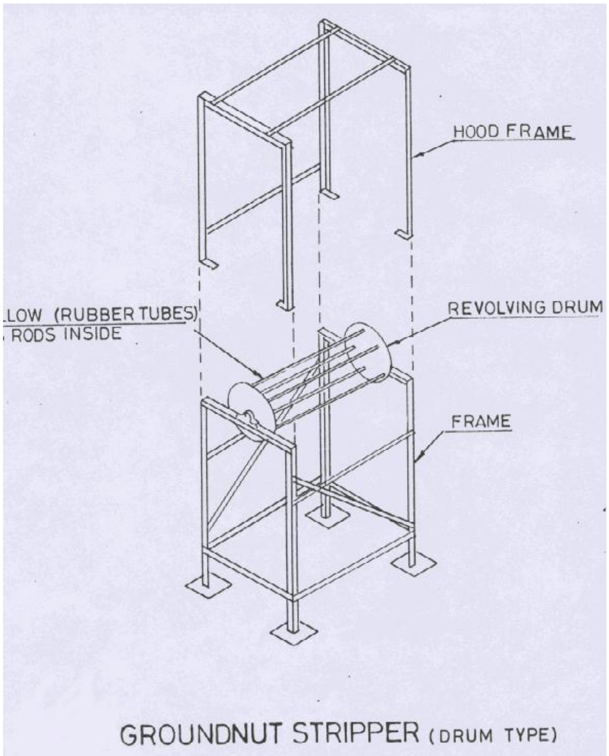



**Figure 9: Drum type groundnut stripper. Source: NDDB**



The pegs become brittle within a week and pods are stripped by hand. In some areas in India the pods are first lifted out of the soil, dried in the field and then the pod ends of the plant are knocked against a crossbar to dislodge the pods. In this process some pods b../img/ch21/ecome damaged. This method of stripping is cheaper. A simple comb-type stripper and peddle-operated stripper are available and can be used for bunch types of groundnut.

In the case of runner types, the plants are first allowed to dry, then are beaten with flails and the pods are separated from the beaten mass by winnowing. The pods left over on the vines are handpicked. This method of stripping is not preferred as it is considered to reduce the fodder value of the vines. The Central Institute of Agricultural Engineering (ICAR) Bhopal, India has developed a CIAE Groundnut power stripper to strip the pods from green vines both runner and Spanish types, however, it need more testing and demonstrations to be implemented at the farmers level (Figure 10).

**Figure 10: Groundnut stripper for stripping green vines developed by CIAE (ICAR), Bhopal.**

Threshing operations also very both within and among the developing countries. It varies from the age-old procedure of using sticks and racks to the modern power threshers. In India the smallholder and marginal farmers do manual threshing using sticks and rakes. Variations also exist in stripping pods from the plant. After harvest bunch type plants are stacked in heaps with the pod-end exposed. After the crop has remained in this state for a week or so the pegs become brittle and the pods are plucked from the plants with labour. This operation is comparatively difficult as the attachment of peg to pod is stronger in bunch type than the runner types, but drying the plants for a few days facilitates this operation.

Sometimes the stripping of the pods is also performed side by side with the harvest when the crop area is small and labourers are available. In this case, the pods are dried immediately after stripping. In Pollachi (Tamil Nadu, India) the usual practice is to separate pods by beating the pod-end of the plants against a rough stone or a thick iron rod. This process damages a small percentage of the pods. Following this method the proportion of the damaged pods is not appreciable and is a considerable labour saving.

A pedal operated thresher based on the Japanese Paddy thresher tried in Tamil Nadu has proved useful for the bunch type in which the pods are clustered together at one end; however in spreading types pod are found all along the branches and have to be plucked individually. The attachment of peg to pod in runner types is also weaker. In this case none of the above methods would work satisfactorily in case of runner type, thus it becomes a laborious process. In most of the groundnut-growing areas in India for example the states of Andhra Pradesh, Maharastra and Gujarat, the harvested plants are allowed to dry well on the threshing floor, the dried mass is beaten with flails. After making sure that the pods have been detached from the plants, pods are separated from the beaten mass by winnowing. Threshing involves quite distinct operations including separating the pods from the vine, sorting the pods from the haulms and winnowing the chaff from the pods. In some parts of India. small farmers employ manual threshing. After drying the groundnut plants in sunlight in the field for 4 to 5 days they are collected at one place. Threshing is done manually by a wooden comb type structure with a long handle (Figure 11). Earlier in Gujarat farmers used to follow this procedure but now it has become an obsolete technology, mainly due to the availability of power operated opener or thresher in local markets.

Groundnut pods are properly picked either manually or by the thresher after sufficient drying. In Gujarat, the farmers, local artesian and traders have designed and developed efficient threshers. At adequate moisture content of groundnut plant, pods are harvested directly in a power thresher. Oil engines or electrical motor operated groundnut threshers can be used for higher land holdings. The capacity of the thresher ranges between 2 000 to 2 500 kg of groundnut pods day-1 and requires at least two people for operation. The first separation of groundnuts from all other material occurs during threshing and or combining. The threshers used in India are quite efficient and require skill to adjust it prior to threshing, otherwise losses like incomplete separation and breakage of pods may occur.

**Figure 11:An old method of threshing groundnut pods.**

The best threshing is obtained with minimum loses at pod moisture content between 18 and 20 percent. Groundnut threshers are generally designed as axial flow where the plant moves in a direction parallel to the beater axis. The pods are separated from the remainder of the plant in the threshing chamber so that the latter is expelled at the other end of the thresher. The impurities fall onto the sieve, where the leaves and light material are removed by air from the blower. The clean pods than fall through the sieve and are discharged through the pod outlet. The clearance between the bar and the screen is too small to admit the pods with the shell. The machine can be trickle-fed automatically or fed by handfuls. The JYOTI Ltd, Vadhodhra, (India) has developed a decorticator, which performs simultaneously decorticating and cleaning operations. The blower separates the hull and clean kernels are discharged through the grain outlet. Ball/bush bearings with oil cups are standard fittings. The capacity is 10 to 20 kg h-1. The thresher requires 10 hp and is operated by 3 to 4 people (Figure 12).

**Figure 12:Threshing operations in the field, groundnut opener being operated with the help of tractor engine and another with a diesel engine.**

**Figure 13:Winnowing and cleaning operations are being performed by the farm family.**

## 2.4 Drying

Curing and its interaction with the maturing process comprise the single most critical factor in establishing the basic flavour quality of groundnut after harvest. The terms curing and drying have been defined as two distinct phases marking the change in groundnut composition following harvest (Blatchford and Hall, 1963). Because of common usage, the terms curing and drying are often used interchangeably. Curing is the process of water removal such that groundnut biochemistry and physiology are optimum for food quality. Proper curing is essential for safe storage, milling quality and flavour quality. Extremely high temperatures, while the crop is in windrows, can promote far too rapid drying and may contribute to the development of off-flavours. The process of curing has not received much attention, especially in the developing countries, where the farmers lack education, quality consciousness or the proper facilities and knowledge.

During the curing process, groundnuts are dried to an average moisture content of approximately 10 to 15 percent. This means that some kernels are drier, measuring as low as 10 percent while others contain more moisture. The moisture content range of kernels in a lot is related to initial moisture and maturity of individual kernels. Immature groundnuts may contain twice the moisture as mature groundnuts at harvest. The difference in moisture content among the pods of various maturity groups during curing is sustained during the storage period.

The word drying is often used to describe all phases of moisture removal, including those already referred to under curing. Speicifcally, drying is used only to describe the period when moisture is being removed after groundnuts have been threshed from the haulms. Groundnut after harvest is dried thoroughly either following the natural or the artificial methods. The equilibrium between the pod moisture content and atmospheric relative humidity during the drying process has been investigated by several workers. The results showed that the shell, the testa (skin of kernel) and the kernel have different equilibrium moisture contents at the same humidity (Table 7). The rates at which pods lose water to the air during curing and drying and the rate at which they change in moisture content during storage, depend on the physical structure of the pods as well as the temperature, velocity and relative humidity of the air.

**Table 7. Equilibrium moisture contents of groundnut at various relative humidity**

| Components of pods | Percentage relative humidity | | | | | | |
|---|---|---|---|---|---|---|---|
| | 44 | 53 | 64 | 70 | 75 | 86 | 92 |
| Percentage moisture content (wet basis) | | | | | | | |
| Unshelled | 6.2 | 6.9 | 8.2 | 8.2 | 9.0 | 12.8 | 19.3 |
| Kernel | 5.2 | 5.8 | - | 6.7 | 7.1 | 11.3 | 17.2 |
| Shell | 9.6 | 11.5 | 12.4 | - | 14.5 | 16.5 | 20.1 |
| Skin (testa) | 13.9 | 14.3 | 15.1 | - | 17.9 | 19.9 | 52.8 |

*Source: Blatchford and Hall, 1963*

Blatchford and Hall, (1963) made extensive surveys of the literature on drying methods for groundnut in various countries. Some of the drying methods being followed in the developing countries are mentioned below.

**2.4.1 Natural methods**

Scattered on ground

In this method plants are placed directly on the ground, foliage downwards, so that the pods are exposed to the sun. Conversely, in some areas, foliage is placed upwards with the pods in contact with the moist-soil and protected from the direct sunrays. Plants are left in this position for varied periods of time, which often depends on the beliefs of the individual farmer. There is no criterion of moisture content for determining when the plants should be collected from the ground. In the Eastern province of Northern Rhodesia it was observed that the moisture content reduced from 21 percent to 5 percent in 7 days. For the case of Uganda, the moisture content reduced from about 40 to 25 percent in one day and further diminished to 6 percent after 20 days. The period of time the plant are left on the ground surface is limited to one to two days in Senegal. In South Africa it is recommended that plant should be allowed to lie on the ground surface for a period of three days to allow leaves to dry out before stacking. Curing by this method locally called sun curing has an adverse effect on the quality of kernels and makes it difficult to sell the crop. Grading regulations now discriminate against groundnuts cured in this way. If groundnuts are left too long on the ground to cure, dew and sunlight tend to discolour the nuts. Moulds may develop and cause breaking of pods while overheating may cause splitting of the kernels during shelling.

***Windrows***

This method is used for curing groundnuts prior to further drying in stacks in South Africa and Israel. After harvest plants are dried in inverted windrows for 2 to 3 days. In these windrows, the pods on top may be exposed to the weather or they may be underneath, next to the ground covered by the foliage. Loose fluffy windrows seem to permit good air circulation, which ensure uniform and fast curing of the pods. Groundnuts 'dried' in fairly large windrows with the pods protected from full sunlight by the haulms have been shown to lose moisture more slowly and suffer no apparent damage as compared to the pods exposed to the sun in small, thin windrows. If there are rains before the pods are dry enough to be picked-up, they may become damaged by the moulding and consequent blackening of the shell, together with some blackening of kernels. Heat and too rapid drying usually damage groundnuts exposed to direct sunlight at the top of windrows for more than two days. Pods dried following thin windrows produce hard kernels, excessive skinning and breakage during shelling. The seed also loses their viability rapidly during storage. Consequently, in colder areas freshly dug and windrowed groundnuts, which become frosted, will have impaired viability and reduced vigour of seedlings. When windrow drying is used as a preliminary to all drying, curing may be done for three to four days to attain moisture content between 15 and 20 percent. It is recommended that when windrow drying is used before drying in sacks, the plants should only be left in windrows to wilt for 18 to 24 hours (Blatchford and Hall, 1963). Please see Figure 14.

**Figure 14:Groundnut hand-sheller.**

***DOR Method***

In India loss of seed viability is a serious problem in groundnuts produced during the summer season. For drying the pods under shaded conditions, Directorate of Oilseeds Research (1983), Hyderabad, India, developed a method for maintaining seed viability. In this method two big heaps one-metre in diameter are tied near the base with a rope.

**Figure 15:DOR-method for the drying of groundnut pods.**

One heap is inverted over the other in such a way that haulms of the upper heap cover the exposed peripheral pods from the direct sunlight (Figure 15). Seed of the pods dried following this method retains about 80 percent germinability, even after 8 months of storage. In the regions, where groundnut is grown only in the summer season, pods dried following the DOR method could be stored for the sowing of the next summer season.

There are two major drawbacks to this method. First, in case of cultivars with less height and foliage, if the upper bundle does not completely cover the peripheral pods of the lower bundle by its haulms completely, the peripheral pods are exposed to sunlight and become prone to lose seed viability. Second, if there are rains within 1 or 2 days after the harvest, the seed quality is damaged seriously.

***NRCG Method***

To overcome the drawbacks of the DOR method as mentioned above, a new method for the drying of groundnut pods was developed at National Research Centre for Groundnut (NRCG). In this method a tripod type structure (pyramid shape) can be raised in the field with the help of three bamboo poles of about 1.5 m long. A coir rope can be wound around the structure starting from the bottom to the top, while maintaining a space of 6 to 8 inches between two loops. Immediately after harvest groundnut plants are hanged on the rope of the structure in inverted position, pods up and haulms down and the structure is filled with groundnut plants in a way that the pods of an upper ring covered the haulms of the lower ring thus forming a sloping structure like the roofing of a thatched house. The plants can be arranged bottom ring upwards (Figure 16). Groundnut pods along with the plants can be allowed to dry in the structure in the field for five days. Seed dried following this method maintains >80 percent germinability, even after 10 months of storage. In India this method was found very useful in maintaining the viability and quality of the seed in the areas where rain-showers are frequent during drying period i.e. the Northeastern parts, state of Orissa and Bengal. This method of drying was demonstrated to the farmers of Gujarat in Kodinar Taluka, Junagadh (India) in the summer of 2000, while the crop was being dried in the field it experienced rains during 2nd and 3rd day. Seed obtained from the pods dried following NRCG method retained more natural testa colour than the conventional, windrows and DOR methods. If there are heavy rains during the drying period the structures may be covered with polyethylene sheeting, to serve as protection from rainwater.

**Figure 16: NRCG-method of drying of pods, the basic structure raised with the help of three bamboo sticks and structure loaded with groundnut plants.**

***Stacks***

Different types of stacks are built in different countries. These may be in a series ranging from those of simple structure, rather like a large heap of plants, to those of complex structure built around a pole and requiring some skill to construct. Blatchford and Hall, (1963) defined the term 'stack' as structure formed by grouping a number of plants together. They described four types of stacks: ordinary, ventilated, poled and ventilated poled stacks. The ordinary stack is the simplest type of stack and is formed by gathering the plants into heaps, the dimensions of which often range from 3 feet in diameter and 2 to 3 feet high to about 12 feet in diameter and 5 feet high. The pods may either be scattered throughout the stacks, which is common in the African countries or lie at the stack centre or around the outside of the stack, depending on the area and the type of groundnut grown. In several groundnut-growing areas, pods are picked from the plant after drying for about two to four weeks in these stacks and are made ready for selling or storage. The drying period in these stacks also varies, frequently lasting from 10 to 15 days but in a few cases only two to three days. The small stacks are gathered together into large stacks with the haulms towards the outside and the pods towards the inside. These larger stacks are usually built at the edges of fields and some farmers choose shaded sites for stacking to avoid over drying by the sun. In the Eastern Province of Northern Rhodesia farmers are encouraged to build the freshly lifted plants in to stacks three to four feet high, placing the plants with the pods to the inside of the stack. In ventilated stacks the plants are grouped together so that the centre of the stack remains open to assist ventilation. The pods, as with ordinary sacks, may be scattered throughout the stack or all lie at the stacks centre or around the periphery of the stack. Farmers in Rhodesia and Nigeria build stacks of this type locally known as 'cocks'. The stacks should be built on small mounds of earth and the pods placed at the inside of the stacks. The central funnel should be covered with grass to prevent the pods at the top from being scorched by the sun. It is also suggested

that pieces of plastic sheeting cover the stack would help to shed rain to outer edges. When stacks are built near the farm buildings on an area of cleared ground, 'ventilation tunnels' constructed with the help of poles available locally is recommended. In most humid parts of Kenya plants are often built into a stack called 'poled-stacks'. In this method plants are grouped around a centre pole, which supports the stack and prevents it being blown down by the wind. The pods may be scattered throughout the stack or may lie the stack centre or round the periphery. It is reported that drying in such stacks takes about three to five weeks. The losses are shown in general to be less in the stacking method than in the scattered or windrows methods.
After lifting, plants can be stocked by hand to dry, on some kind of simple frame or pole as used in some parts of Central Africa. Stooking groundnut normally produce excellent quality hay and pods, but are confined to less-developed areas, where machinery is not easily available or where labour is still plentiful. When it is necessary to leave the plants to dry in the field after lifting, some method of keeping the pods off the ground is necessary. This will reduce losses from rotting and termites etc. and allow air to circulate more freely. The simplest method is to invert the plants in lines, so that pods are upward resting on the foliage. Machines which can dig, shake and produce inverted windrows are available and in commercial use. The machine consists of digging blades which span two rows, loosen the soil and cut tap-roots, a pick-up and elevator to lift plants and shake them clean of soil plus a mechanism to invert the plants and place them in windrows. Windrows can be re-turned in wet weather, or re-shaken if large amount of soil remain on pods. Some groundnut varieties produce considerable vegetative growth, which remains green when pods are mature. To reduce the volume passing through lifters and threshers, half the haulms may be cut off before digging. When pod moisture content has fallen to 20 to 25 percent the groundnut combine can be used on the windrows.
Groundnuts required for seed purpose must be handled with greater care than that permitted by normal commercial operations. When groundnut is a major cash crop in the areas, crops should be grown specifically to provide seed. As the extent of mechanical damage and its effect on germination and seedling vigour are not always appreciated, damage to kernels may not necessarily be obvious to visual inspection. Hand-harvested seed can give twice the final stand and twice the yield of mechanically harvested seed. Many countries now have central crop marketing boards and these bodies are able to use the production of pure and improved seed as a method of increasing yields and maintaining standards.

***Platforms***

Platforms of various heights may be built to raise the plants off the ground during curing and so reduce moisture damage in the bottom layer of pods and avoid damage by the cattle also. In Gambia stacks of groundnut plants are often put straight on to raised platforms immediately after harvesting. In Guinea after curing the plants in small stacks, local farmers sometimes put plants to dry in larger stacks on raised platforms.

***Racks***

The curing of pods on racks has been referred to in a number of countries. In North Rhodesia to prevent termite damage to groundnuts during the curing period, a horizontal rack is used. The rack consisted of crossed pieces of local wood 36 inches long, 18 inches apart and rose 18 inches off the ground. Plants hung on the rack are protected from termites and could be arranged so that the nuts are shaded from the direct rays of the sun. The moisture content of pods on the rack comes down from 21 percent to 6 percent during the first 7 days of curing.
On ground surface

Drying of pods by spreading them in a thin layer on the soil or woven matting or tarpaulin material is a common practice in many parts of India and Africa (Figure 17). In Uganda where harvesting occurs largely in the wet season a period of four to six weeks is given as the probable time taken for pods to dry to about 10 percent moisture content. In India, the threshed pods being spread out in the farmer's threshing yard on a hardened mud, cement, or stone slab floor. A layer 1 and 1/2 inches deep needs no string, while one 3 inches deep needs stirring on alternate day. Two major disadvantages were noticed in drying the pods by leaving them spread in a layer on the ground or on areas of concrete or on matting, etc. Initially, there is the problem of moisture in the ground in contact with the pods together with restricted air movement within the produce. The second difficulty is the time and effort required to gather the pods together, cover them during rainshowers and re-spreading the pods as soon as possible to continue drying. A new type of plastic sundryer, which help the farmers to overcome these difficulties, has been designed in the Tropical Stored Produced Liaison Department (Pest Infestation Laboratory) and known as Allegate sundryer.

**Figure 17:Thin layer drying of groundnut pods in the courtyard of farmhouse and in the field on polyethylene sheet. A child is playing with the harvested crop in his courtyard.**

***Trays***

In some countries farmers are encouraged to spread their produce on trays, which they leave exposed to sun-drying during the day and shifts into the house at night. In Uganda for example trays, which hold one hundred kilograms of produce consist of a metal mesh base and wooden sides with handles at both ends. These trays can be raised off the ground by supporting the four corners on sticks. The Government subsidizes these drying trays to the farmers.

***Platforms***

Well-cured pods after removal from the plants are practiced to heap on platforms to complete drying. Very often the pods are left on such platforms for an indefinite period of time and may, in some cases, even be stored there.

***In sacks***

In cases where the moisture content of threshed unshelled and shelled pods is too high, the pods are sometimes bagged and every day the bags are brought out to the storeroom and left in the open. This is common practice at agricultural stations in Africa.

***Racks***

Several trials have been conducted on the natural drying of threshed groundnuts in bags in Australia. In the suspended bag trial, groundnuts of 30 percent initial moisture content in open weave bags were suspended vertically from a horizontal wooden rack supported at both ends by strong vertical posts. A galvanized iron roof provided protection from the rain. Staggered hanging of bags at centre distances of 22 inches, two bags rows deep is reported to have permitted safe drying of groundnuts from approximately 30 percent moisture content to safe storage moisture content in 10 days. As a result of this trial it was considered that in humid conditions, it might be necessary to use supplemental heat to achieve safe storage moisture content.

**2.4.2 Artificial Methods**

The artificial drying of groundnuts on a commercial scale has not been widely adopted, but research on the wide applicability of the artificial drying methods is still being conducted in many developing countries like India. Most of the experience in artificial drying of groundnuts has been gained in the United States of America and only a few experiments have been conducted from time to time in other part of the world. In Kenya work has been done on harvesting in which the plants are lifted, cleaned of soil and stripped of nuts in one operation. In Israel tests have been carried out in which groundnuts were threshed from windrows with mechanical harvesters and dried artificially. Intermittent drying of threshed groundnuts has been investigated and shown to reduce the total time of drying when compared with drying without 'rest' intervals. The theory is that by drying the shells and then allowing the nuts to 'rest' for some time, moisture will move from the kernel to the shells; the moisture differential between the shell and the drying air will thereby be greater and drying will consequently be more efficient. Investigations, however, on the danger of internal damage to the kernel and economics of such methods using a drier which is idle during the 'rest' periods are required.
In general, attempts to dry green (uncured) pods on the plant have given poor results in relation to the quality of both the kernels and the haulms. The total moisture percent was such that if drying was at a moderate rate, moulding quickly occurred and if drying was at a fast, quite considerable breakage of the kernels resulted. Unsatisfactory results were also obtained when the haulms were clipped at various periods before curing (Teter, 1954). It has been noticed that an initial period of curing which reduces moisture from about 50 to 60 percent to about 25 percent is necessary, if good quality groundnuts are to be produced by subsequent artificial drying. After partial windrow curing, groundnuts on the haulms have been successfully dried artificially in the United States of America. The best results have been

obtained using a temperature of 27 to 32°C and an airflow rate of 10 to 12 c.f.m.cu-1 ft and discontinuing drying when moisture content reaches below 7 percent.

***Batch dryers***

These consist briefly of a fan and heater unit (oil furnace) connected by suitable ducting to an air chamber, which forms the bottom part of a platform, tray, bin or silo. The threshed groundnuts are contained above the air chamber and the drier is so designed as to ensure that the heated air has to pass through the groundnuts in escaping into the atmosphere. To avoid the possibility of tainting (off flavours) from products of combustion an indirectly fired heater is normally used. In Tanzania test were carried out using a 10-aperture platform or sack drier with uncured groundnuts at about 48 percent moisture content. It was found that in practice using a single layer of sacks and air at 54°C moving at 110 cu.ft per minute (c.f.m) per sack the moisture contend would be reduced from 48 to 8 percent in about 16 hours. During these tests it was also found that the maximum temperature should be limited to 54°C since at 60°C a distinctive smell appeared which may be associated with some form of deterioration. Further drying of nuts at the higher temperature i.e. above 38°C renders the seed unsuitable for the sowings due to loss of viability.

***In bulk***

Two experimental tray dryers, used for drying cured groundnuts in-shell in Northern Nigeria, consisted basically of a rectangular pit, the laterite soil used to build walls bounding the pit and supporting the drying floor and forming the plenum chamber. Both dryers are of the heat exchange type the wood fuel in oil drums is placed in the pit, being completely gas tight and heating air in the plenum chamber which rise through the drying floor; one drier used the forced draught. One drier takes a maximum charge of 1 600 lb and other 2 600 lb wet kernels in-shell. The need of this artificial drier for groundnuts arose from the fact that the Mokwa and also in the Riverian area of Nigeria nuts are harvested at the wettest time of the year. In Tanzania using an experimental tray drier with a slatted floor, it was concluded that a two ft depth of freshly harvested (threshed) pods could be dried from 48 to 8 percent moisture content in about 42 hours using air at 38 °C at the rate of 55 c.f.m sq-1. ft (27.5 c.f.m cu-1 ft). The output of dry pods in shell using a two ft depth would be about 2 000 lb per 10sq.ft drier floor area in a six-day week. It was emphasized that the drying of wet pods stored in bulk should be started as soon as possible. This work in Tanzania led to design East African Industrial Research Organization to simple twin tray drier capable of dealing with about 75 tonnes of dry pods in shell in a drying season of 33 days. A fan, driven by a diesel engine, blows air heated to 38°C under the floor of perforated metal trays. Each tray is loaded to a depth of about two ft. and drying is completed in about 45 hours. Also in Alabama shelled nuts were satisfactorily dried in tray drier from 11.8 to 7.1 percent moisture content in 5.5 hours at 39°C; the fan was operated for an additional three hours to cool the nuts (Blatchford and Hall, 1963).

Tests were conducted in Israel on the artificial drying of groundnuts in three rectangular wooden bins, 2 m high with a slatted and wire netting floor. Air for drying was supplied by a fan to a plenum chamber below the bins and additional heat could be supplied to the air stream by indirect heating. These tests showed that there was no decrease in the quality of the product if it was dried in bulk in layers of 1.8 m high at an air velocity of about 0.5 m per second (m sec-1) which is equivalent to 98.4 ft per minute (f.p.m.) and an air temperature less than 40°C. Artificial drying had no influence on the colour and appearance of the shells or on the germination of seed. A bin-type drier used in Alabama to dry rain-soaked nuts consisted of an underground air duct and drying bins placed over vents in the air duct. The drying temperature was 46°C and the results were satisfactory (Smyth 1959).

Since work on drying of freshly harvested groundnuts has not been conducted much in the developing countries, due to resource constraint, the work conducted in Australia and the USA is described below. Before implementing the techniques various additions and modifications would be necessary based on the local environmental conditions and drying requirements. During experimental work in Georgia the moisture content of freshly harvested groundnuts on haulms was reduced from 35 to 8 percent in two weeks by spreading the plants in layers in what is described as a barn drier consisting of ducting through which air is blown. Fair results were obtained with this method and the pods and hay maintained very high quality. However, the enormous amount of space required has rendered this method impracticable for drying groundnuts. Column dryers consist of tall towers, the diameter being small in comparison with the height; the floor of the drier is constructed of ducting through which the air is blown. Dryers of this type have been used experimentally to dry groundnuts.

***Continuous flow dryers***

These consist essentially of tall towers down which the produce moves, usually by gravity and are designed to enable heated air to be blown through the produce. Alternatively, they are tray-type dryers with the tray inclined to take advantage of gravity or cause movement of the produce from one end to other. Usually these dryers have a cooling section in which only ambient temperature air is used. Various types of batch dryers have been used successfully, particularly in the USA, providing the drying air temperature does not consistently exceed about 38°C with an air flow rate of 5 to 100 f.p.m (c.f. sq-1 ft. effective floor area) and provided that the final moisture content does not exceed below 7 percent. Following are some general recommendations from America on the conditions for artificial drying of groundnuts. Although fresh nuts can be safely dried artificially if adequate care is taken, most of the workers seem to agree that windrow-cured pods can be dried artificially with great success and economy as long as the conditions are properly controlled. Over-drying should be avoided, otherwise the shelling quality is lowered, the flavour impaired and viability reduced; for this reason consistent drying temperature above 38°C should not be employed. Intermittent artificial drying is considered optimum procedure, where feasible. Under certain conditions it may be advisable to use slightly higher temperatures for a faster drying rate even at the expense of the quality of the pods. In the tropics, where ambient temperatures can be above 30°C the use of forced air without additional heat may be sufficient for drying groundnuts. If the airflow rate is higher it even without heating the ambient air increases the temperature of the pods during drying. After curing and picking up the pods from the vine they must be dried promptly to safe moisture level for storage. Failure to reduce the moisture content to a marketable level of less than 10 percent (w.b.) with in a period of two or three days may result in quality losses from biological activity.

## 2.5 Cleaning

When groundnuts are harvested they contain wide range of foreign material. This impacts quality, beginning with airflow restrictions and uneven moisture distribution during curing. Foreign material at 5 percent and above results in a deduction in the value of farmer’s stock groundnut brought to market.

During storage, foreign material interferes with airflow, reducing the ventilation that is necessary to removemoisture from the warehouse. To improve the quality of groundnuts, further modifications are needed in the threshers being used in the developing countries. Still, threshers used in India perform asatisfactory job of cleaning. The cleaning of threshed groundnut is normally done when there is no blower in the thresher or the cleaning efficiency of the thresher is low. In general most of the threshers have blowers, which perform the cleaning operation by the process of winnowing.

In the developing countries, less attention has been paid to cleaning material by the machines before storage. For the benefit of readers of this report, the cleaning operations of a typical peanut pre-cleaner and the methods to reduce the incidences of foreign material in groundnuts are displayed in Table 8.
Foreign material and loose-shelled kernels (LSK), groundnut seed inadvertently shelled by harvesting and handling operations cause problems in storage and processing (Dickens and Hutchison, 1976). LSK are often dirty, mouldy, mechanically damaged, or insect damaged. They deteriorate more rapidly during storage than in shell groundnuts. Small-shrivelled pods (raisins) contain high concentrations of moisture and often mould during storage. The incidence of foreign material in the farmers' stock groundnut may be reduced with a program of prevention and removal.

**Table 8. Methods to reduce the incidence of foreign material in groundnuts.**

| Foreign material(s) | Best conventional method(s) of prevention | Best conventional method(s) of removal |
|---|---|---|
| Dirt | Harvest when soil is not too wet or dry. Control weeds. | Screening |
| Rocks pieces | Avoid planting on rocky or pebble-type soil | Specific gravity |
| Sticks/previous crop residue | Remove of burry old crop residue before planting. Set groundnut digger to cut taproots as shallow as possible | Aspiration and screening |
| Immature pods | Harvesting at optimum maturity. Remove immature pods | Screening, aspiration and specific gravity |
| Pops, leaves, stems and hulls | Harvest at optimum maturity | Aspiration |
| Weed fruit/seed/nut grass and rhizomes | Control weed | Screening and colour sorting |
| Metal | Maintain machinery in good condition | Screening and magnetic separation |

Despite the obvious advantages, most of the groundnuts are not cleaned before storage. Doing so requires a large investment in equipment and labour, provides another significant cause of breakdowns and delays during the rapid harvest season and usually results in a small loss of marketable groundnuts. Developing countries have manufactured cleaning equipment and created methods to remove some of the foreign material that segregate in storage . Cleaning with sand-screens at ground level and employing additional elevators is also an effective cleaning method. In Senegal, a rotary cleaner made by SISMAR®, is used which can be operated by hand. This machine has a double sieve designed to separate groundnuts from husk and other rubbish. It is fitted with a large hopper, having a capacity of 80 kg (approximately one sack)plus two outlet spouts allowing the independent or simultaneous filling of two sacks. Output is 155 to 2 000 kg h-1. The sieve axle is mounted on ball bearings. Recommended turning speed is 15 rpm, weight 212 kg.

***Decorticating or shelling***

Due to the lack of an efficient machine to shell groundnut, small farmers generally depend upon mouth shelling or employing labour to prepare seed for sowing purpose. This is a time consuming operation and does not match the shelling requirements within a limited period of time to retain seed viability. A small machine is required for this purpose, which may also meet the shelling needs of the farmers for their domestic consumption of kernels. This can also facilitate the shelling of graded kernels by the farmers instead of pods. Sale of kernels in graded quality will also fetch them more price for the produce. In Gujarat, a small manually operated sheller is available in the market for the use of small farmers and for shelling of groundnut at the time of sowing (Figure 18).

**Figure 18:Groundnut hand-sheller.**

A power operated groundnut pod opener (decorticator) has been developed at Zonal Research Centre, Tamil Nadu Agricultural University, Coimbatore. The decorticator is used to shell groundnut pods and to separate kernels with least injury or damage for use as seed. The unit consists of a hopper, double crank lever mechanism, an oscillating sector and blower assembly, all fixed on a frame. In the oscillating sector unit, a number of cast iron peg assemblies are fitted. The whole sector assembly oscillates close to a concave sieve fitted just below. A hopper is fitted at the top of the unit and the pods are fed through it gradually. The groundnut pods are broken between the oscillating sector and the fixed perforated concave sieve. The blower separates the kernels and shells; kernels are collected through a spout at the bottom of the machine, while the blower blows off the lighter materials. The clearance between the concave and the oscillating sector is adjustable to decorticate the pods with the different varieties of groundnut. Similarly, the sieves are also replaceable thus avoiding the damage to the kernels at any time. Power required: 1 hp motor. The machine output is shelling 400 kg of pods per hour. Percentage of breakage is only 4 kg.

## 2.6 Packaging

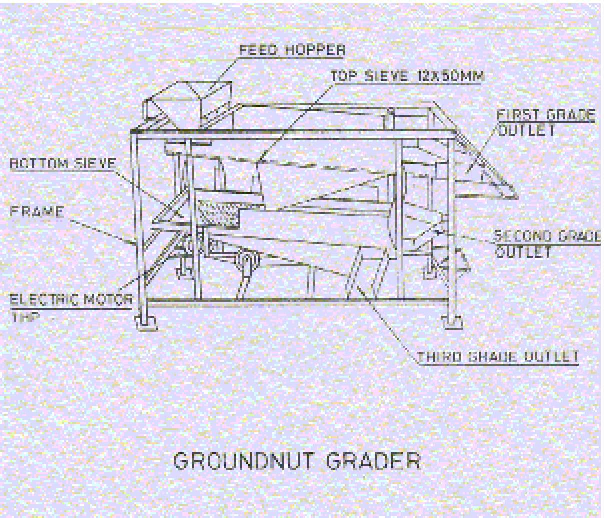
### 2.6.1 Grading

The cultivated groundnut is defined as one of four types: i.) runner: runner have become the dominant type, because of their attractive size range which makes them useful for a variety of products; ii.) Virginia: Virginias have the largest kernels and account for most of the groundnuts roasted and eaten as in-shell. When shelled, the larger kernels are sold as salted-groundnuts. They are also used in confectionery products; iii.) Spanish: Spanish type groundnuts have small kernels covered with a reddish-brown skin. They used predominately in groundnut candy, with significant quantities used for salted nuts and groundnut butter.

They have a higher oil contents than others types iv.) Valencia: Valencia's usually have three or more small kernels to a pod. They are very sweet groundnut and are usually roasted and sold in the shell. They are excellent for fresh use as boiled groundnuts.

After drying, groundnut pods are graded at a prescribed moisture level in the kernels such as 9 percent. Undersized pods, chaff, inert matter, if any, is separated. The factors such as foreign material over 4 percent, moisture over 7 percent, damage over 1 percent, loose shelled kernel content, and split percent over 4 percent determines the value of the produce in the national and international markets. Seed size is another important characteristic that also determines both quality and value. The 100-seed weight may differ among genotypes from <30 g to >150 g. Size also varies within a genotype, and cultivars with more uniform seed size are desired for improved processing efficiency and marketing of groundnut products.

**Figure 19. Groundnut grader line diagram (Source: NDDB, Manual on Groundnut).**




India produces two sizes of groundnut kernel, medium and small. The medium-size kernels, known as "Bombay Bolds", generally count 50/55 kernels per ounce. They can also be graded to 40/50 kernels per ounce, though availability at this size is not unlimited. The small-size kernel are called the "Java" type, is equivalent to the US "Spanish" or the South African "Red Natal". The generally traded grade of Java is 70/80 kernels per ounce. In internal trade the quality of pods and kernels is judged by a visual examination except in contract sale when the proportion of damage kernels, nooks, broken and splits, percentage of foreign matter, and moisture content is determined. The ISI has prescribed certain grades for groundnuts (kernels for oil milling and handpicked selections) produced and marketed in the country. These standards are based on the trade practices followed in the country in respect of the type and grades. The specifications are given in Table 9. A line diagram of groundnut grader is shown in Figure 19.

**Table 9. ISI specification for groundnut kernels for oil milling.**

| Characteristics | Requirement for milling | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Damaged kernels and weevil kernels, % by weight (max) | 0.5 | 1.5 | 3.0 |
| Slightly damaged kernels, % by weight (max) | 1.0 | 2.0 | 4.0 |
| Shrivelled and immature kernels, % by weight (max) | 1.0 | 30. | 6.0 |
| Split and broken kernels, % by weight (max) | 5.0 | 10.0 | 15.0 |
| Nooks, % by weight (max) | 1.0 | 2.0 | 3.0 |
| Impurities, % by weight (max) | 1.0 | 2.0 | 3.0 |
| Admixture with other types, % by weight (max) | 1.0 | 2.0 | 5.0 |
| Total of 1-7 above (max) | 6.0 | 12.0 | 30.0 |
| Moisture content, % by weight (max) | 6.0 | 6.0 | 6.0 |
| Oil content on moisture free basis, % by weight ( max ) | 48.8 | 46.0 | 42.0 |
| Acid value of extracted oil (max) | 2.0 | 4.0 | 6.0 |

For preparing export grade edible groundnut, "Hand Picking and selection" (HPS) through hired labour is still in practice. Although, in the Indian context, human endeavour is worthy of appreciation and encouragement, the need to install mechanical graders cannot be over emphasized. Use of machine for grading groundnuts will not only be faster and more reliable but hygienic also. Optical sorting machine grading is not used at present, but colour sorters are now in use in some developing countries to remove aflatoxin-infested kernels. The ISI (Indian Standard Institute) specifications for the HPS are given in the following Table 10.

**Table 10. ISI specifications for groundnut kernels- handpicked selection (HPS).**

| Characteristics | HPS Bold 1 | HPS Bold 2 | HPS Bold 3 | HPS Khandesh |
|---|---|---|---|---|
| Number of kernels per 25 g of the material | Max 40 | 45 to 53 | 54 to 58 | 71 to 75 |
| Broken, damaged and slightly damaged kernels, % by weight (max) | Nil | 1 | 1 | 1 |

Note: The groundnut kernels shall also be free from non-edible oils such as mahua, castor, neem and argemone.

### 2.6.2 Packaging

Pods after grading to the requisite normal size are packed in gunny bags. Seed are seldom shelled and packed because in the kernel (seed) form they lose viability quickly than in-shell (pod) form. Therefore, seed is mainly sold in the form of pods and a small pack of thiram or captan is also kept in the gunny bag with the instruction to treat the seed (kernels) at the time of sowing. Packing for the milling or seed purpose in polyethylene bags is generally recommended, as it helps in maintaining the quality during storage. Similarly in several developing countries the roasted kernels are sold loose in the market, packaging of the confectionery groundnut in polyethylene bags may add to the value and quality of the product in the local markets. Other value-added product should also be sold with proper packaging to maintain the moisture content and the crunchy and crispy nature of groundnuts (Figure 20).

**Figure 20. Confectionery groundnut available in polyethylene packages.**


After filtration groundnut oil is packed in big drums or tanks, and in tins of 15 kg capacity. A part of the population in the developing countries, living below the poverty line, purchase unbottled or unpackaged groundnut oil for their consumption from the market daily. This practice boosts the risks of adulteration. Recently the Government of Gujarat has decided to make packaging compulsory for groundnut oil sold in the market. Even quantities as small as 50g of groundnut oil will require packaging before sale. This will have a major impact on the state's edible oil market, leading to a 10 to 15 percent price increase in this politically sensitive commodity. Similar regulations are desirable from other governments in the developing world.

## 2.7 Storage

Smallholder farmers store groundnut in-shell, in earthen pots, mud bins, bamboo baskets or in other types of wicker receptacles. These containers are often plastered with mud and cow dung with little or no use of pesticides. For long-term storage the containers are sealed with mud after the addition of ashes, ground pepper, dried neem leaves or other local herbs to control storage pests. In Andhra Pradesh groundnuts are stored in big earthen pots and the mouth of the container is sealed with the sand or mud or cow dung. Daily storage of groundnuts in gunny bag is a common practice requiring utmost care to protect the produce from the pests. For consumption and seed purposes, groundnuts are stored for longer periods up to 8 to 10 months. Farmers generally have inadequate facilities and use their houses to keep bags of groundnuts over long periods of time. This finding calls for an effort on the part of governments in the developing countries to improve facilities for storage. Farmer level storage conditions for groundnut in gunny bag is shown in Figure 21.

**Figure 21. Storage of groundnuts in gunny bags under farmers' storage conditions.**

Groundnuts following proper drying are either packed in gunny bags or stored in heaps in big rooms in the farmhouse. Eighty percent of the farm produce reaches the market to be crushed for oil extraction by the millers via the local market or cooperative societies. Due to storage problems, the oil mills also do not store groundnuts for a long time. When pods are stored at ambient farm storage conditions, they interact with the storage humidity (RH percent) and temperatures. At high RH >80 percent and temperatures >40°C the process of ageing accelerates and the kernels start deteriorating.

Groundnut pods are generally stored at the moisture content between 6 and 8 percent. In India summer season groundnut is harvested in the month of May to June, and the environmental RH increases immediately after storage, and may reach up to 80 to 90 percent on the onset of monsoon in the month of June to July. Consequently the pod moisture also increases and may reach between 10 and 15 percent, depending on the RH of storage environment. Pod moisture percent >10 percent is harmful for the maintenance of seed viability and quality. The RH of the storage environment may be reduced with the help of dehumidifiers or use of desiccants like silica gel and calcium chloride (anhydrous or fused). On the other hand the rainy season produce is harvested in the month of October to November, when monsoon resides and the temperature and RH of the storage environment become favourable for the storage of groundnuts. Thus the storage environment between December and March remains quite favourable, under such situations farmers can store their produce in ordinary gunny bags at the ambient storage conditions, provided care is take to protect the produce from the storage pests. It is recommended that the summer season produce either should be processed immediately after harvest or may be stored for 1 to 2 months taking utmost care. For example the produce may be stored in polyethylene bags with desiccant like silica gel or calcium chloride ($CaCl_2$, anhydrous) and sealed.

In the assembling markets, decorticating factories and oil mills, produce is generally stored in the form of pods, either loose or in bags. The period of storage may be very short. Beside storage in godowns, pods are often heaped loose or stacked in bags in the open in places where the risk of damage by rain is minimal. If it does rain, the sacks are covered with tarpaulin. Wooden planks or matting must be arranged on the floor to prevent damage from damp. The pile of bags in the godowns should be kept to 4 to 5 feet below the roof to allow free circulation of air. The period of storage of individual lots in most cases may not exceed two to three months. Storage conditions may very in the terminals markets and ports. At these centres invariably storage is in the form of kernels, which are most often packed in gunny bags. Sometimes, it becomes imperative to store kernels at ports for longer periods, waiting for the shipment, such situations lead to serious damage to the kernels.

Groundnuts are semi-perishable and are subject to quality losses during storage through microbial proliferation, insect and rodent infestation, biochemical changes, i.e. flavour change, rancidity, viability loss; physical changes, i.e. shrinkage, weight loss, and absorption of odours and chemicals. When subjected to suitable storage environments, clean groundnuts can be stored for several years. High moisture and temperature regulates the rate of deterioration of kernels in storage. During shelling serious losses in milling quality may result, if groundnut kernels are dried below 7 percent moisture content (w.b.) or stored at a temperature less then 7°C. Thus, best storage conditions for normal dry bulk storage of unshelled groundnuts is about 7.5 percent kernel moisture content (w.b.) at 10°C and 65 percent RH. If these storage conditions are maintained, unshelled groundnuts can be stored without significant loss in quality for about 10 months (Patee and Young, 1982).

Some groundnut varieties have been noted to have poor storability for example in Gujarat cultivar GG 2 loses its viability rapidly than any other cultivar. The methods of cultivation, harvesting, curing, and post-harvest handling of the groundnuts may affect their storability. In developing countries the conditions of most farmers stock warehouses are not good, practically they don't have the warehouses. The warehouses require ventilation and/or aeration system to help in maintaining the quality of groundnuts. These systems remove excessive heat and moisture, equalize groundnut moisture content and temperature throughout the mass of stored groundnuts and reduce the differences between the ambient and groundnuts temperature. The aim should be to keep the conditions of the air in the pile of groundnuts within the limits and to prevent moisture migration and condensation inside the storage structure. In Ghana mature groundnut kernels, following harvesting and drying are stored in jute bags and kept in barns built of mud or thatch. The major problems in stored groundnuts in Nigeria include weather, insects, rodents, and infestation by toxicogenic fungi. In South Africa the recommended maximum drying temperature is 35°C, however, commercial cultivars react differently to drying temperature. In India groundnuts in-shell and seed of cv. Big Japan and M 13 were stored in polyethylene bags for up to 14 months (Sinha, et al. 1997). Groundnut stored in polyvinyl bag at 7 percent moisture content showed the highest germination. Seed treated with an insecticide/fungicide, were stored successfully for one year without significant loss of viability in laminated polyvinyl bags (Krishnappa, et al. 1998).

Certain factors known to accelerate the ageing process are: i.) soil moisture content during pod development, harvest stage; ii.) drying methods mainly the temperatures during curing of pods, and iii.) ambient relative humidity during storage. Based on these principles a simple and economic storage technology has been developed to prevent the exposure of pods to high humidity during monsoon season. In this technology $CaCl_2$ is used as a desiccant in side a polyethylene-lined gunny bag containing the groundnut pods (Figure 22).

**Figure 22. Storage of groundnuts in gunny bags under farmers' storage conditions.**

The summer season's produce stored with $CaCl_2$ in polyethylene-lined gunny bag showed 80 percent germinability with high seedling vigour, even after 10 months of storage. On the other hand produce stored in ordinary gunny bags without calcium chloride could retain only 10 percent germinability (Nautiyal and Joshi, 1991). Two factors known to influence the preservation of groundnut seed are temperature and relative humidity. To preserve groundnut seed for one year at 21 °C, moisture content of 5 percent or less is necessary. The farmer's stock groundnut may be stored to 8 to 10 percent seed moisture content in mechanically and naturally ventilated miniature metal warehouses for six months.

Rapid loss of groundnut seed viability during storage is a common problem in seed production. It was found that the specific iso-esterases are prone to deterioration during ageing of groundnut seed (Aung and McDonald, 1995). In several developing countries, studies of the farmers stock of groundnut seed showed that improvement in seed quality and farmers` seed management is required immediate attention to maintain healthy seed stock. It is also emphasized that availability of quality seed at the time of sowing is sometimes a problem. If storage facilities are created at the farmers' level or village level and farmers are made aware regarding the benefits of the quality seed this problem may be solved to a certain extent. Thus seed production activity at village level may be advantages over existing centralized large-scale production and procurement by state owned organizations in various developing countries.

High temperature drying i.e. >40°C adversely affects the seed viability and oil quality. Groundnuts for edible or culinary purpose should be kept separately from those required for industrial use, and greater care is necessary to handle and store them. In Gambia for instance, a type known as Philippine Pink, grown especially for edible use, is kept separately in the buying and marketing organization. The smallholder farmers usually produce groundnut for their consumption and store it in mud bins, basket, and earthen pots or in gunny bags for 6 to 8 months. The medium-holder farmers produce groundnut for their consumption as well for the sale in the local market, they mostly store it loose in a room, or bags, metal bins. The millers store the groundnut in gunny bag or large heap in the open courtyard for at least 2 to 3 months. These widely contrasting storage practices may explain the range of storage loss in the developing countries. The type of storage plays a fundamental role in storage efficiency. If a concrete or mud storage structure can absorb water or allow the water vapours to pass through, in the case of a jute bag, the biochemical changes and mould attack are minimal, but the risk of insect infestation increases. Aeration greatly minimizes mould growth, insect activity, and respiration of the seed. Further aeration provides a cooling action and equalizes the temperature through the mass of the kernels stored. Bad odours developed by stored kernels can be easily and effectively removed.

Following are the findings of investigations on various aspects of storage of groundnut under commercial conditions in India (MAD, 1949):

1. All produce intended for storage should be well dried to have not more than 5 percent moisture.
2. Groundnuts always should be stored as pods rather than as kernels.
3. If storage is done as kernels, pods should be decorticated carefully to avoid splits and broken kernels. The period of storage should be reduced to the minimum possible.
4. Storing of kernels on hard floor or hard bedding material and piling of bags to great height should be avoided to minimize caking up of kernels and damage to gunnies. Dry-sand bedding to a depth of about a foot covered by Hessian cloth appears to be best.
5. Produce from the summer crop should not be stored for long period as it deteriorates more rapidly than that from the winter or rainy season crop. The summer produce is best utilized for the crushing for oil.
6. For storing small quantities of kernels, bin appears to be most suitable.

### 2.7.1 Semi-underground storage of farmers' stock groundnut

Throughout history reasonable success has been achieved in storing various foods underground. A small semi-underground warehouse was constructed by waterproofing and placing 7.6 cm thick pre-cast concrete tank 304.8 cm long by 152.4 cm deep in the ground with the top of the tank at ground level. Two courses of 20.3 cm concrete blocks were installed above the walls and the warehouse was covered with sheet-metal gable roof having a 45° slope. The warehouse had a groundnut storage capacity of approximately 10.2 m-3. A fan located in the south gable changed the headspace air once every two minutes. Thermocouple and relative humidity sensors placed at various locations throughout the warehouse indicated temperatures and relative humidity at these locations. Free fatty acid and total carbonyl analyses indicated acceptable quality maintenance in the underground storage and compared with groundnut in conventional storage. Temperatures were more uniform in the underground warehouse than the conventional warehouse (Smith, et al. 1987). Thus this semi-under ground warehouse for storing farmers stock groundnut offer the potential for maintaining quality of groundnut in storage.

### 2.7.2 Durability of farmers' stock groundnut in mechanically and naturally ventilated miniature warehouses

Farmers stock groundnut from the same field dried either 8 or 10 percent seed moisture content were stored for 6 months (October through March) in mechanically and naturally ventilated miniature metal warehouses. The initial temperatures for the 8 percent moisture content groundnut were 2 to 3°C higher than those for the 10 percent moisture content groundnut. This difference was maintained until February. Relative humidity, 10 percent points higher in the 10 percent initial moisture content groundnut began to equilibrate in December and similar buy late January. Final moisture of the groundnut from the two mechanically ventilated warehouses was about 7 percent compared to 7.5 percent in the two naturally ventilated warehouses. Only small changes in total carbonyls and free fatty acids observed during storage in the warehouses and sensory evaluation after storage indicated no significant differences among treatments. No aflatoxin was detected in any seed category before or after storage. Results indicated that quality of farmer's stock groundnut at 10 percent or less can be maintained when stored in a properly constructed and operated mechanically or naturally ventilated warehouse (Smith, et al. 1989).

## 2.8 Processing

### 2.8.1 Chemical composition of groundnut

The world is experiencing a shortage of edible oil and proteins. Groundnut plays a useful role in alleviating these deficiencies as it is a rich source of edible oil and protein. Groundnut has an outer thick woody shell. Inside normally there are 2 or 3 embedded seeds (kernel). The seed consists of 2 cotyledons and the germ covered by an outer thin skin called the testa. The colour of the testa may be red, brown, purple or white depending upon the type and variety. Testa constitutes about 4 to 5 percent of the weight of the kernel. The cotyledons constitute the bulk of the seed in the range of around 92 to 94 percent of the weight. The germ constitutes around 3 to 4 percent of the seed weight. The testa protects the seed against pests and diseases. Cotyledons are the storage organs, which supply food the germ during germination. As a result of these functional differences, the chemical make-up of the parts of the kernel also differ. Composition of groundnuts parts, oil cake and haulms is revealed in Tables 11 and 12.

**Table 11. Chemical composition of kernel (g 100-1 g).**

| Constituent | Testa | Germ | Cotyledon |
|---|---|---|---|
| Moisture | 9.01 | - | 3.9-13.2 |
| Protein | 11.0-13.4 | 26.5-27.8 | 21.4-36.4 |
| Oil | 0.5-1.9 | 39.4-43.0 | 35.8-54.2 |
| Total carbohydrates | 48.3-52.2 | - | 6.0-24.9 |
| Reducing sugar | 1.0-1.2 | 7.9 | 0.1-0.4 |
| Sucrose | - | 12.0 | 1.9-6.4 |
| Starch | - | - | 0.9-5.3 |
| Crude fibre | 21.4-34.9 | 1.6-1.8 | 1.6-1.9 |
| Ash | 1.9-4.6 | 1.9-3.2 | 1.8-3.1 |

Source: Cobb and Johnson (1973), NDDB (1982)

**Table 12. Chemical composition of groundnut shell, haulms and oil cake.**

| Constituent | Percentage |
|---|---|
| Shell | |
| Cellulose | 65.7 |
| Carbohydrates | 21.2 |
| Proteins | 7.3 |
| Minerals | 4.5 |
| Lipids | 1.2 |
| Haulms | |
| Protein | 8.30-15.0 |
| Lipid | 1.39-2.88 |
| Crude fibre | 22.11-35.35 |
| Carbohydrates | 38.06-46.95 |
| Minerals | 9.0-17.04 |
| Moisture | 7.13-10.0 |
| Oil cake | |
| Moisture | 8-10 |
| Oil | 0.7-6 |
| Crude protein | 45-60 |
| Carbohydrates | 22-30 |
| Mineral matter | 4-5.7 |
| Crude fibre | 3.8-7.5 |

Source: Reddy, P.S., 1988.

### 2.8.2 Groundnut quality characteristics

Harvested crop is allowed to dry in the field in developing countries and the vagaries of weather affect the seed and haulms quality. The uses of groundnut are diversified, as are the quality parameters based on these uses. Kernel size is one of the most important factors that decide the quality of groundnuts for table use. Normally cultivars with a hundred-seed mass of 60 g or more are considered as large-seeded groundnut and they are preferred in the domestic and international markets. The percent sound mature kernels (SMK) should be as high as possible, which prompts consumer and producer acceptance. Oval or elongated kernels are preferred over round kernels as mechanical blanching (removal of testa) is easier with the former type. Uniformly-sized kernels are preferred, as they are appealing to the consumer and to the processing industries. Normally, pink or salmon testa colours are preferred over dark testa-coloured seed. At present variegated testa colour is not acceptable for table purposes. However, if variegated groundnut in future is bred specifically for the table purposes with higher sugar content and improved textural quality, the product may attract the international consumer market. Table 13 summarizes seed quality characteristics of the two American standard varieties. This data is provided for the benefit of scientists, traders and producers in the developing countries.

**Table 13. Comparative shelling, oil quality and flavour evaluations of groundnut.**

| Grade Components | Range of parameter |
|---|---|
| Total Shelled Pods (%) | 100 |
| Good Seed (riding 17/64" screen) | 52-71% |
| Good Seed (riding 15/64" screen) | 62-74% |
| Loose Shelled Kernels (LSK) | 0.5-1% |
| Split and Shrunken Seed (%) | 5-9 |
| Pick Outs (%) | 1-7 |
| Shelling Outtern (%) | 72-80 |
| Moisture of Seed (%) | 6.22-6.62 |
| Oil (%) | 48.7-48.8 |
| Oil Colour (Abs 450 mu) | 0.035-0.054 |
| Iodine Value | 94.9-95 |
| Percent Linoleic Acid | 29.6-29.6 |
| Percent Oleic Acid | 50.1-50.8 |
| Organoleptic Score (CLER score) | 58-67 |

*Source: Norden, et al., 1969.*

Edible groundnut has to satisfy very strict standards in West Africa. Some of these quidelines are specific, whereas others lead to an overall improvement of groundnut production. This is particularly true in terms of health pertaining to aflatoxin control and seed technology. Edible groundnut is a driving force and a benchmark for the entire product range. Market and producer demands are concerned with the following:

1. Shelling percentage,
2. Germination capacity,
3. Prevention of aflatoxin,
4. Seed and pod size and shape,
5. Skinning and splitting performance, and
6. Organoleptic qualities after roasting.

Reliable and reproducible tests have been developed to measure the above parameters. Current research in the Savannah region of West Africa is helping to develop post-harvest technology for more effective improvement of groundnut products. Disinfecting stocks, refrigerated seed storage and vacuum storage of seed have been developed. Industrial production of ready-to-use seed will be undertaken in Senegal soon. Action is being taken on technological screening, packing and storage procedures, skinning, ready-prepared seeds, electronic sorting among other industrial tasks. Mixed research and development operations are underway, notably in seed production and processing (Schilling and Misari, 1992).
The quality of Indian stored groundnut kernels is considered low due to higher percentage of free fatty acids. Free fatty acids tend to accumulate during storage and transport. The practice

of wetting pods prior to decortication or shelling accelerates the development of free fatty acids. If there is damage to the kernels in shelling, free fatty acids develop at a faster rate. Shrivelled and immature kernels also contain more free fatty acids than fully developed kernels. Free fatty acid contend may be reduced by harvesting mature pods, drying the produce properly, careful decoration to avoid breakage and splits, better storage and avoiding unnecessary handling.

***Relationship between blanching quality and seed physical characteristics***

The blanching process that primarily involves the removal of skin (testa) is a major step in processing groundnuts for many edible end products. Several factors affect the blanching quality of groundnut. Grain hardness, grain volume and flotation indexes are considered important factors that could influence the blanching quality of groundnut genotypes. Methods of determination of seed hardness using Instron Food Testing Machine (IFTM) and floatation index by gravimetric procedure have already been standardized. At ICRISAT effects of temperature of heating on seed hardness (texture) were examined, it was observed that groundnut heated at 200°C for 8 minutes is suitable for the testing the texture and blanching quality of different genotypes (ICRISAT, Annual Report, 1995).

***Oil quality***

At ICRISAT screening groundnut germplasm has demonstrated the large range in the oil content (31 to 55 percent) with an average of 50 percent. The chemical and physical properties of groundnut oil as compiled by Cobb and Johnson are shown in Tables 14 and 15. The stability or shelf-life of oil is important globally, but deserves more attention in developing countries where storage conditions are not ideal. A major influence on oil storage stability is its fatty acid composition, especially the proportion of unsaturated fatty acids. Cultivar, maturity stage and environmental conditions influence fatty acid composition of groundnut oil. Groundnut oil is relatively more stable than safflower and sunflower oil which both have higher content of polyunsaturated fatty acids (PUFA). However about 80 percent of the lipid in groundnuts is unsaturated, with about 50 percent monounsaturated fatty acids and about 30 percent polyunsaturated fatty acids and consequently groundnut oil has a longer shelf-life. It is light yellow with slightly nut-like flavour and low viscosity fluid. Unsaturated lipids are susceptible to oxidation and are indicated by its relatively high iodine value and refractive index. All cultivars contains 12 fatty acid, 3 of which present in amount exceeding 5 percent of the fatty acid composition i.e. palmitic, oleic and linoleic acids. Fatty acid composition of groundnut cultivars at ICRISAT showed that the oleic (O) to linoleic acid (L) ratio (O:L) varied between 0.91 and 1.23 among various cultivars and is an indicator of oil stability. A minimum O: L ratio of 1.6 has been recommended for groundnut by food processing industry purchasers in the United Kingdom (Jambunathan, 1991). Though scientifically there is no definite basis for this 1.6 value. The primary dietary essential fatty acid for man is linoleic acid. The amount of dietary linoleic acid found to prevent both biochemical and clinical evidence of deficiency in several animal species and humans is 1 to 2 percent of dietary calories.

**Table 14. Fatty acid composition of oil.**

| Fatty acid | Range | Average |
|---|---|---|
| Saturated fatty acids | | |
| Myristic (C 14:O) | 0.01-0.23 | 0.09 |
| Palmitic (C 16:O) | 9-24.9 | 12.6 |
| Stearic (C 18:O) | 0.0-5.5 | 1.7 |
| Arachidic (C 20:O) | 2-10.2 | 4.2 |
| Behenic (C 22:O) | 0.7-3.9 | 2.1 |
| Lignoceric (C 24:O) | 0.0-2.8 | 0.3 |
| Unsaturated fatty acids | | |
| Palmitoleic (C 16: 1) | 0.6-3.3 | 1.4 |
| Oleic (C 18:1) | 38.7-56.2 | 47.9 |
| Linoleic (C 18:2) | 16.2-38.4 | 29.9 |
| Eicosenoic (C 20:1) | 0.74-2.27 | 3.9 |

**Table 15. General properties of groundnut oil.**

| Parameters | Range |
|---|---|
| Melting point | 0-3°C |
| Iodine value | 82-106 |
| Thiocyanogen value | 58-75.5 |
| Saponification value | 188-195 |
| Acetyl value | 8.5-9.5 |
| Reichert-Meissl value | 0.5 |
| Polenske value | 0.5 |
| Free fatty acids | 0.02-0.6% |
| Unsaponifiable matter | 0.3-0.7% |
| Refractive index (ND20) | 1.4697-1.4719 |
| Density at 15°C | 0.917-0.921 |
| Density at 25°C | 0.910-0.915 |
| Mean viscosity at 20°C | 71.07-86.15 centipoises |
| Titer | 26-32°C |
| Heat of fusion | 21.7 cal/g (unhydrogenated) and 24.7 cal/g (hydrogenated) |
| Colour: Visual | Light yellow |
| Lovibond, 1 in. | Yellow: 16-25; Red: 1-2 |
| Taste and odour | Slightly nut-like |

*Source: Cobb and Johnson (1973), NDDB (1982)*

The committee on Dietary Allowances (1980) believes that in view of the possible hazards of high intake of polyunsaturated oils an upper limit of 10 percent of dietary energy as polyunsaturated fatty acids is advisable (FAO, 1977). Groundnut oil, due to its lower linoleic acid content (33.2 percent of total fatty acids) than corn oil (58 percent), safflower oil (79.5 percent) or mixtures of soybean oil and cottonseed oil (46.7 percent), satisfies the recommendation of the Committee on Dietary Allowances. The ratio of ά-tocopherol to polyunsaturated fatty acids could be used as a measure of the adequacy of dietary Vitamin E and that ratio should be 0.6 or higher; later on a ratio of 0.2 has been suggested to be satisfactory indicator of Vitamin E adequacy (Pattee and Young, 1982).

The enhanced stability of oils obtained from runner types of groundnut is mainly due to their higher linoleic acid and slightly higher tocopherol contents, there is some evidence that crude groundnut oils contain some non-tocopherol antioxidant and/or synergist (Fore, et al., 1953). The stability of oil in groundnut-based foods may be increased by low temperature and humidity storage, packaging under vacuum or inert gas and addition of antioxidants to these foods (Shewfelt and Young, 1977). It is also suggested that the selection or development of raw groundnuts with low levels of linolenic acid is also a means for extending product shelf-life. A low O/L ratio may result in rancidity because of release of free radicals and peroxides. The stability or shelf life is important in both developing and developed countries, but deserves more attention in developing countries.

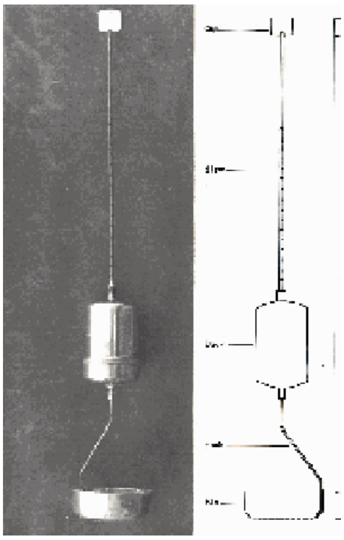
The oil from fresh and ripened kernels should have less than 1 percent free fatty acids. A higher concentration indicates damage to the tissues especially during storage. The ά- and β-tocopherols (Vitamin E) are nutritionally important both in the seed for direct consumption and in oil. The aflatoxins do not become a major hurdle in the oil industry as they are associated with the protein bodies and are easily removed by proper filtering. With solvent extraction this problem could totally be overcome. However, there are few reports that oil not properly filtered contains some traces of aflatoxin.

Fatty acid composition is very vital for oil quality and shelf-life of the stored products. To develop a rapid and cost-effective method for determination of fatty acids, three methods were compared at ICRISAT i.e. microanalytical, direct transmrthylation and standard FAME (fatty acid methyl ester) method. For screening large numbers of samples for O/L ratio, the direct transmethylation method could be used. This method is rapid and less expensive than the other two methods. Thirty-five mutant lines obtained by the use of ethyl methane sulfonate (EMS), including their parents (standard cultivars) as controls, were analyzed for oil, sugars, protein and fatty acid composition. The O/L ratio of these lines ranged between 0.99 and 3.06 and some mutant showed high O/L ratios. The protein content of these lines also varied markedly from 15.7 to 29.1 percent. Preliminary results indicated that short-duration genotypes had lower oil (40.0 to 50.9 percent) and higher protein content (20.4 to 29.5 percent) when compared to long-duration types. It was observed that starch content decreased and protein content increased, when plants were exposed to low root temperature and high pod temperature (ICRISAT, Annual Report, 1996).

A simple device to determine oil content of groundnut seed

Oil content and specific gravity of groundnut kernels have an inverse relationship. Utilizing this principle, an arachilipometer was developed to determine the oil content of groundnut samples (Figure 23). Compared to NMR spectrometry, which is widely used to determine oil content in groundnut, the arachilipometer technique is very simple and economical (Misra and Yadav, 1997).

**Figure 23: Arachilipometer developed and designed and developed at NRCG.**



**Nutritive quality**

Proteins: There is growing demand for protein throughout the developing world. Groundnuts are good sources of proteins and have high-energy value (average 564 calories/100 g seed), thus in the developing countries groundnut is very important crop to meet the demand of oil and protein in daily diet. Groundnut germplasm collection at ICRISAT demonstrated protein content ranges between 15 to 34 percent depending upon the cultivar, location and year. The genetic variability in the mechanism of protein synthesis during development of seed suggests that there is potential for the development of groundnut cultivars possessing nutritionally desirable proteins by manipulating protein synthesis.

The major proteins are arachin and conarachin. Groundnut proteins undergo changes due to heating or roasting of the seed and removal of the oil from the seed by solvent extraction. On heating the antigenic structure of the major reserve protein α-arachin should remain intact in groundnuts and groundnut products, when heated during processing. Generally this reserve protein remains unchanged even heating for 1 hour at 145°C (Jambunathan, 1991).

Amino acids: The contents of amino acids in groundnut seed very according to type of groundnut, cultivar, location, year and length of maturation period of seed. With advancing the maturity of groundnut seed, amount of free amino acids decreases, while protein content increases. Arginine undergoes the greatest reduction in content upon maturation; thus it is proposed that argenine content could be used to determine the degree of maturity of groundnut seed and also suggested that free amino acids can be incorporated into protein at different rates. Thus high-protein cultivars contained higher amounts of free amino acids than the low protein cultivars, during seed maturation. This implies that certain polypeptides or proteins with a specific amino acid composition are selectively deposited in the maturing seed at different time intervals and at different rates among the various groundnut cultivars. Conarachin proteins that are high in essential amino acids were observed to be deposited during early stages of maturity while the arachin protein that are low in essential amino acids deposits during the later stages of maturation (Basha, et al., 1980).

According to FAO (1970), the limiting amino acids in groundnut are lysine and methionine, but there are reports, which indicate that lysine, metheonine and threonine are equally limiting (Miller and Young, 1977). Tryptophan has also been included as a possible limiting amino acid in groundnut (Milner, 1962). Much published information is available on the amino acid composition of groundnut (FAO, 1970). The ranges reported for the amino acids, lycine, methionine and threonine as per cent of protein are 2.1 to 3.9, 0.35 to 1.0 and 2.3 to 2.7, respectively.

Carbohydrates: In groundnut sucrose is the major sugar measuring from 2.86 to 6.35 percent among different cultivars, followed by stachyose and raffinose (Pattee, et al., 1974). Slight loss in sugar contents is found upon roasting and there is about 15 percent loss in sucrose and inositol and about 33 percent loss in glucose and fructose. Please see Table 16 and 17. Fructose and glucose occurs in small concentrations, but it was found that the sucrose undergoes hydrolysis to the two monosaccharides, fructose and glucose, which in turn reacts with some free amino acids to form the characteristic flavour of roasted groundnuts.

**Table 16. Effect of roasting on sugar content (mg g-1 fat-free groundnut meal) of Spanish type groundnut.**

| Sugar | Raw | | Roasted | |
|---|---|---|---|---|
| | Mean | Range | Mean | Range |
| Fructose and or/ Mannose | 2.7 | 1.6-3.3 | 1.8 | 1.4-2.0 |
| Glucose | 1.9 | 1.7-2.1 | 1.3 | 0.9-1.5 |
| Inositol | 1.3 | 1.0-1.6 | 1.1 | 0.7-1.6 |
| Sucrose | 149 | 109-197 | 125.3 | 107-161 |

*Source: Mason, et al., 1969*

Minerals and vitamins: Groundnut contains much more potassium than sodium and is good source for calcium, potassium, phosphorous and magnesium. Three forms of vitamin B1 exist in groundnuts such as thiamine, thiamine-mono-phosphate and thiamine-pyrophosphate. Thiamine occurs in groundnut seed at a concentration of about 1mg/100g. Each ounce of groundnuts can meet the daily dietary requirement of several important vitamins and minerals. Groundnuts are rich source of agrinine (about 3.5 percent), which helps in wound healing and immunity. Vitamin E, selenium and zinc are regarded as antioxidants, which protect body tissues from free radicals. Incidentally, National Aeronautics and Space Administration (NASA) of the United States of America has selected groundnut as a possible food for the Advance Life Support system for extended space missions.

**Table 17. Nutritional characteristics of groundnut kernel.**

| Characteristics | Content 100-1 g | | |
|---|---|---|---|
| | Raw | Roasted | Defatted flour |
| Calories (g) | 564.0 | 582.0 | 371.0 |
| Proteins (g) | 26.0 | 26.0 | 45.0 |
| Fat (g) | 47.5 | 48.7 | 5.8 |
| Carbohydrate (g) | 18.6 | 20.6 | 30.0 |
| Calcium (mg) | 69.0 | 72.0 | 127.0 |
| Phosphorus (mg) | 401.0 | 401.0 | 800.0 |
| Iron (mg) | 2.1 | 2.2 | 3.5 |
| Thiamine (B1) (mg) | 1.14 | 0.32 | 0.75 |
| Riboflavin (B2) (mg) | 0.13 | 0.13 | 0.35 |
| Niacin (mg) | 17.2 | 17.2 | 2.5 |

*Source: Burn and Huffimann, 1975*

***Sensory quality***

Sensory quality is the summation of all physical and chemical characteristics of edible seed or their products that influence human senses and result in acceptability judgements by the consumer. Several volatile components isolated from roasted groundnuts were described as contributors to "nutty" odour or a "nut-like". Some of which are 2-crotolsctone, 3-methyl-2-carotolactone, 5-hydroxy-4-nonenoic acid, pyrazines, 2-isopropyl-4, 5-dimethylthiazole and 2-propyl-4, 5 diethylthiazole, most of them have been characterized as having green nutty aroma (Ho, et al., 1982). Several flavour evaluation lies on the use of human subjects as the detectors of sensors of food-flavour. For roasted nuts, the Quality Committee of APREA (1971) has adopted the CLER flavour score method. Twenty roasted half-seed are tested individually and a score is assigned to each seed. The total of these scores will represent the treatment flavour score. It is suggested that standardized sensory methodology should be followed to evaluate the flavour of food products. Such methodologies are outlined in several publications (Rodriguez, 1976; Larmond, 1977).

Studies in Japan showed a negative correlation exist between whole pod mass and eating quality. For the same level of yield varietal differences in eating quality exist, which enables the selection of a high-yielding variety with better eating quality. The correlation between sweetness and eating quality and seed hardness and eating quality increases as sweetness and seed hardness is augmented. On the other hand, eating quality is more closely correlated with sweetness. The correlation between external quality and eating quality was so low that good external quality as determined by pod and seed is not necessary associated with good eating quality. Based on the studies it was suggested that the sucrose content and hardness of the seed, which are most closely related to the eating quality, could be used as indicators for the evaluation of the eating quality in tests (Gocho, 1992).

Seed hardness decreased with the delay in harvesting time and selection for seed hardness should be determined 85 days after flowering. Sucrose content of seed decreases when the harvesting time was delayed. The eating quality also shows a similar trend. Therefore, sampling time for this character is very important. The sucrose content should be analyzed at the optimum sampling time of the lines, based on the harvesting time, namely 75 days after flowering for early-maturing varieties, 80 to 85 days for medium maturing varieties and 95 days in late-maturing varieties (Pattee and Young, 1982).

### 2.8.3 Oil processing

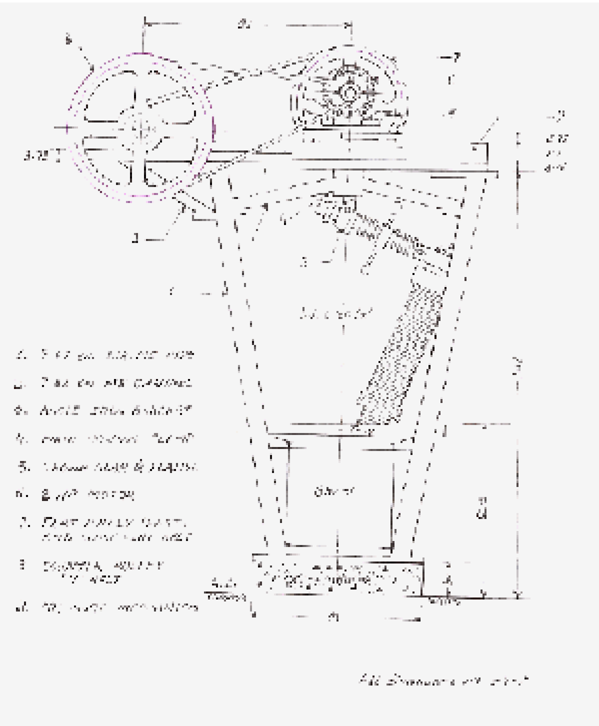
Food processing constitutes a major economic sector in developing countries, especially in urban areas where low-income families are not equipped to carry out the basic processing of agricultural and animal products. Food processing also allows the consumption of seasonal agricultural products over the whole year and therefore minimizes the important price fluctuations resulting from the periodic gluts and shortages of the fresh products. In addition, food processing could generate substantial foreign exchange. Thus extraction of oils from the kernel of groundnuts is a well-established industrial activity in a number of developing countries. Since the early 1950s, most groundnut-growing countries have favoured indigenous oil extraction in preference to the export of kernels. They have thus support the setting up of factories for this purpose, which, are large-scale plants situated in or near urban areas. Commercially oil is extracted from groundnut by three methods including hydraulic pressing, screw pressing and solvent extraction.

***Power ghani mill***

The ghani mill originated from India where these indigenous oil crushers have been improved over the time. The original animal-powered ghani consists of a wooden mortar and a pestle.

The mortar is fixed to the ground while the pestle attached to one or a pair of bullocks (or buffaloes or camel) is rotated in the mortar where the kernels are crushed by the generated fraction and pressure. The oil runs through a hole at the bottom of the mortar while the residue or cake is scooped out. Depending on the size of the mortar and the type of kernels, an animal-powered ghani can process 5 to 15 kg of kernels at a time. An improved version of the ghani has been developed in India, known as the Wardha Ghani (see Figure 24). It is larger as well as more efficient than the traditional ghani and can crush charges of kernels of up to 15 kg in approximately 1.5 hours or close to 100 kg per day. Two or three family members are required for the operation of the mill. It is essential that one of the workers should have the necessary qualifications for running, maintenance and repair of the ghani unit. An engine-powered ghani is now replacing, to a large extent, the bullock-powered ghani. In this type of ghani, either or both the mortars and pestles are made of cast-iron. Power ghanis are often work in pairs. The crushing capacity of a two-ghanis unit is approximately 500 kg to 600 kg of kernels per day.
Some of the technical advantages of the power ghanis, as compared to bullock-powered ghanis include a higher oil extraction rate per unit of raw materials representing an increase of approximately 1 to 2 percent of the extraction rate. There is a higher output per unit of time and less space is used than in the case of bullock-powered ghanis. The quality of the oil produced by the power ghanis is identical to that produced by the bullock-powered ghanis. Power ghanis are now increasingly replacing bullock-powered ghanis (ILO, 1990).

**Figure 24: Line diagram of Wardha Power Ghani.**



Improved power ghanis have oil extraction efficiency, which fairly close to that of small-scale expellers and often constitute a viable alternative to the latter, especially in rural areas. While this has been the case in India and in a number of Asian countries, there is no guarantee that ghani mill meet the same approval in other developing countries. For example, the introduction of ghani in Tanzania has met with little success. It is therefore, important to analyze all the requirements for the successful adoption of ghani mills prior to investigating in such units. For example it is important to investigate whether qualified labour is available in ruler areas, whether the miller or local mechanics can carry out the maintenance of ghani without much difficulty and whether power ghanis may be manufactured locally or must be imported. A large number of designs of powered ghanis have been developed and marketed in India. The detailed information regarding the drawings and name and addresses of manufacturers may be obtained by writing to: Appropriate Technology Development Association, P.O. Box No. 311, Gandhi Bhawan, Mahatma Gandhi Road, Lucknow-226001, India.

***Oil extraction by pressing***

The unit is a double ghani-mill, powered off a single 3-hp motor. Each ghani takes a charge of about 35 kg, which is processed in approximately one hour by the rotary movement of the iron pestle in the bowl. Thus such a unit may process 560 kg of kernel per day. Separate engines may also power the two ghanis. In this case, 2-hp motors are needed. The pestle in power ghanis rotates at approximately 10 to 12 revolutions per minute as compared to 3 to 5 revolutions for bullock-powered ghanis.
Oil filtration: To remove small impurities, oil must be filtered using an ordinary cloth stretched over a frame onto a tank of sufficient capacity. The filtered oil should be left in the tank for a few hours in order to allow the settling down of any fine impurities. The oil than is transferred into tins or bottles with a funnel from a tap on the tank. The tap should be attached over the sediment layer. The cake can be removed from the ghani manually. It may need little or no further breaking-up. The broken up cake meal can be loaded into bags manually. In general, the cake may spoil rapidly after a few days, unless it is properly treated, packaged and stored.

***Advantages and disadvantages of ghani crushing***

When ghani crushing was widespread, fresh oil was in greater demand than it is today. Flavour, which was traditionally an important attribute of all oils, was best in oils produced from mild ghani crushing. Since vegetable oils are naturally sterile, problems of hygiene in ghani oil are unlikely. Ghani cake is also known to be exceptionally hard and dry and is not prone to mould infestation unless inadvertently wetted. However, the ghani has disadvantages, which are mainly economic in nature. Traditional ghanis have a maximum capacity of about 50 kg per day and modern powered units only about twice that much. As a result, running costs are disproportionately high. If animals are used, they need to be trained and they are expensive to feed. Artisan training is also essential. Ghani oilcake as pressed out of the unit after crushing is externally hard and is not accepted by the trader for further solvent extraction, as are expeller oilcake (Achaya, 1993).

***Baby expeller mills***

The baby expeller mills as defined in the joint memorandum of International Labour Office (ILO) and the United Nations Industrial Development Organization in 1990 have 45 to 55 kg per hour capacity. Therefore, by working only a one-day shift, as is normal for small plants, the unit can process between 350 and 450 kg of raw material per day. In a few cases such units do work 2 or 3 shifts per day and may then process up to one tonne of raw materials. Before crushing the seed remedial drying may be carried out in the open air or under a covered shade in case of adverse weather conditions. A drying ground of approximately 20 m2 is sufficed. This mill may use a crusher of the swing beater type with a capacity of 100 kg of material per hour, a 2-hp power requirement and revolving at 1 400 rpm. The seeds can be heated in open pans over enclosed fireplace to ensure fuel economy. The raw materials may be mechanically stirred through, for example, a linkage to the expeller or crusher drive. The length of time required is about 20 to 30 minutes and temperature 60 to 90°C. Trial and error will show the best conditions in terms of oil yield and quality. Cooking or scorching of seed is needed for three reasons: to facilitate oil extraction, to lower or increase the moisture of seed and to reduce the wearer in the screw press. The best temperature and moisture content depends on the extraction system, however the temperatures attained during cooking should not exceed 120°C as otherwise the protein quality may be adversely affected. In general, the required cooking temperature is a function of the cooking time, the type of oil extraction technology, the moisture content of the row material and the type of seed. The cooking or scorching of seeds should be carried with care in order to avoid the deteriorating groundnut kernels. Overheating reduces the oil extraction rate and yields lower quality oil. Since small rural processors neither may nor afford scorching equipment with automatic control of temperature and moisture of the material, they should arrive at the right cooking conditions through learning and experience.

Oil extraction by pressing: Pressing can be achieved a single, duo or duplex expeller. Their drive can be provided by either an electrical motor or via a pulley and v-belt from a separate diesel engine. Various specialist manufacturers, notable in Japan and in India, produce small capacity expellers. When using a single expeller, the decision on whether to pass the seed once or twice should be based on economic considerations. A second pressing raises the oil extraction rate and therefore, yields additional revenues, but also increases processing costs. Thus, a second pressing is justified only when the increase in revenues is at least equal to the increase in cost. In general, at relatively low extraction rate of small expellers, small rural mills in developing countries find it profitable to press the row materials twice, the first time at low pressures and therefore, high hourly output and the second time at higher pressure through an adjustment of the choke.

The extraction of groundnut oil in small expellers is a highly skilled job as it is necessary to add groundnut shells to the kernels in order to prevent the forming of groundnut butter. The adding of shells is necessary because groundnut kernel unlike copra have little fibre. The need for skilled labour should therefore be taken into consideration while choosing among various types of expellers. Expellers require periodic maintenance and repairs, the principal wearing pieces being the liner bars, the worms and the distance pieces. The periodicity of maintenance and repairs is a function of the rate at which the abrasive action of the row materials and that of foreign matter i.e. sand, pieces of iron wear the above piece of the equipment. The abrasive action of foreign matter is particularly harmful and can considerably shorten the life of various parts of expellers.

Filtration: Alternatively and whenever it is economically feasible, the mill may use a small chamber filter press with 10 plates of 18 x 18 cm, with attached oil pump. The pump makes 170 rpm and has a power requirement of 0.5 hp. Such a press may process up to 50 litres per hour and should therefore be sufficient for the filtering of the daily out put of oil. Filtration takes place through paper and filtre cloth. The mill owner should have the necessary skills for the running of the equipment, as well as for maintaining and repairing the latter. The daily out put of oil is 156 kg and cakes 215 kg. Two or three family members should suffice for the running of the unit. The mill owner should have the necessary skill for the running of the equipment, as well as for maintaining and repairing (ILL, 1990).

***Solvent extraction plant***

Even the most perfect expeller leaves at least 6 percent of the oil in the expeller cake. It is possible to recover these losses using a solvent extraction plant and can reduce the residual oil in cake to less than 1 percent. A major drawback of this process, especially in view of the bias of the memorandum towards small-scale production, is that it is by nature suited to large-scale extraction. The range of production leaves employed in solvent extraction plants is between 50 to 200 tonnes per day. Other drawbacks include high investment costs, the need for highly skilled labour, low employment generation and danger of explosion if the plant is not kept in perfect conditions. While solvent extraction plant may not constitute a viable rural industry, a number of these plants may be profitably established for the processing of both oil seeds and the cake produced by small oil extraction units. This will however, require a good cake collection system and a sufficient supply of oil seeds in order to maintain the solvent extraction plant running at sufficiently high capacity utilization rate.

***Oil in human consumption***

Groundnut oil is used primarily as a cooking and salad oil. Small quantities of groundnut oil are used in the manufacture of shortening and margarine. Groundnut oil is excellent fat for pan-frying or deep fat frying. Pastries shortening, oleomargarine, mayonnaise, salad dressing and other food products can be easily made with this bland vegetable oil. For use in mayonnaise, it should retain its natural yellow colour, for oleomargarine, it should be colourless, for shortening and other plastic fats, for all purposes it should contain an antioxidant. Groundnut oil is also marketed as crude oil for soaps and detergents. It forms the base for many face creams, shaving creams, hair lotions and other cosmetics because it is believed to energize the skin. It is used extensively for massaging polio patients. It is also used as a carrier of adrenaline in the treatment of asthma and other ailments.

Adequate amounts of dietary fats are essential for health. In addition to contribute to meet energy needs, intake of dietary fat must be sufficient to meet requirements for essential fatty acids and fat-soluble vitamins. The minimum intake consistent with health varies throughout a person's life and among individuals. Adequate intake of dietary fat is particularly important prior to and during pregnancy and lactation. Increasing the viability and consumption of dietary fats is often a priority for overcoming the problems of protein-energy malnutrition. The role of dietary fats and oils in human consumption is one of the most important areas of concern and investigation in the field of nutritional science. The findings of investigations on this subject have wide-ranging implications for consumers, healthcare providers and nutrition educators as well as food producers, processors and distributors. New evidence concerning the benefits and risks associated with particular aspects of dietary fat is constantly emerging in both the scientific literature and the popular media. At the invitation of FAO and the World Health Organization (WHO), an international group of experts in nutrition, public health, food science and technology gathered in Rome in 1993 to consider the latest scientific evidence about dietary fats and oils. Following are the general conclusions and recommendations of the expert consultation on fats and oils in human nutrition (FAO, 1994).

- For most adults, dietary fat should supply at least 15 percent of their energy.
- Women of reproductive age should consume at least 20 percent of their energy from fat.
- Concerted efforts should be made to ensure adequate consumption of dietary fat among populations where less than 15 percent of the dietary energy supply is from fat.

Excessive dietary fat intake has been linked to increased risk of obesity, coronary heart disease and certain type of cancer. The mechanisms by which these are linked are complex, varied and in many instances not clearly understood. Elevated levels of serum cholesterol and low-density lipoprotein (LDL) constitute major risk factors for atherosclerosis and coronary heart disease. The degree of risk for these and other factors may vary according to, inter alia, type and level of fatty acid intakes, percentage of energy from total fat, dietary cholesterol, lipoprotein levels, intakes of antioxidants and dietary fibre, activity levels and health status. Low fat diets are often lower in cholesterol and higher in antioxidants and dietary fibre. Among adults, there are no nutritional advantages in consuming high fat diets once essential energy and nutrient needs are met.

### *Anti-nutritional and other factors in groundnut*

Lusas (1979) has briefly reviewed various anti-nutritional factors present in groundnut. Trypsin inhibitor activity in groundnuts has been reported as one half to approximately one fifth of the activity found in soybeans. Trypsin inhibitor activity in groundnut is significantly enough to cause pancreatic hypertrophy in rats receiving 15 percent of protein intake from groundnuts. Lectins shown to possess a remarkable array of biological activities have been found in groundnuts. An interesting aspect of the lectins in groundnut is that, roasting of groundnut does not destroy the lectins. Oil seed proteins constitute the most highly allergenic food groups. Groundnuts also have been shown to be highly allergic and shown some hypersensitivity reactions in children. Groundnut oil has been attributed to contain potent anti-inflammatory compounds, however, Calloway, et al. (1971) observed that groundnuts are absolutely non-flatulent. Later on varietal differences were noticed for the differences exist in groundnut in their ability to cause flatulence. In this connection, the consumption of new raw groundnuts is not advisable; groundnuts always should be consumed fried, boiled or roasted. Plant breeding programmes should also focus on developing varieties of groundnut with minimal content of allergenic proteins and antinutritional factors.

### *Groundnut oil and atherosclerosis*

The atherogenecity of groundnut oil is well established, as is the fact that the structure of the component triglycerides of groundnut influences its atherogenecity. It is also atherogenic in the rabbit and rhesus monkeys. This property is not related to the degree of unsaturation of its component fatty acids. Some studies suggest that the atherogenic potency may be due to the triglycerol structure of the groundnut oil. If the atherogenic property is indeed due to the triacylglycerol structure, there seems to exist some genetic potential among cultivars for development of non-atherogenic lines of groundnut.

## 2.8.4 Secondary products

### *Boiled groundnuts*

Newly harvested groundnut pods are boiled or steamed in East and Southeast Asia before they are eaten as a vegetable. On a commercial scale, the boiled pods are dried, packed in airtight plastic bags and sold. Sweet-tasting Valencia types with 3 to 4 seeded pods; tan-rose or tan coloured seeds with high protein and low oil content are the most preferred. Unshelled immature pods can also be boiled in medium brine and eaten fresh or alternately canned and frozen and marketed commercially. At ICRISAT groundnut germplasm was screened for the boiling type of groundnuts with three controls, JL 24, Gangapuri and TMV 3. Six germplasm accessions identified were comparable to JL 24 and Gangapuri for shelling percentage, 100-seed mass, oil and protein content, O/L ratios and polyunsaturated/saturated acid ratios. Some lines significantly out yielded TMV 3, which has been released as Khon Kane 60-2 for boiling purpose in Thailand.

***Roasted groundnuts***

**Figure 25: Fresh or dried groundnuts are roasted.**

Groundnut is roasted either by applying dry heat (see Figure 25) or using some vegetable oil. Mature groundnut can be soaked in brine and subsequently roasted. Dry roasted groundnut can be used in the preparation of groundnut butter, confectionery or bakery products. Roasting reduces the moisture content, develops a pleasant flavour and makes the product more acceptable for consumption. The reduction in moisture during roasting prevents moulding and reduces staling and rancidity.

It is important to note that excessive heating during roasting lowers the nutritional quality of proteins. Roasted groundnuts are ground into a paste and mixed with honey and cocoa in South America. A considerable amount of raw groundnut paste is made in South Africa near Cape Town and used as a spread on bread.

***Salted groundnuts***

Salted groundnuts are very popular in Western India and prepared by soaking the groundnut kernels (HPS) in water with 4 percent common salt (NaCl) solution for 12 hours (please see Figure 26). Soaked kernels are dried and roasted with sand. If the skin is pealed off and the roasted kernels are packed in attractive packs it may add to their value. Kernels like these are sometimes served on Indian AirLines flights.

**Figure 26: Salted groundnuts, very popular in West India, are being processed.**

***Frozen unshelled groundnut product***

Quick-freezing and low temperature storage technique is widely used for food processing keep freshness and quality of the product. This technique was applied to fresh, unshelled groundnut to develop a new type of product, which could maintain fresh taste and nutritive values even after several months of storage. Immature pods were harvested around 10 to 20 days before full maturity, washed and steamed at 105°C for 5 minutes to stop enzyme activity. After vacuum packing (at -760 mm Hg for 10 min) in 0.08 mm polyvinyaldichloride film, the pods were immediately frozen groundnut investigated after 2 months of storage and compared to those of conventionally dried groundnuts. When thawed after 2 months storage, the kernels were very palatable with softness and fresh taste. This study suggested that frozen groundnut can be consumed after the steaming and freezing technique described above. However, such groundnut will require transportation under cold storage to deliver this product safely to consumers.

***Groundnut milk***

Groundnut milk can be prepared by soaking kernels in 1 percent sodium bicarbonate ($NaHCO_3$) solution for 16 to 18 hour, drain off the water and grind the kernels in aqueous medium. Steep the wet mass for 4 to 5 hour and filtre through cheesecloth to remove the product. In India groundnut milk called Miltone® is a commercial reality. Miltone® consists of groundnut milk extended with buffalo milk. Groundnut milk can be used in the preparation of yoghurt-like products, ice cream and other products. Following steps may be followed to prepare groundnut milk.

1. Shelled groundnuts
2. Add groundnuts to boiling water, remove from heat and let soak for 7 minutes
3. Drain, remove skins, soak the cotyledons in 2% $NaHCO_3$ overnight
4. Rinse cotyledons with tap water, blend in warming blender with water (1:5 w/v) for 4 to 5 minutes
5. Filtre the homogenate through 4 layers of cheese cloth
6. Add whey powder to the filtre at 4% level (w/v), mix thoroughly for 1 hour and boil for 10 minutes
7. Groundnut milk

*Source: Singh, B. 1992, ICRISAT*

***Preparation of mishi***

Mishi is concentrated, spiced yoghurt prepared from whole milk in Sudan and usually consumed along with bread. Mishi can also be prepared from peanut milk by following the steps:-

1. Groundnut Milk
2. Boil for 3 minutes, cool to 45°C and inoculate with yoghurt culture (1:1 mixture of Lactobacillus bulgaricus and Streptococcus thermophilus grown in whole milk for 6 hours) at 5% level
3. Incubate at 45°C for 16 hours
4. Add spices (garlic 1.7%, whole cayenne pepper-0.8%, whole black pepper-0.15%, ajwan - 0.15%)
5. Refrigerate the mix for 24 hours
6. Drain whey through 4 layers of cheese cloth
7. Add salt at 1% level
8. Mish

*Source: Singh, B. 1992, ICRISAT*

***Groundnut-based yoghurt***

Groundnut yoghurt may be prepared by the pasteurization of groundnut milk containing 5 percent lactose. After cooling inoculate with yoghurt culture and incubate at 37°C for 4h. Final product before consumption may be refrigerated.

***Groundnut bars***

The formulation contains 72 percent finely ground groundnuts, 12 percent maltose syrup, 9.5 percent finely ground sugar, 3 percent roasted desiccated coconut, 2 percent finely ground rice, 1 percent roasted sesame (Sesamum indicum) seed and 0.5 percent salt. Mix all the ingredients at 60°C and pass through a peanut-butter mill. Press the mixture into a rectangular-shaped mould.

***Protein isolates***

The technology now exists for the production of groundnut proteins in the form of concentrates and isolates, which are acceptable for human consumption. Groundnut protein isolates are akin to soy protein isolates (please see Figure 29). Defatted materials obtained from oil extraction processes may be soluble in neutral to base reaction washes to extract much of the protein which subsequently separated from the whey formed by reducing the pH to isoelectrical levels. Isolates once separated are neutralized with alkali and may be spray dried.
Groundnut cake or meal can be used for human consumption after partial hydrolysis of the component protein by fermentation using certain moulds. Such products are racially digestible and nutritious. Spray-dried groundnut protein isolate can be used to replace non-fat milk solids in the ice cream. Chocolate-flavoured groundnut beverage containing 3.5 percent groundnut protein, 3.5 percent fat, 8 percent sugar, 0.7 percent cocoa powder, 0.1 percent stabilizer and water can be produced. Groundnut seed protein isolates may be prepared by following the steps given in Figure 29. Coprecipitated isolates containing 95 percent protein can be prepared from various combinations of groundnut seed, cottonseed and soybean flours by following the procedure mentioned in Cereal Chemistry. 56:95 (1979), American Association of Cereal Chemistry and also given in the book by Patee and Young, 1982.
Fortified milk systems were prepared by blending pasteurized standardized whole milk with dried skim milk, groundnut flour or groundnut protein isolate, to increase the TS to 15, 18, 20 or 23 percent. This was followed by processing at 60 or 80°C for 30 min and storage at 4°C for 24 hours. Curds were prepared by lactic culturing of the processed milk systems. The theological properties showed that all the systems exhibited pseudoplastic flow. The flow became less Newtonian with increasing TS, heat treatment and storage time. Curd obtained from fortified milk processed at 80°C showed increased yield stress along with curd strength with enlarged concentration of added protein. Degree of heat treatment, TS and storage had a pronounced effect on the apparent viscosity, consistency index and yield stress of the fortified milk systems (Ramana and Ramanathan, 1992).

1. Blanched groundnut seed
2. Grind, hexane de-fat
3. Flour extraction (dilute alkali pH 9.0)
4. Filtre
5. Protein liquor
6. Precipitate (Iso-electric pH 4.5)
7. Wash and concentrate

8. Protein curd
9. Dry 9. Neutralize and dry
10. Protein isolate (Isoelectric form) 10. Protein isolate (salt form)
.
*Source: Patee and Young, 1982.*

***Groundnut butter***

Commercial manufacture and consumption of groundnut butter is largely an American art. About half of the edible groundnuts are used for groundnut butter. Groundnut butter is mainly used as a spread for bread or biscuits, in cookies, in sandwiches, in candies and frostings or icings. It is fair sources of calcium, iron, thiamine, riboflavin and excellent source of niacin. Manufacture of groundnut butter involves roasting for controlled browning at 160°C for 40 to 60 minutes; cooling to stop the cooking process of roasting; a dry blanching operation to remove the skins (testa); and a grading or sorting operation to remove light, scorched or discoloured kernels. Several varieties of groundnuts may be optionally combined and ground to a paste or butter according to the form of product desired. Additions of salt, stabilizers and other optional ingredients including sweeteners are metered and blended with the butter prior to cooling and packaging. Other additives include hydrogenated vegetable oil, antioxidants, honey, lecithin, whey etc. The butter is used as spread on bread and in the manufacture of candy, cookies, sandwiches, wafers, patties and bars, etc.

***Groundnut cheese***

Groundnut cheese is a novelty item that may compete in price and quality with animal cheese. Cheese like products have been made from groundnut like protein isolate just as cheese is made from cow's milk. It has good quality protein, is easily prepared and low in cost. It is being used for "Mixed" feeding of undernourished groups in the developing countries. A processed cheese spread has been prepared from groundnut protein based tone milk in India. It has a smooth consistency and milky flavour. The flavour and other organoleptic qualities are comparable with the standard cheese.

***Fermented products***

Groundnut cake or meal can be used for human consumption after partial hydrolysis of the component protein by fermentation using certain moulds. Such products are readily digestible, tasty and nutritious. Oncom is a popular dish of Indonesia and can be prepared by pressing the kernels to remove oil. Soak the cake in water for 24 h, drain and add with high starch material such as cassava or residue from soybean milk. Stem the material, incubate with fungus Neurospora intermedia or Rhizopus oligosporus and ferment for 1 to 2 days at 25 to 30°C after wrapping in banana leaves. It may be fried in oil or margarine and consumed. Fermented dough and kisra is prepared in the traditional way employed by the typical Sudanese housewife (Singh, 1992).

***Tofu (curd)***

Tofu is popular groundnut product in China and Japan. Soaking the groundnut kernels overnight and grinding into an emulsion may prepare it. Boil the fine mash or steam and filtre it through a cloth. The curd may be precipitated from the resulting fluid by adding calcium or magnesium sulphate. The product is left to settle and transferred to boxes lined with cloth filtres or spread on trays. May be sold as slices or slabs, curd is served in soup; the wet curd can be deep fried in oil.

***Bakery products***

Groundnut cake meal or defatted meal, can be used to prepare bakery products (Table 18). Breads, biscuits, cookies and other products could be excellent vehicles for enhancing the utilization of groundnut protein in the diets of malnourished people in the developing countries.

**Table 18. Acceptability of different bakery products prepared from wheat: groundnut meal blends.**

| Acceptability1 | | | | | |
|---|---|---|---|---|---|
| Flour blend | Bread | Bun | Cupcake | Cookie | Doughnut |
| Control, 100% refined wheat flour | 4.4 | 4.8 | 4.8 | 4.9 | 4.8 |
| Wheat: PDM2 | | | | | |
| 90:10 | 4.1 | 4.2 | 4.3 | 4.5 | 4.4 |
| 80:20 | 3.6 | 3.6 | 4.0 | 4.0 | 3.8 |
| 70:30 | 3.1 | 3.0 | 3.2 | 3.4 | 3.1 |
| Wheat: CDM3 | | | | | |
| 90:10 | 4.1 | 4.1 | 4.6 | 4.7 | 4.4 |
| 80:20 | 3.5 | 3.3 | 4.0 | 4.3 | 3.8 |
| 70:30 | 2.7 | 2.8 | 3.5 | 3.7 | 3.2 |
| CD at 5% | 0.70 | 0.64 | 0.66 | 0.54 | 0.74 |
| SE value (±) | 0.25 | 0.22 | 0.22 | 0.19 | 0.26 |

Acceptability was judged by the panellists for taste, flavour and appearance.
Partially defatted flour.
Completely defatted flour
Score:
Excellent=4 to 5, Good=3 to 4, Fair=2 to 3, Poor=1 to 2 and Very Poor=0 to 1.

*Source: Kadam and Chavan, 1991, ICRISAT*

***Weight Watchers®***

Health-conscious consumers in the developed countries prefer low-fat groundnut that is now being sold under the trade name Weight Watchers®. A commercial process that squeezes out about 50 percent of the oil from raw groundnuts, which then regain their shape after being squeezed, makes low-fat groundnut. The groundnuts are then soaked in hot water and roasted in oil for 5 minutes. The water steaming out of the kernels prevents roasting oil from entering them resulting in a crunchy groundnut with 50 percent less fat than normal. This product may be prepared by the groundnut-producing countries for export to developed countries to earn valuable foreign exchange.

***Composite flours***

Groundnut is used to improve protein content and quality of several cereal-based food products in India, Kenya, Malawi, Nigeria, Senegal and Zimbabwe. In India alone, there have been several agriculture-product with groundnut as the protein-enriching medium. The partially defatted flour is used to improve the nutritional quality of various cereal-based products such as gonfa, millet (Pennisetum glaucum) based product and epo-ogi, a corn (Zea mays) based gruel. Uji is food product commonly prepared from maize or sorghum in Tanzania.

In Sudan groundnut cake after oil extraction is exported, kisra is sorghum-based food can be prepared to convert the groundnut cake into flour for local consumption. Acceptable and nutritionally superior quality kisra is prepared from sorghum flour fortified with defatted groundnut flour. The addition of defatted groundnut flour resulted in improvement of baking ease, colour and texture of the final product. The percentage increase in protein content at the 30 percent level of fortification varied from 53 percent to 122 percent. Fortification with groundnut and subsequent fermentation improves the in vitro digestibility of the sorghum flour (Singh 1991). A supplementation level of 20 percent is considered adequate to achieve the desired nutritive benefits. The proportion of total amino acids (T), which must be supplied as essential amino acids (E), the E/T ratio is considered as a quality index in the FAO Provisional Pattern (FAO/WHO Adhoc Expert Committee 1973). In developing countries where sorghum is a staple diet, there is a need to have a nutritional improvement programme on sorghum. Acceptable gari, a commonly used cassava-based Nigerian food, can be prepared with 15 percent defatted groundnut flour. There was a four-fold increase in the amount of protein at this level of fortification and a remarkable increase in the concentration of all amino acids was observed.

***Groundnut sweets***

In India groundnut is used to prepare laddu and chikki. To prepare laddu, groundnut kernels are roasted and seed coat is removed, the separated cotyledons are mixed with thick, hot jaggery syrup. Small portions of the mixture are pressed by hand to obtain balls or laddus, about 3 to 5 cm in diameter. Chikki is very popular product in Western India. It is prepared by mixing roasted and decorticated groundnut kernels with hot slurry of sugar. The mixture is spread in a 1.0 to 1.5 cm thick layer on a tray or similar flat surface. After, cooling the product is cut into small pieces and packed. Roasted groundnuts are also used in the preparations of various other traditional recipes such as khichadi, guradani, barfi and vegetable curries, in India. Recently National Institute for Nutrition, Hyderabad, India has introduced a new sweet prepared by groundnut, jiggery and wheat floor with low fat and high energy, named Suruchi. The product is being tested on the school children for its calorific value and consumer acceptance. Such products may give food-nutritional security to the school going children in developing countries. Please see Figure 30.

The United Nations Development Programme (UNDP), in partnership with the Food and Agriculture Organization of the United Nations (FAO), in collaborating with the Technology Mission on Oilseeds and Pulses Ministry of Agriculture, Government of India (GOI) have published a "Culinary Preparations with Groundnut". The publication mentioned 42 delicious preparations with groundnut with the intent to promote groundnut as food crop for sustained nutritional security. Some important recipes are: groundnut curry, chow chow fry, groundnut omelette, groundnut vada, groundnut pakodi, groundnut chakkilam, groundnut halava and various chutneys with groundnut (Soluchana, et al., 2000).

**Figure 30: Groundnut confectioneries.**

Technologies are also available to prepare the following items from groundnuts: Yuba (groundnut film) a protein-lipid film, may be developed from groundnut milk, groundnut-based yoghurt, groundnut bars, chicken patties extended with groundnut flour, chocolate-flavoured groundnut beverages, groundnut patties, tube feeding product containing groundnut protein, nutritious snacks for school-age children, groundnut nougat, fermented groundnut milk and groundnut sauces (Beuchat, et al., 1992).

***Partially defatted groundnuts***

This process involves removing the oil from the groundnuts and then reconstituting and roasting the kernels. It is interesting to note that the process was developed in the USA out of the quest for the low calorie product and not because of a need to get at the oil in groundnuts. Roasted groundnut kernels without skins generally contain 24 to 26 percent protein, 46 to 50 percent oil, 18 to 20 percent carbohydrates, 1.5 to 2.5 percent moisture and 2.5 to 3 percent ash. They also contain many essential minerals and vitamins. The defatting process removes up to 80 percent of the oil in groundnuts, thereby reducing the calorie content while still retaining the protein value. This process consists essentially of three simple mechanical operations: i.) pressing ii.) reconstitution and iii.) drying and roasting, either raw (with skin) or blanched groundnuts are hydraulically pressed to remove the desired amount of oil. The pressed de-shaped blanched groundnuts are heated in boiling water to expand them and to restore their original shape and size. Salt and other ingredients can be added during the expansion step. The expanded groundnuts are then dried and roasted with or without oil. Using a hydraulic press, it is possible to remove 80 percent of the oil from the groundnuts at a pressure of 2 000 psi in 50 minutes. In commercial operations both the cage pot presses are being used. Partially defatted groundnuts air-dried and roasted after 80 percent oil the oil removed. There is a little loss of taste, however defatted groundnuts become slightly harder than real roasted groundnuts. Research is needed to produce a softer product.

***Synthetic fibres from groundnut proteins***

The process developed for the manufacture of Ardil on a commercial scale is as follows:
The protein is first extracted from blanched groundnuts with dilute alkali and it is precipitated again by the addition of acid or SO2 until the iso-electric range pH 5 is reached. The precipitated protein is again dissolved in dilute caustic soda so that a solution of 20 to 30

percent concentration of protein with an initial pH of at least 12.5 is obtained. The solution is allowed to mature for a certain period to attain the spinnable viscosity (between 50 to 5 000 poises). It is then extruded at a constant rate through a spinnerets into a coagulating bath containing 15 percent sodium soleplate and about 1 percent sulphuric acid at temperature 25°C to 40°C. At the end of this treatment the fibres are washed free from acid and salt. They are then adjusted to a pH of about 8 so that they will dye evenly with wool. The final product is a cream coloured crimped fibre with a soft wool-like feel.

Groundnut cake meal is also useful for the preparation of vegetable protein adhesives. Groundnut cake protein glue is already being used in the production of commercial plywood by some of the plywood factories in India. Ardein a commercial preparation of the groundnut rich in the globulin arachin when isolated and fed to milch cows has been found to increase milk production by 35 percent and fat production by 54.1 percent.

***Groundnut protein film***

Groundnut protein film is one of the alternative edible films that can be used in an intermediate moisture food (IMF) due to its promising characteristics: bland flavour, low oxygen permeability and its ability to incorporate antimicrobial agents. This study has provided information on possible use of peanut protein film with and without sorbic acid, as an edible coating for IMF. The predicted sorbic acid profile in coated food showed that groundnut protein might be used to retard sorbic acid migration from surface to food core and extend the product shelf life. Contrary to the expected result, the use of coating did not show any significant effect in delaying Salmonella aureus growth. A thin coating used may have attributed to this observed performance (Jangchud, et al., 1999).

***Uses of groundnut shell***

Of the several million tonnes of groundnut produced each year, hulls form about 25 percent of the total mass produced and their utilization thus becomes very important. At present in the developing countries the majority of groundnut hulls are either burned, dumped in forest areas or left to deteriorate naturally. Sufficient information is available to use groundnut hull in cattle feed, as carrier of insecticide, in the manufacture of logs and production of pulp and as a fibre component in human diet. Hull digestibility is quite low; research efforts are being directed to improve it as it contains more than 60 percent fibre. Inoculation and biodegradation of hull have been tried but these efforts have not been successful (Kerr, et al., 1986). The shell also used for the production of alpha-cellulose. By adopting the neutral sulphate method about 40 to 42 percent of unbleached pulp yield on an average 93 percent of alpha-cellulose from groundnut shell. Finely ground groundnut shells are often used for polishing tin plate.

***Groundnut shell charcoal making***

Charcoal making is based on the principle that groundnut shell can be converted into charcoal by incomplete burning. Limiting the amount of air used during the burning process produces incomplete burning. Thus, the quality and quantity of charcoal depend largely on how well the amount of air is regulated in the charcoal chamber. Groundnut shell can also be used for preparing activated carbon.

Pelleted groundnut vines

Tests have shown that dehydrated and pelleted groundnut vines is valuable by-product and are far superior to Bermuda grass particularly in digestible nutrients and possibly as a source of carotene.

*Briquette and pelletization*

Energy shortage in rural areas has several far-reaching ill consequences, the security of fuel wood forces people to use animal dung and crop residue as fuel, reducing the soil fertility and productivity. Following is the method for briquette and pelletization of groundnut shell for fuel purpose. The process of briquette and pelletization is based on the principle that at set pressure fraction is related logarithmically to the height of the layer of compressed material. During the pelleting of fine-ground material, fraction increased as the diameter of the cylinder decreased and as pressure increased. It was calculated that the length of the holes in roller type disc dyes and ring dyes should be increased as the diameter of the holes and particles size of the material increased. Wafers of groundnut husk and bark could be formed by pressure <11MPa. The moisture content of the material should be between 10 to 16 percent and particle density 1.0 to 1.4 g cm-3. (Esaki, et al., 1986). In India small-scale industries are forming briquette from groundnut husk, which is being used in other industries as a fuel for boilers. The briquette industries require a strong support and encouragement from the governments. Please see Figure 31.

**Figure 31: Small-scale industries preparing groundnut Briquettes for fuel purposes.**

The shell is also used as soil amendment and manure, mulch, particleboard, in India and other developing countries.

**2.8.5 Aflatoxin contamination**

History and origin: The aflatoxin problem was first recognized following outbreaks of Turkey "X" disease in the United Kingdom in 1960. Research revealed that the disease was caused by toxins produced by strains of the fungus Aspergillus flavus, which had grown in the groundnuts. The term aflatoxin is used to designate a group of organic metabolites, more or less toxic to animals, of certain strains of fungi belonging to the species Aspergillus flavus ands A. parasiticus. Six aflatoxins have been identified:

Aflatoxin B1 = C17 H12 O6
Aflatoxin B2 = C17 H14 O6
Aflatoxin G1 = C17 H12 O7
Aflatoxin G2 = C 17 H14 O7
Aflatoxin M1 = 4-hydroxyflatoxin B1
Aflatoxin M2 = 4-hydroxyaflatoxin B2

Detailed studies show that aflatoxin B1 is the most commonly occurring form. All the aflatoxins can be toxic at certain concentrations and may cause primarily liver cancer in animals and human. They can also cause lack of appetite, loss of weight, haemorrhage, ascites and abortion. Young animals are more sensitive and vulnerable to aflatoxicosis than older ones. There are two types of aflatoxin toxicity: direct toxicity and relative toxicity; both can be acute or chronic. This issue has become a subject for concern in agriculture on global scale. Many countries have assigned high priority to research to find a solution to aflatoxin contamination of groundnut. It is a serious problem in the warm to hot subtropical moist regions of the world and is more serious during and following alternative dry and wet periods, i.e. drought followed by showers. Fungal growth and aflatoxin production in the pods is favoured, when temperature range from 20 to 30°C and the relative humidity in the pod microenvironment ranges from 85 to 95 percent. Invasion of fungus to groundnut can occur during flower and peg formation, gradually as the pod mature and rapidly as the pod become over mature. Mature intact pods with thick sclerotize cellular components and kernels with compact seed coat (testa) are less susceptible. Seed coat is a barrier to fungal infection, as in seed with higher Ca content in seed coat decreased the growth of A. flavus. The results revealed that Ca content in seed coat is more important than Ca in pericarp (Field Crop Research, 1997 pp. 9). The presence of a "natural barrier" to invasion of undamaged pods was also considered and suggested possible antagonism and competition by Trichoderma viridi and Penicillium spp. With in the endocarp community (Garren, 1966).

Preharvest contamination: Late season drought spell, particularly in the semi-arid region is a major factor associated with aflatoxin contamination. Reduced metabolic activity associated with decreased pod moisture content under drought stress seems to increase susceptibility of groundnuts to A. flavus infection. However, another possible role of drought stress in pre-harvest fungal infection could involve suppression of microbial competitors of aflatoxin producing fungus by elevated temperatures in the pod zone (Mehan, et al., 1991). Pod splitting is another factor contributing to aflatoxin contamination. Pod maturing under fluctuating soil moisture conditions during seasons of inadequate or irregular rainfall, are prone to pod splitting. Seed in split pods are frequently invades by A. falvus and subsequently become contaminated with aflatoxins. It is well established that A. flavus invasion can occur in soil during pod development and maturation; the fungus directly penetrates the pod wall or enters passages created by pod pests and diseases/lesions. However, the exact mode of infection of groundnut pod has not been fully elucidated. To control the invasion of A. flavus under the drought situations efforts are needed to under stand the mechanism of A. flavus invasion at different levels of pod moisture and genotype variations for the pod characteristic to develop cracks under varying soil moisture regimes.

***Post-harvest contamination***

During drying: In most of the groundnut-producing countries the weather remains warm, wet during the drying period and the risk of aflatoxin contamination is increased. At harvest groundnut pods contain moisture content about 45 to 55 percent and a complex of microorganisms, the endocarp microflora, which includes A. flavus also. When moist pods are lifted and cured/dried in windrows or heaps there may be considerable invasion of seed by A. flavus and other fungi already existed in the shell. This process is encouraged, if drying is slow because seed remain in very susceptible range of 12 to 30 percent moisture content for extended period. A rain shortly after lifting is not particularly harmful, but a rain after the groundnuts are partially dried, followed by poor drying is likely to result in aflatoxin contamination (Troeger, et al., 1970). Rains in the evening may keep the groundnuts wet all night, thus providing fungi with needed moisture to multiply. Rains early in the morning are less likely to slow down drying and accelerate mould growth, because of effective daytime drying. In Nigeria, in the areas where rains continue after harvest, field drying of groundnuts is serious problem of aflatoxin contamination (McDonald and Harkness, 1965). The use of inverted windrows compared to random windrows or heap has shown to speed the curing and drying process (Pettit, et al., 1971). Groundnut pods positioned at the top of inverted windrows reside where air currents move more rapidly and the atmosphere humidity is low as compared with positions close to soil surface. Thus the pod at the top of inverted windrows has less chances of invasion by A. flavus than the pods close to soil surface.

Lower levels of A. flavus infection and aflatoxin contamination have been reported in groundnuts dried in inverted windrows than in inverted random windrows (Porter and Garren, 1970). Thus inverted windrows shorten the time required to cure groundnuts in field and help to reduce the number of kernels invaded by A. flavus and other fungi. However, to avoid infection and aflatoxin contamination because of prolonged periods of rain, groundnut should be threshed as soon as possible with final drying achieved under controlled conditions, if groundnut is cultivated in large scale. In case the drying facilities are inadequate groundnuts should be left in the inverted windrows rather than combined and held for drying. Even during periods of rain, the risk of aflatoxin contamination is probably less for groundnuts in inverted windrows than for those held in dryers without proper ventilation (Dickens, 1977).

In India lot of work on the aflatoxin problem has been conducted by the ICRISAT, from other developing countries the reports are sporadic, however, more systematic studies are required to prevent the invasion of A. flavus during curing and drying.

During storage and shipment: The number of ecological studies of storage fungi involving quantitative mould count of populations is limited. In Egypt, groundnut seed were adjusted to 8.5, 13.5, 17.5 and 21 percent moisture levels and stored for 6 months at 5, 15, 28 and 45°C and A. flavus was found to be the dominant fungus followed by A.niger, A.terreus and P.funiculosum (Moubasher, et al., 1980). The main factors influencing the growth of A. flavus and other storage fungi in groundnut are moisture (relative humidity), temperature, storage period and gaseous composition of the storage atmosphere. High mycofloral counts have been associated more often with high initial moisture contents of groundnuts going into storage than with any other factor. The literature on the influence of moisture, temperature and other factors on the growth of A. flavus in groundnuts have been comprehensively reviewed by Diener and Davis (1977). A. flavus infection and aflatoxin contamination may increase in groundnuts during storage until their moisture content drops below 9 percent. Natural accumulation of carbon dioxide ($CO_2$) and decreased levels of oxygen ($O_2$) in closed storage reduce mycoflora development. Fungus growth and sporulation were reduced with each 20 percent increase in $CO_2$ from 40 to 80 percent. No growth occurred in 100 percent $CO_2$. Visible growth and free fatty acid (FFA) formation by A. flavus were inhibited at 86 percent. RH decreased by 20 percent at 17°C and 60 and 40 percent $CO_2$ at 25°C. FFA levels decreased as RH decreased from 99 percent to 92 percent to 86 percent (Lander, et al., 1967). Low temperatures and uniform moisture distribution reduce mould growth and insect activity. Aeration is necessary to reduce aflatoxin contamination during storage. High relative humidity and temperature, rainwater leakage and insect infestation are critical factors that contribute to aflatoxin contamination of groundnuts in storage.

Groundnut meal has traditionally been an important component of poultry and other livestock feeds both in groundnut producing and importing countries. The economics of some of the developing countries are strongly dependent on export of groundnuts and groundnut products. Therefore, every effort should be made to reduce aflatoxin contamination and so maintain trade in groundnuts and groundnut products. The problem of mould damage and mycotoxin contamination can be minimized by improving facilities for storage at port and transient points and on ship. Use of airtight polyethylene bags with silica gel may reduce the proliferation of A. flavus by lowering the relative humidity of the storage microenvironment.

Need of aflatoxin contamination control in developing countries

In developing countries the problem of the aflatoxin contamination is more serious and farmers are still following the old practices of harvesting, curing, drying and storage, more over the environment during harvesting and storage remains congenial for the mould growth. Farmers need to be educated about the ill effects of the aflatoxin production and to follow a package of practices for the control of invasion by the fungus A. flavus. Therefore several National and International Organizations in the developing countries are organizing the programmes for the control of the aflatoxin in groundnuts.

In October 1987 ICRISAT organized International Workshop on Aflatoxin Contamination of Groundnut. To present overview of the work and problems of aflatoxin contamination in the developing countries, showed that in many developing countries there is only limited or no facilities for monitoring groundnut and groundnut products for aflatoxin contamination. There are also possible synergistic interaction between aflatoxin and infectious hepatitis virus B and there is evidence that the effects ingestion of aflatoxin are much more serious in the case of children suffering from severe protein malnutrition and unfortunately this is a common condition in some countries where aflatoxin occur.

African Groundnut Council (AGC) in 1975, on the basis of scientific information on A. flavus and other mycotoxin producing fungi launched an aflatoxin control programme in collaboration with EEC (European Economic Community) and UNDP (United Nations Development Programme) with technical assistance from the FAO. In Zambia, groundnut kernels meant for export are routinely monitored for aflatoxin contamination. A committee to coordinate action on the aflatoxin problem in Nigeria was constituted in 1961 with representatives from four ministries, the Institute for Agricultural Research (IAR) Zaria, The Nigerian Stored Products Research Institute (NSPRI) and Northern Nigeria Marketing Board. This committee was charged with the responsibility of assessing the extent of the aflatoxin problems in groundnut in the country and of initiating and coordinating all actions leading towards its elimination.

The IOPEA has started, in small way in India, its endeavour to educate farmers about sound post harvest practices in Gujarat, which is one of the largest groundnut-producing states in the country. In Andhra Pradesh the farmers do not seems to be as conscious as their counterparts in Gujarat about proper drying, storage and moisture levels. In both the states in UNDP sub-programme on "Promoting Groundnut as Food Crop for Sustained Nutritional Security" implemented by National Research Centre for Groundnut to educate the farmers regarding the proper drying and storage methods and the serious consequences of aflatoxin

contamination. More organizations are now joining the campaign to educate farmers regarding the quality concept like in Gujarat NGOs are joining hands with NRCG to promote the cultivation of Bold seeded groundnuts especially in the Kutch-Bhuj area.
Developing countries mainly face the problem of mould growth and aflatoxin contamination in commodities transported over long distance through the sea route and need immediate attention of the researchers, producers and traders. If the contamination occurs during transit, often no insurance coverage for the risk is available. Because of the different methods of sampling followed in the exporting and importing countries, it is often difficult to define the exact responsibility of the development of aflatoxin as having taken place during transit.
Management of aflatoxin contamination
Following strategies may be followed to minimize the aflatoxin contamination:

1. The presence of a "natural barrier" to invasion of undamaged pods was also considered and suggested possible antagonism and competition by *Trichoderma viridi* and *Penicillium spp*., with in the endocarp community, therefore *Trichoderma viridi* and *Penicillium spp*., may be added to the soil at the time of sowing.
2. Adequate mineral nutrient is important for maximum groundnut production and the factors that increase quality might also reduce contamination. Calcium is the only nutrient that has been shown to have an effect on aflatoxin contamination; therefore gypsum may be applied during flowering phase to the pod zone. Use recommended rate of calcium for location specific application.
3. Late-season drought stress with soil temperatures 25 to 32°C is by far the most important single determinant of pre-harvest aflatoxin contamination. Therefore late-season drought must be avoided by arranging irrigation.
4. Soil-inhibiting insects that damage pods, such as termite in Africa and white grab in India, can increase aflatoxin contamination of damaged kernels and infection of undamaged kernels by *A. flavus*. These insects may be more active under drought conditions. Therefore every precaution may be taken to control soil-inhibiting insects.
5. Damaged pods, loose-shelled kernels and immature groundnut are the most likely to be contaminated, so these should be removed by visual inspection manually or by machines, for example the belt-screening technique.
6. After harvest moisture content of pods must be reduced for safe storage. Drying should be done first in the windrow or following any method suitable to obtain 20 to 25 percent moisture, followed by thin layer or artificial drying to in-shell moisture content of 10 to 11 percent, with in a weeks time.
7. Moisture content is the single most important variable in stored groundnut. Maximum relative humidity for safe storage is 84 percent at 30°C. This roughly corresponds to a moisture content of 10 to 11 percent in unshelled groundnut and 6 to 8 percent in shelled groundnut.
8. Groundnut may be stored in atmospheres with low oxygen or high carbon dioxide levels to control *A. flavus* growth and insects.
9. In India during the shelling of groundnut water is sprinkled over the pods to increase the moisture percent to reduce the number of damaged kernels. However, this higher moisture content provides favourable environment for the growth of *A. flavus.* Thus adding water at the shelling stage must be avoided.
10. Edible groundnuts may be sorted by hand on a pick-out table, with electric colour sorters or by a combination of the two. The pick-out may be diverted to oil stock. Careful hand sorting is more effective than colour sorting, so a combination may be preferred. Damaged groundnut pods may be removed by sorting during the shelling or blanching process. These separation methods physically remove the majority of contaminated kernels and improve the quality of the finished product.

11. Groundnut varieties resistant to *A. flavus* invasion and/or do not allow *A. flavus* to produce the aflatoxins may be developed. At present integrated approach may be followed to prevent pre and post-harvest *A.flavus* invasion, to minimize the aflatoxin contamination to the prescribed limits.

## 2.9 Marketing and policies

Marketing practices vary among the developing countries. Within 3 to 4 weeks after harvestime farmers take about 70 to 80 percent of their produce personally to the market to fulfil their cash requirements. The marketable surplus of the small and marginal farmers is so small that they do not find it economically feasible to take it to wholesale markets, even though these distant markets often offer better prices. Rural markets often lack facilities and are generally strips of land serving as a meeting place between buyers and sellers. Market yards are owned either privately or by local governing body called panchayat. In India, marketing period for the rainy season crop commences in October and remains till February, with a peak between November and December. Within this period about 45 percent of the marketable surplus of groundnut arrives in the markets. The disposal of the produce, either at the market or in the village is closely connected with the producers holding capacity. The sales in the village level markets are invariably in the form of pods, while in the assembling markets transactions take place both in the form of pods and kernels. Regulated markets have been organized in some of the main groundnut producing areas, which provide certain amenities to the sellers and forbid exorbitant market charges and malpractice of the traders. The number of regulated markets and the volume of produce passing through them are still inadequate. Please see Figure 32.

**Figure 32:Groundnut is directly being transported from the field to the market yard, Junagadh, India in the month of October.**

India has historically persuaded a policy of self-sufficiency in vegetable oils and related products by banning imports and imposing other quantitative restrictions on trade. These policies kept domestic groundnut prices higher than international prices and consequently depressed the consumption. The government provides support prices for many oilseeds, including groundnut, but these have normally been below market prices and have, therefore, not been effective in procuring supplies. A survey conducted in Gujarat showed that, most of the markets are efficient in pricing for groundnut. As the farmer's share of the consumer's rupee is the highest (73 to 79 percent), followed by the miller's (5 to 8 percent), wholesale-trader's (1 to 4 percent) and retailer's (1 to 4 percent). The government procurement has added a new dimension to agricultural marketing and the Primary Cooperative Marketing Societies help farmers to fetch a better price for their produce (Raju and Bhatt, 1985).
In Gambia threshing of the crop is carried out in two separate operations; a portion of the crop is reserved for seed is threshed first, bagged and transported to the National Seed Stores, treated with insecticides and stocked. The second threshing operation takes place between December and February. The farm families utilize this portion of the crop in local consumption and surplus is marketed. In Niger the harvest is usually divided into three parts; the largest part is sold, the second is kept as seed for the next cropping season and the family uses the third.
In Senegal the government parastatal SONACOS, which is responsible for crushing and marketing refined groundnut oil, still operates a form of price fixing body through arrangement with licensed private traders. Similarly the Gambian Cooperative Union, a Government parastatal, continues to operate alongside an emerging private sector and dominates groundnut marketing. In Zambia, the National Agricultural Marketing Board continues to enjoy a statutory monopoly, but in practice private traders by informal sector conduct the bulk of groundnut trade. Consequently, market liberalization has little effect on prices. In Malawi the government parastatal ADMARC exerted strong monopoly power during 1980s through an intensive network of rural buying points at which producers were paid guaranteed prices. The sluggish response of the private sectors in groundnut marketing following liberalization in most African countries is due, in part, to high transaction costs. Sudan has implemented very different pricing and marketing policies. The private sector play a dominant role in groundnut marketing policies-producer price support, exchange rate subsidies and preferential export taxes have been used to maintain producer incentives, thus favouring groundnut producers (Freeman, et al. 1999).
The Gambia Produce and Marketing Board (GPMB) have a monopoly over the purchase and export of groundnut. Both the public and private sector carries out the domestic marketing of

groundnut. All traders are required to pay farmers the officially announced produce price (Drammeh, 1990). The Ghana Food Distribution Corporation (GFDC), a government marketing and distribution organization buys groundnut from the rural areas and stores for reselling it to the public. GFDC handles only a small portion of groundnut produced and therefore, most farmers depend on middlemen for the ready market. Domestic sector and macroeconomic policies in AGC countries have played critical role in the decline of production and exports by AGC countries. Their combined effect on national groundnut sectors has resulted in average annual changes in AGC-wide groundnut production of 4 percent to 15 percent from the late 1960s to the end of the 1980s. The regional markets have hardly played any role in AGC exports (Atuahene-Amankwa, et al., 1990).

In Zimbabwe farmers in the large scale commercial farming areas were required by law to sell their produce to the parastatal Grain Marketing Board (GMB) at state-controlled prices. These prices did not keep pace with real market prices and their levels relative to other crops, often resulted in swings from one crop to another depending on profitability. This situation led to steady decline in groundnut production in the country. In March 1992 the government-decontrolled groundnut marketing producers and permitted to dispose of regulated crops to best advantage. The GMB offers a guaranteed floor price and retains control of imports and exports. Exports are normally permitted only after local requirements are satisfied.

A common feature in all major groundnut-producing countries is government intervention through price and marketing policies that directly influence prices and costs. The pattern of intervention, however, is different in developing and developed countries. In the past, in developing countries, the government price and marketing policies discriminated against the groundnut sector by directly suppressing producer prices. In international groundnut oil markets large swings in prices are observed. Such swings become more pronounced in South Asian countries, where domestic production has to be augmented by imports, which fluctuate due to the poor balance of payments position (Rai, et al. 1993).

The role of market places varies not only between developed and developing countries, but also within the developing countries. It depends to a greater extent upon the general socio-economic and political pattern of the respective region. In developing countries the markets are very important elemental components in the spatial articulation of economic and social activities, their changing role for wholesale and retail trade, in rural and urban environments and for different strata of the population need to be evaluated in the context of the general stage of development in any particular country or region.

# 3. Overall Losses

## 3.1 Pre-harvest losses due to diseases and pests

The major diseases of economic importance affecting groundnut crop in the field in India are early and late leaf spots (Cercospora arachidicola [Mycosphaerella arachidis], Phaeoisariopsis personata (M. berkeleyi), rust (Puccinia arachidis), collar rot (Aspergillus spp.), root rot (Macrophomina phaseolina) and stem rot (Sclerotium [Corticium] rolfsii). These ailments cause 13 to 59 percent yield losses during both the rainy and summer seasons. Thrips and jessed are the major pest of groundnut, incidence of these pests is reported significantly higher in the fields not sprayed by the insecticide monocrotophos and pod yield loss due to the pest attack are about 39 percent, which exceeded the economic loss of 12 percent.

Crop losses caused by Sclerotinia sclerotiorum, S. minor and Sclerotium rolfsii [Corticium rolfsii] were evaluated in the southern region of the groundnut-producing area in the province of Cordoba, Argentina. Production losses were calculated using the equation: PL=(AY/1.0-LP)-AY where PL represents losses, AY the actual yield and LP the proportion of losses. The actual yield is that obtained by the producer while proportional losses are equivalent to the percentage of dead plants (incidence). Furthermore, the incidence of blight and wilting was often higher in groundnut crops where the preceding crop had been groundnut, soyabean or sunflower (Helianthus annuus) than in groundnut crops preceded by sorghum (Sorghum bicolour), maize, alfalfa (Medicago sativa, lucerne), lovegrass (Eragrostis curvula) or grassland. The fact that these diseases are becoming increasingly widespread, together with the losses caused by them throughout the groundnut-growing region are of major importance (Marinelli, et al., 1998).

Among the major arthropods in soil and plant samples taken from groundnut farms in Mali, Burkina-Faso, Niger and Nigeria, termites of the genus Microtermes (Isoptera: Termitidae) were the most abundant and widely distributed species of economic importance. Most of the whitegrub (Coleoptera: Scarabaeidae) and millipede (Myriapoda: Odontopygidae) species identified belonged to the genera of Schyzonycha and Peridontopyge, respectively. Percentages of plants attacked by termites, white grubs and millipedes were 39, 11 and 9 percent, respectively. Yield loss due to termites, which predominantly damaged harvested kernels, was estimated at 10 to 30 percent and was significantly correlated with percentage of plants damaged by termites (Umeh et al., 1999).

Termites and julids are very serious pests of groundnut in Burkina Faso causing scarring and perforation of pods just before the groundnut harvest. Other more qualitative damages, such as increases in aflatoxin content in the damaged pods are also directly linked to pest attacks. Farmers of Burkina Faso are unable to use chemical control against these pests due to their poor purchasing power. Varietal resistance, which is less expensive and definitely more environment-friendly, offers a better alternative. The relationship between resistance level of varieties and their pod yields is low. For example, NCAC 2243, RMP 40 and NCAC 2240 showed a high level of resistance to combined attacks of termites and julids, they had lower pod yields compared to the other susceptible varieties. Losses due to insect pests in India are sown in Table 19.

Attempts to manage insect pests often emphasize an understanding of the relationships between insect densities and crop yield loss, because of many variables involved. For instance, the stage of the crop, the weather pattern and the season are all important. Groundnut seedlings are susceptible to relatively low population densities of defoliators, whereas established plants can withstand a considerable degree of leaf loss, more in the rainy season.

**Table 19. Losses due to insect and mite pests as reported from various groundnut-growing areas in India.**

| Name of insect pests | % Losses |
|---|---|
| Termites belonging to the genus Odontotermes | 5-50% plant mortality and up to 46% pod damage |
| Earwing (Anisolabis annulipes) | Pods damage up to 3-19% |
| Scirtothrips dorsalis | 17-29% yield loss and 30% in haulm yield |
| Groundnut aphid ( Aphis craccivora) | 16% pod yield |
| Defoliators, Hairy caterpillars (Amsacta albistriga) | When an outbreak of this pest occurs, a total yield loss over a large area is not uncommon |

| | |
|---|---|
| Leafminer (Aproaerema modicella) | Avoidable loss of 49% (pod yield) |

### 3.2 Losses due to weeds

In India yield loss in groundnuts due to weeds ranges between 17 and 96 percent. The loss in yield due to competition by weeds may range between 30 to 34 percent. The yield losses are higher in a rain-fed crop and also Spanish compared with an irrigated crop and Virginia runner. Reduction in pod yield because of weed infestation is estimated around 52 percent in Spanish-bunch and 18 percent in Virginia runner types. Weeds in rain-fed Spanish groundnut removes 38, 9 and 23 percent N, P and K per hectare, respectively from unweeded plots. Approaches in weed management include growing suitable intercrops like cowpeas, hand weeding on 15, 30 and 45 days after sowing and chemical methods such as the pre-emergence application of fluchloralin at 1.0 kg $ha^{-1}$, oxyfluorfen at 0.1 to 0.15 kg $ha^{-1}$ or pendimethalin at 1.0 kg $ha^{-1}$. Adoption of integrated weed management practices such as pre-emergence application of herbicides coupled with one hand weeding on 20 to 25 days after sowing are the most effective for getting higher yields and net profit (Rajendran and Lourduraj, 1999).

### 3.3 Drought and yield losses

Drought is the main factor inhibiting groundnut production in the semi-arid tropics where most of the developing countries are situated. Drought causes sizable losses, since it deters efforts to combat the nutrient, disease and pest stresses through managerial practices, besides its direct effect in reducing groundnut yields. From the drought resistant trial conducted at ICRISAT three varieties ICGV 87354, ICGV 86014 and ICGV 86124 showed 36 to 54 percent pod yield superiority over the drought-tolerant control ICG (FDRS) 55. Losses due to drought stress may vary based on the intensity and duration of the drought and plant growth stage. For example a mild stress during vegetative phase is beneficial, however stress during pod development phase is highly detrimental to pod development and yield.

### 3.4 Losses due to nutrient deficiencies

The major mineral that is required for the development of groundnut pod is calcium. Calcium deficiency causes groundnut pegs and pods to abort, causing decreased shelling percentages and yield. Environmental factors influencing calcium viability include soil Ca content and soil moisture. Genetic attributes that influence the sensitivity of cultivar to soil Ca supply includes pod size, soil volume per pods (varied by plant growth habit) and pod wall attributes. Where Ca fertilization is not possible, genetic solution to Ca deficiencies is important and breeders need information on the relative importance of these attributes. There are substantial yield losses due to the deficiency of iron, phosphorous and sulphur in groundnut. Kernel development in groundnut is sensitive to boron deficiency, making the crop a good indicator of low boron status in soils. In Thailand, Chiany Maivally and surrounding areas in the dry season of 1984 to 1985, the damage due to the boron deficiency in pod yield was approximated to be up to 28 percent.

### 3.5 Losses due to peg drying

A new peg drying problem of groundnut has been observed in about 6 000 ha of the crop grown in sandy soil in the Chirala, Vetapalem and Bapatla regions of the southern coastal Andhra Pradesh, India. The affected plants were slightly stunned and had mottled leaves and blackened pegs and pods. Some pegs were free from lesion but were flaccid. The roots of affected plants appeared bushy. Seeds are generally well formed and often showed hollow heart symptoms in the Vetapalem area. Yield loss due to this problem was estimated at about

30 percent. Low pH, calcium and zinc concentrations in problem soils and improved response of plants to calcium + boron indicated the possible involvement of these abiotic factors in the `peg drying` problem (Sharma, *et al*. 1995).

## 3.6 Losses in post-production system

Pod losses during harvesting are substantial (20 to 30 percent), however the losses are more in the Virginia than the Spanish types. The harvesting losses are also depending on the method of harvest and soil moisture content. Excessive soil moisture at the time of harvest also damage the crop quality, on the other hand soil moisture-deficit may increase the pod losses. Therefore, after reaching to the physiological maturity irrigation must be stopped, but at the same time it may also be insured that at the time of digging the soil moisture content in the field is optimum. Soil moisture at the time of digging is most important both to reduce the pod losses due to poor peg strength especially in Virginia types and in situ sprouting of seed due to lack of fresh-seed dormancy in Spanish and Valencia types (Nautiyal et al. 2001). Farmers' implements for recovering the pod losses during harvest are shown in Figure 33.

**Figure 33:After harvest left over digging the soil with blade attached with a plough is helping in collecting pods.**

Lack of awareness and actual skills on groundnut post-harvest technologies have caused significant losses starting from the harvesting to curing, drying and storage. The efficiency of the drying process at the farm level is the most critical stage as this affects subsequent loss in terms of product quality. In spite of the FAO efforts in the "Symposium on Crop Losses" held in Rome in 1967 the information on these aspects is very limited. The conference was intended to examine the international need for factual data on crop losses while suggesting possible ways to obtain reliable information on the losses during harvest and post-harvest processes, Although, the FAO Symposium essentially dealt with pre-harvest losses by biotic agents only and later initiatives amplified this field of interest to include post-harvest losses, as well as losses or constraints caused by abiotic agents. In 1975 a resolution of the United Nations General Assembly established the goal of reducing post-harvest losses by 50 percent with in 10 years. One of the greatest deficiencies in crop loss work, recognized by the 1967 FAO Symposium, was the lack of suitable methodologies. Thus FAO/CAB manuals were published on Crop Loss Assessment Methodologies. The main scope of these manuals is to provide general guidelines about the principles in crop loss work as well as of giving specific detailed examples of methods already available (Chiarappa, 1981). Please see Figure 34.

**Figure 34:Collecting the left over pods after harvest is a regular practice in Saurastra (Gujarat). Farmers collect about 20 to 30 percent pods of the total yield in this process.**


Harvesting usually consists of a series of operations; digging, lifting, windrowing, stocking and threshing, some of which can be combined or eliminated, depending on the system used. In most of the developing countries groundnut production is usually nonmechanized, there are now more opportunity for mechanizing those operations which are either unpopular or have a limited period for optimum results. In developed countries approximately 100 to 150 hectares of a high yielding variety is considered the minimum economic unit for full mechanization including artificial drying.
Spanish and Valencia types of groundnut usually mature 110 to 130 days after sowing; Virginia types after 130 to 150 days and once the majority of pods are mature delay in harvesting results in substantial loss. The reasons for harvesting loss varies one region to other, but it has been well established that to harvest outside the relatively short optimum period can substantially reduce yield. Too early is as damaging as late. The difference in yield for various harvesting periods in Tanzania is shown in Table 20.

**Table 20. Effect of harvesting date on yields of bunch and runner types groundnut in Tanzania.**

| Bunch type | | Runner type | |
|---|---|---|---|
| Days to harvest | Yield (shelled) kg ha-1 | Days to harvest | Yield (shelled) kg ha-1 |
| 99 | 1 007 | 130 | 1 310 |
| 104 | 1 060 | 140 | 1 495 |
| 109 | 2 130 | 150 | 875 |
| 114 | 1 270 | - | - |
| 119 | 1 001 | - | - |

Source: Weiss, E.A. 1983.

The loss can be higher if the crop is also sown outside the optimum time of sowing. Soil moisture at the time of harvest together with the type of cultivar and method of harvest play an important role in pod losses. Pods are attached to the plant with pegs, on maturity pod get detached from the peg easily, thus during harvest and on lifting a sizeable number of pods remain in situ. Example of pod loss due to the variation in the soil moisture at the time of harvest in an experiment conducted at National Research Centre for Groundnut, Junagadh is shown in Table 21.

**Table 21. Pod losses in groundnut during the harvest under two soil moisture regimes in the soils of Saurastra (Gujarat), India.**

| Habit group | Soil water potential | |
|---|---|---|
| | -0.4 bar | -0.6 bar |
| | Pod losses (%) | |
| Virginia runner | 8.4 | 29.1 |
| Virginia | 2.2 | 10.0 |
| Spanish | 3.2 | 8.8 |
| Valencia | 3.1 | 6.5 |
| Mean | 3.8 | 12.2 |

Source: Devi Dayal, 1985, personal communication.

Harvesting techniques are also important in determining the milling quality of groundnut. Stoking groundnuts normally produces excellent quality haulms and pods but is confined to the developing countries, where machinery is not easily obtainable or where labour is still plentiful. In most of the developing countries plants are left as such to dry in the field after harvest, some method of keeping the pods off the ground is necessary to reduce losses from rotting, termites and moulds. In the literature pod loss in manual harvesting estimated about 10 to 20 percent, where as in the mechanical harvesting pod loss estimated by the USDA are 3 percent in digging and 5 percent during lifting. A survey conducted in Australia concluded that in case of curing in windrows, there is generally a higher incidence of bird, mice and insects damage than in stacking methods. It is estimated that losses in the windrows method are about 10 percent of the total crop in normal years and much higher with adverse weather conditions. It is considered that these losses could be lowered considerably by reducing the length of time that pods are in the windrows (Smyth, 1959). Please see Figure 35.

In developing countries groundnut is harvested using diffe../img/ch21/rent types of digger, which essentially weaken the bondage between the plants and soil or may cut the root part. Plants are subsequently collected in small heaps and left in the field for drying. After digging operation the collection of plants and pods is done manually. During harvest some of the pods remain in the soil and one more attempt, usually, is made to pick-up the left over pods. This operation is done manually and consumes lot of time and labour.

**Figure 35:After drying groundnut is being transported for threshing by a bullock cart. Blue coloured opener (thresher) is seen in the background.**

In Gujarat the summer crop is harvested in June and the rainy season crop in October in both seasons the chances of experiencing rains during curing/drying in the field remains high. Such rains may cause a serious damage to the crop and pod losses may range up to 50 percent. Pods become blackened and attacked by the mould and lose the market value. In the All India Coordinated Research Project (ICAR) on "Harvest and Post Harvest Technology Scheme" at Gujarat Agriculture University the following harvest and post-harvest losses in groundnut have been assessed (Table 22).

**Table 22. Harvest and post-harvest pod losses in groundnut in Gujarat, India.**

| Operation | Pod loss (%) |
|---|---|
| Harvesting | 16 to 47 |
| Curing/Drying | 5 to 50 |
| Threshing | 10 to 20 |
| Storage | Not assessed under the farmers storage conditions |

Source: Singh and Memon, 1983.

In Sudan groundnut is cultivated in heavy clay soil, the particles of the soil adhere to the pods causing problems during harvesting. It is also observed that extra shaking reduced combining losses by decreasing pre-combine and header losses. One extra shaking could reduce total combining losses by up to 3 percent.

## 3.7 Storage losses

Post-harvest losses during storage are among the major problems of the tropical environment, where high relative humidity and temperature are prevalent. As a consequence, mould growth in groundnut seed contributes considerable to bio-deterioration. Groundnut being an oilseed crop is more prone to mould attack than starchy seeds. Lipid peroxidation results in the formation of aldehydes, ketones and other low molecular weight compounds, which may cause off-flavours and odours in stored groundnut seed. Further, these react with proteins, amino acids and vitamins to decrease the seed quality.

Maintenance of seed quality increases with increasing impermeability of packaging and storage material. Seed stored in-shells resulted in 50 percent greater viability than storage as kernel. In estimating the losses caused by insect pests to a consignment of any stored commodity, it is not practical to examine every grain. Measurement of the loss to the commodity as a whole has to be based on the losses recorded from a number of samples. These samples cannot simply be removed from the commodity where it is most accessible, e.g. from the top of sacks or from the surface of a large heap. Insect infestations are seldom uniformly or even randomly distributed within a stock of stored grain. Thus, to obtain samples that give a true indication of loss, methods must be used which ensure that every grain has an equal chance of selection. The theoretical principles of representative sampling should be applied to all types of groundnut storage regardless of the scale of the storage operation. However, the practical problems involved will differ with the storage situation. For the benefit of the readers following methods for calculating the yield losses due to storage pests as mentioned in the ICRISAT Technical Bulletin no. 22 are given below (Dick, 1987).

### 3.7.1 Sack storage

Sampling from grain stored in sacks usually involves numbering all the sacks in a stack or warehouse and using random number to decide which of the sacks are to be sampled on any one occasion. With large consignments, the conditions of storage may very markedly between the sacks, e.g., the temperature at the centre of a sack may be different from that at the surface. These differences should be taken into account by using a "stratified" sampling procedure. At its simplest, this involves the division of a single stack into a number of layers, each containing the same number of sacks. A given number of sacks in each layer are then chosen at random for sampling.

As a practical guide, the optimum number of sacks to be sampled from consignments of differing size is as follow:

- 10 sacks or less, sample each sack,
- between 11 and 100 sacks, sample 10 sacks,
- more than 100 sacks, the number to be sampled equals the square root of the total.

Ideally, the sacks can be numbered and the first samples removed, when the consignment is being placed in storage. This provides a baseline measure against which the losses recorded in subsequent samples can be compared. One the sacks have been stacked many of them are inaccessible. To obtain representative samples, the sack must be dismantled and this will inevitably involve some expenditure on labour and disruption of normal stock movements with in the store. When sacks are broken down for sampling, the sacks should be replaced in their original positions so that the distribution of insects within the stacks is affected as little as possible. It is stressed that if samples are taken only from the most accessible sacks then the loss measurements obtained only represents that part of the total bulk from which they are collected. Similarly, if stocks are removed during the survey then loss levels in subsequent samples must be applied only to that part of the original material still in store.

Just as each sack to be sampled must be selected without bias, every grain within a sack must have an equal chance of inclusion in the final sample. Specialized equipment is available for removing representative samples from sacks of groundnut, e.g. the TDRI Produce Flow Sampler or for reducing the size of large samples without bias in the laboratory, e.g. Boerner or Gamet dividers. Representative samples can be obtained by "coning and quartering" if no suitable equipment is available. This involves emptying a sack onto a smooth surface, thoroughly mixing the pods or kernels by hand and forming a cone shaped heap, which is then divided into quarters using a flat board. Two opposite quarters are returned to the sack. The remaining two are recombined and the process is repeated until a sample of the appropriate size is obtained.

### 3.7.2 Bulk storage

Representative samples can be taken accurately from groundnut in sacks, because the consignment to be examined can be divided into easily identical units. These can then be numbered and sampled at random. This can also be done with bulk storage, when the storage is being filled. The containers used to transport the crop to the storage can be designated as the sampling units; these can be numbered and then selected at random for sampling.

### 3.7.3 Quantitative loss determination

Sampling at monthly intervals is generally recommended. When a delay between sample collection and analysis is expected the samples should be placed in plastic bags with a drop of liquid fumigant such as carbon tetra chloride in order to prevent further development of the insect population in the sample.

There are several acceptable methods for estimating the mass (weight) loss stored cereals and pulses. Yet, there is little experience in using these methods with groundnut. The procedure selected depends on factors such as the availability of equipment and the estimated number of samples to be collected. Whichever method is chosen, groundnut samples must be shelled before mass loss can be assessed. As the wet mass of groundnuts will change with the ambient RH it is usually necessary to perform the calculations using the dry mass of each sample. This can be obtained either placing a sub sample of the groundnut kernels in a suitable calibrated moisture metre or by drying a number of sub-samples (5 x 10 g) in an oven at 103±2°C for 16 h.

### 3.7.4 Standard volume/mass method

The accuracy of this method depends on obtaining an exact standard volume of grain using a simple apparatus called volume of grain using a simple apparatus called a chondrometer that drops an amount of grain from a fixed height into a container of precise volume. The relation between the dry mass and the moisture content of the standard volume of non-damaged grain at the time of storing is plotted on a graph. The dry mass of standard volumes of grain from later samples can then be compared to that of the initial sample and the percentage mass loss calculated as follows:

$$\text{\% dry mass loss} = \frac{D1 - Dx}{D1} \times 100$$

where: D1= dry mass of the standard volume at the beginning of the experiment (read from the graph using the same moisture content as that obtained for DX) and DX= dry mass on occasion X.

In large-scale surveys, which may include numerous sampling sites and different crop varieties, grain size often varies markedly between samples. A single volume/mass relationship cannot be applied to all the samples. The standard volume/mass method can be adopted to allow for situations where baseline samples could not be collected. Each sample can be divided into damaged and apparently non-damaged portions. The mass loss is the difference in dry mass between the non-damaged and damaged portions. With this 'adapted' method relatively large samples (>1 kg) may be required in order to obtain enough damaged or non-damaged grain to measure the mass of the standard volume.

### 3.7.5 Thousand-grain mass (TGM) method

In this method, a sample taken when the commodity is placed in storage is weighed, the number of grains is counted and their moisture content is determined. The dry mass of 1 000 grains is then obtained using the formula:

$$TGM = \frac{1\,000 \times m \times (100-H)}{N \times 100}$$

Where: wet mass of the working sample; H= percentage moisture content of the grain; and N= number of grain in the working sample.

The mass loss to subsequent samples as a result of infestation is calculated by using the formula:

$$\text{\% dry mass} = \frac{M1 - Mx}{M\ 1}$$

Where: M1 = TGM of grain at the beginning of the study; and MX = TGM of the grain on occasion X.

### 3.7.6 Count-and-weight method

This method involves weighing and counting only and generally requires smaller samples than the standard volume/mass method. Each sample is divided into damaged and non-damaged portions. The grains in each portion are then counted and weighed and the moisture content of sample determined. Mass loss is calculated as:

$$\% \text{ dry mass loss} = \frac{(Und) - (DNu)}{U (Nd + Nu)} \times 100$$

Where: Nu= number of non-damaged grains; Nd= number of damaged grains; U= dry mass of non-damaged grains; and D= dry mass of damaged grains.
The count-and-weight method was used by The ICRISAT to assess losses to in-shell groundnuts stored in sacks at an oil mill warehouse near Kurnool in Andhra Pradesh, India. The results showed that if hidden infestation was ignored, loss were underestimated by 1 to 2 percent of the initial dry sample mass (Dick, 1987).

# 4. Storage Pests

Several insects attack groundnuts and groundnut products in storage, sometimes causing severe damage. Approximately 6 to 10 percent of the groundnut insects destroy kernels stored in bags. However, no precise numbers of losses are available. For estimation of losses quantity as well as quality losses should be considered. The standard methodology of collecting samples should be followed.
Groundnuts are stored in shells and as kernels and are highly susceptible to attack by various insect pests. The amount of deterioration caused by these biological factors depends upon the condition of the groundnuts defined by moisture content, how it is stored and its maturity at harvest. Insect infestation causes dry mass loss and increases the level of free fatty acids in the kernels. The result is a reduction in quality.
Due to heavy pest infestation the kernels are completely damaged, losing their germinability. The heat and moisture generated by large insect populations within heaps or stacks of groundnuts may also increase the risk of mould growth. The treatment of groundnuts before storage including harvesting, curing, drying, threshing and handling affects the degree of infestation in storage. Mature pods are less susceptible to deterioration than immature pods. Cracks in the pods developed during drying and handling also boosts the susceptibility to pest attack. The careful and scientific drying of pods prevents the infestation of the fungi and mites.
The number and variety of insect species found in groundnut warehouses and farmers' stocks are quite extensive. Groundnut in storage, particularly in farmers' stock, may contain extraneous plant material. Therefore, the insect species found associated with these groundnuts may actually be attracted to feeding on the extraneous plant materials including fungi, rather than the groundnut crop. These insects are considered contaminants together with the arthropods, parasitoids and predators of the phytophagus pests. An extensive record of these pests has been documented by Pattee and Young (1982). The caryedon serratus is the major pest of groundnut in shell in most of the developing countries.

## 4.1 Major pests species of stored groundnuts

There are 100 insect species that infest stored groundnuts according to the literature. Only those species considered major cosmopolitan pests are described below.

### 4.1.1 Caryedon serratus (Oliver) Coleoptera: Bruchidae, Common name: Groundnut borer and groundnut weevil.

This species found in the Gambia, Senegal, West Africa and India, breeds on common tree legumes such as Tamarindus indica L. plus harvested groundnuts. It is the only species that can penetrate intact pods to infest the kernels. Infestation of the harvested groundnuts can occur while the crop is being dried in the field, stored near infested stocks or crop residues.

Adult females attach their eggs to the outside of pods or kernels. When the first instar larva hatches it burrows directly through the pod wall to reach the kernel, where the larva feed and develop. A single larva can make a large excavation in the cotyledons, but no sign of damage is visible externally at this stage. Mature larvae emerge partially or completely from the pod and construct an oval papery cocoon. The egg to adult development period is about 42 days under optimum conditions of 30°C and 70 percent RH. The adult is 4 to 7 mm long, with small black markings on the elytra. It is readily distinguished from the other pests of groundnuts by its very broad hind femur, serrate antennae and elytra that do not completely cover the abdomen. Groundnuts damaged due to bruchidae is shown in Figure 36.

**Figure 36. Damage due to the storage insects and pests, mainly by Caryedon serratus Bruchidae.**

**4.1.2. Tribolium castaneum (Herbst) Coleoptera: Tenebrionidae, Common name: rust-red flour beetle.**

This species is found throughout the tropics and is regarded major pest of shelled groundnuts. Female lay about 450 eggs at random in the produce. These eggs hatch into cylindrical larvae, which, like the adult, feed on the kernels. Pupation takes place inside the food without a cocoon and the adult beetles may live for 18 months. The developmental period from egg to adult is about 20 days under optimum conditions at 35°C and 70 percent RH. The role of the red flour beetle in the deterioration of shelled groundnuts has been assessed as loss in weight (4.5 percent) and loss in germination (73 percent). The free fatty acid content of the groundnut oil increases manifold, resulting in additional deterioration of quality.

**4.1.3. Oryzaephilus mercator (Fauvel) Coloeptera: Silvanidae, Common name: merchant grain beetle.**

This species is cosmopolitan in distribution. The adults are 2.5 to 3.5 mm long with a distinctive ridged prothorax bearing six large teeth on either side. Each female lays about 300 eggs loosely in the groundnuts over a 10-week period. The eggs hatch into cream coloured larvae, which move freely until fully grown. Both adult and larvae feed on produce and the adult may live as long as 3 years. The life cycle is completed in 4 to 5 weeks under optimum conditions at 30°C and 70 percent RH. The adult and larva burrow into the groundnut seed causing "warm-cut" groundnut and an increased percentage of split seed. Losses occur through contamination of product by live and dead insects, cast skins, frass and excrement.

**4.1.4. Trogoderma granarium (Coleoptera: Dermestidae), common name: Khapra beetle**

This species is more tolerant of hotter, drier conditions than many other storage pests and is commonly found in semi-arid areas of Africa, West Asia and Northern India. The female lays about 50 to 80 eggs that develop into adults with in 25 days under optimum conditions (35°C and 25 percent RH). When nearly mature, the pre-diapauses larvae often leave the stored commodity to enter crevices in the storage structure where they can remain without feeding for many months. The adult beetle is small, 1.5 to 3.0 mm long, densely covered with hair and the larvae are straw coloured with numerous tufts of hair. The adult lives about 14 days.

Consequently, complete disinfestations are difficult and for this reason many countries reject consignments of a commodity infested by this species.

#### 4.1.5. Elasmolomus sordidus: (Fabricius), Hemipetera: Lygaeidae

This bug is widespread in tropical Africa and India, occurring on pods left for drying in the field and in store. The adult is dark brown, approximately 2mm wide. In the field females lay their eggs in the soil or on groundnut haulms but in store, eggs are laid loosely among the groundnuts or in sacking. The first instar nymphs have a bright red abdomen; later instars become progressively darker. All stages feed on kernels, perforating the pods with their rostrum. This causes the kernels to shrivel and increases the free fatty acid content of the oil, producing a rancid flavour.

#### 4.1.6. Corcyra cephalonica: (Stainton) Lepidoptera: Pyralidae, common name: rice moth

This species has the ability to develop at low humidity (<20 percent RH). The adult is brown and 12 to 15 mm long with its wing folded. The head bears a projecting tuft of scales. The female lies up to 150 eggs within a few days of emergence from the cocoon. The larvae are mobile and feed upon and within the kernels. Infestation causes aggregation of kernels by the presence of webbing. The development period at optimum temperature (range: 28 to 30°C) is 4 to 5 weeks. The larvae are capable of damaging intact kernels and feed both on the surface and within seed. They spin a tough silky fibre, webbing together kernels, frass and cast larval skins.

#### 4.1.7. Ephestia cautella (Walker) Lpidoptera: Pyralidae, common name: tropical warehouse moth, almond moth

This pest is common throughout the tropics but is less prevalent in arid areas. It commonly infests shelled groundnut in store. It is a dull greyish brown moth. The forewings have obscure markings, with an outer pale band and broad dark band with a broad pale band on the inner edge. The adult avoids strong light and rests in dark places during daylight. Female lays up to 300 eggs in the groundnut produce often by simply dropping the eggs through holes between the fibres in jute bags or by laying eggs liberally on the surface of the kernels. The larvae move freely through the produce contaminating it with webbing and frass. They feed on the kernels until they are mature. In optimum conditions at 28°C and 70 percent RH, the eggs hatch in three days, develop from egg to adult in about 24 days and complete the life cycle within 40 to 50 days.

#### 4.1.8. Plodia interpunctella (Hubner), Lpidoptera: Pyralidae, common name: Indian meal moth.

This species is more frequently found in cooler areas of the tropics, e.g. highland regions. The basal third of the forewing of this moth is a pale yellowish buff colour. The reminder is reddish brown. The larvae feed on and within kernels and spin a silken thread on which the larval droppings accumulate. Females lay about 500 eggs at a time and development from egg to adult takes about 26 days. The life cycle of this moth may be prolonged by the diapause under certain temperature conditions. During diapause the metabolic activities are very low and normal application rates of control chemicals, especially use of fumigation may not prove effective.

#### 4.1.9. Alphitobius spp. (Coleoptera: Tenebrionidae), Common name: Black fungus beetle.

These species (Alphitobius diaperinus ans A. laevigatus) are 5 to 7 mm long. They feed upon damp kernels, groundnut cake plus other grain residues and their presence in groundnut stores and oil extraction mills is indicative of poor storage conditions involving spillage and dampness.

**4.1.10. Cryptolestes ferrugineus: (Coleoptera: Cucujidae), common name: Flat grain beetle.**

These beetles are small, 1.5 to 4 mm long, flat-bodied and light brown in colour, with long antennae which can be more than half the length of the body. They are mainly scavengers and tend to breed in broken or dusty produce with high moisture content. They are not normally a primary pest of groundnut or groundnut products, but may frequently be found in association with other species.

## 4.2 Relative status of major pests species

Records list over 100 insect species that infest stored groundnuts. In India the major pests of groundnut in store are: rust-red flour-beetle, *Tribolium castaneum* Herbst; the saw-toothed beetle, *Oryzaephilis surinamensis* Linn., the almond moth, *Cadra cautella* (Walker) and the rice moth, *Corcyra cephalonica* (Stainton). The first two species cause damage both in adult and larval stages while the other species harm the crop only in the larval sage. The other minor pests in storage are: *Necrobia rufipes* (Degeer); corn-sap beetle, *Carpophilus dimidatus* Fabr.; the khapra beetle, *Trogoderma granarium* Everts; caddle beetle, *Tenebroides mauritanicus* Linn.; and the lesser grain-borer, *Rhizopertha dominica* Fabr. Bruchid Beetle (*Caryedon serratus*) is the major storage pest of groundnut found in many parts of tropical Asia and Africa. It breeds on common tree legumes such as *Terminalia indica* L. as well as on harvested groundnuts. It is generally regarded as the only species that can penetrate intact pods to infest the kernels. The insect infestation causes considerable losses to the stored groundnuts either stored in-shell for the seed purpose or shelled for milling. Estimated losses due to this pest in India are about 19 to 60 percent when stored for more than 5 months (Pal *et al.*, 2000).

In Gujarat the only primary pest of stored pods *Caryodon serratus* was reported in 1969 but remained a pest of tamarind and only a minor pest of groundnut. However, this pest became a major problem in 1990s. In this part earlier farmers use to store their rainy season produce for the summer planting and next rainy season (about 8 to 10 months storage). Now, due to Bruchid, farmers are unable to store their produce. Storage of the seed by the seed cooperative agencies is being managed by fumigation of Clphos®. In a study of the development of pest populations on stored groundnuts in warehouse in Andhra Pradesh, India, serious losses by groundnut Bruchid were recorded. Reports of damage to groundnuts by this species had previously been confined to West Africa (Dick, 1987). A good post harvest pest management based on good storage practices is the most vital solution. The need for alternatives to chemical measures for the protection of stored products is also strongly felt. In particular, the discovery of insect resistance to methyl bromide and phosphine, the most common fumigants, has intensified the pressure to minimize the use of conventional insecticides against post-harvest pests.

Though various approaches like dissemination of insect pathogen of stored product moths, e.g. the bacterium *Bacillus thuringiensis* or Nuclear *Polyhedrosis* and *Granulosis* virus are in use, either by directs application onto the stored commodity or by applying formulated products (Pal *et al.*, 2000). Looking for the possible source(s) of resistance of Bruchid beetle in germplasm pool and following the IPM approach may be helpful in the control of the Bruchid.

In West Africa, the extent of post-harvest losses has prompted several studies in insect population development on groundnuts stored as pods and kernels. Still, few attempts have been made to measure the extent of losses caused by insects either in farmers` stores or in large commercial storage. Various methods of estimating the extent of storage losses are outlined in Information Bulletin No. 22 published by ICRISAT (Dick, 1987). The most important storage pest in Nigeria is also Bruchid.

## 4.3 Pest control

As most post-harvest groundnut pests except Bruchid are unable to penetrate intact pods, leaving the crop in the shell for as long as possible during storage is an effective method of limiting damage. Infestation of clean stock usually begins in the surface layers of a stack or bulk of groundnuts; the application of an insecticide spray or dust will provide some measure of protection against Bruchid. In sack stores, the sacks on the surface of each stack can be sprayed with any of the insecticides recommended for residual application on store walls etc. although at a lower rate of application (Table 23 and 24). The decision on when to shell groundnut stocks is often based on factors apart from good storage practices, e.g., the economics of transporting a crop destined for export. Groundnut destined for confectionery use or for seed are often shelled soon after harvest so that imperfect or damaged kernels can be discarded. This increases their susceptibility to attack by a number of insect pests. The direct application of insecticides to shelled groundnut is not recommended as this can result in the presence of unacceptable high level of toxic residues. Yet, kernels in sacks can be protected in the same way as groundnuts in-shell, by applying one of the recommended insecticides as a spray or dust to the outside surface of the sacks.

In most of the developing countries where, *Caryedon serratus* is most common storage pest, it is advantageous to store groundnuts unshelled. It is important to detect low-level infestation of storage pests if control measures are to be implemented in sufficient time to prevent losses. The use of traps for this purpose often requires less time and efforts than more conventional methods of inspection, such as 'spear' sampling. Traps cause less damage to the commodity and often provide the first evidence of an infestation that has developed between store inspections. A variety of traps are available differing in cost, sophistication and in the range of insects attracted to them. In the developing countries the high cost of insecticides, the frequent nonavailability of suitable formulation and packaging along with the increasing incidence of insecticide resistance necessitate an approach to post harvest pest management based on sound storage practices. When determining the need for insecticide application, the economically acceptable level of insect infestation must be considered. This will depend on whether the groundnuts are destined for oil production, local consumption, resale as seed or export.

Insecticide-resistant strains of stored-product pests are known therefore the need for alternatives to chemical control methods for the protection of stored products is now seen as increasingly urgent.

- Control of temperature, humidity and atmospheric gases in storage facilities to create conditions unsuitable for insect development.
- Admixture of abrasive materials such as fine sand, kaolin or wood-ash to protect grain in farmer’s level storage.
- Use of plant material such as crushed neem seed, neem leaves or neem oil, which has an antifeedant or repellent effect on storage pest.
- Dissemination of insect pathogens of stored product moths e.g., the bacterium Bacillus thuringiensis, Berliner or nuclear polyhedrosis and granulosis viruses, either by direct application onto the stored commodity or by attracting insects to traps containing a source of the disease.
- Control of pest by natural enemies.
- Use of genotypes resistant to attack by the main post-harvest pests.

**Table 23. Summary of chemical used for prevention of infection of stored groundnuts.**

| Control operations | Insecticide and formulation[1] | Application rate with specified a.i. concentration[2] |
|---|---|---|
| Application of insecticidal spray to interior surfaces of infested stores before refilling | Malathion (w.p) | 250 g 25% a.i. in 5Lwater $100m^{-2}$ |
| | Fenitrothion (e.c) | 200 ml 50% a.i. in 5L water $100m^{-2}$ |
| | Chlorpyriphos-methyl (e.c.) | 200 ml 50% a.i. in 5L water $100m^{-2}$ |
| | Primiphos-methyl (e.c.) | 200 ml 50% a.i. in 5L water $100m^{-2}$ |
| | Iodofenphos (s.e.) | 200 ml 50% a.i. in 5L water $100m^{-2}$ |
| | Deltamethrin (w.p.) | 200 ml 50% a.i. in 5L water $100m^{-2}$ |
| Space treatment of empty stores before refilling | Dichlorvos (resin strips) | 1 strip 30 $m^{-3}$ |
| Direct application of spray to pods or to sacks containing pods or kernels | Malathion (w.p) | |
| | Fenitrothion (e.c.) | Apply at half the rate recommended above |
| | Chloropyriphos-methyl (e.c.) | |
| | Primiphos-methyl (e.c.) | |
| | Iodofenphos (s.c.) | |
| | Deltamethrin + piperonyl butoxide (e.c.) | 10 ml in 990 ml water $t^{-1}$ |
| Surface application to or admixture of insecticidal dust with pods | Malathion (dust) | 500 g 2% a.i. $t^{-1}$ |
| | Deltamethrin (dust) | 500 g 0.2% a.i. $t^{-1}$ |
| | Fenitrothion + carbaryl (dust) | 500 g 1.2% + 0.8% a.i. $m^{-2}$ of surface area |
| | Bromophos (dust) | 200 g 2% a.i. $m^{-2}$ of surface area |

**Table 24. Summary of chemical used for control of infection for protection of stored groundnuts.**

| Control operations | Insecticide and formulation[1] | Application rate with specified a.i. concentration[2] |
|---|---|---|
| Fumigation of bagged or bulk stocks in gas-tight stores or under gas-tight sheeting | Methyl bromide + chloropicrin (gas) | 10-15 g $m^{-3}$ for 24 h (dosage increased for control of *T. granarium*) |
| | Phosphine (solid aluminium phosphide) | 3-5 tablets or 15-25 pellets 57% a.i. t-1 for 7-10 d. |
| Fumigation of small quantities of pods or kernels in polyethylene-lined sacks or containers such as drums | Phosphine (solid) | 2-3 pellets 100 $kg^{-1}$ for 7-10 d. |
| | Ethylene dibromide (liquid) | 3 ml 100 $kg^{-1}$ |
| | Ethylene dibromide + carbon tetrachloride, 1:8 mixture (liquid) | 12 ml 100 $kg^{-1}$ |

a.i. = active ingredient; e.c. = emulsification concentration; s.c. suspension concentration; w.p. = wettable powder.Source: Dick, K.M. 1987
If other formulations are used with a.i. concentrations differing from those given above, the amount of whole product used must be changed accordingly.
In countries resembling India and its subcontinents where groundnut is sown immediately after the summer season, the shelling of pods and storing of seed (kernels) for even a month or two in advance of the sowing period may result in the impairment of the viability and damage by insects pests. It is therefore recommended that the seed should be shelled only a week before sowing. There is urgent need to establish the potential and practicality of the integration of biological, physical and chemical control measures, in order to reduce the problems created by the synthetic insecticides. Information on the effect of mainly the bruchid (*C. serratus*) insect infestation plus on the quality of groundnut oil from the groundnut-growing areas other than West Africa is urgently required. This might eventually allow the determination of economic thresholds for the main pests attacking stored groundnuts in the developing countries.
A new method for the protection of stored groundnuts in Africa Numerous pests, notably rats and insects invade groundnut in storage in the granary. Groundnut bruchid is the most important pest. Damage caused by this insect in 1988 to 1992 was extensive for whole granaries were totally destroyed. Research into low cost technology to protect stored groundnut showed that Samakada (*Swatzia madagascariensis*), 2 kg of powder fruits to treat 100 kg groundnuts was very effective against Bruchids and Pyralids for the groundnuts stored in granaries. Additions of sand as an abrasive material at the farm level was very effective (Doumbouya, 1998).

## 5. Economic and Social Considerations

Field operations of groundnut crops correspond in many respects to other annual crops. Only in the preparation of seed for sowing, harvesting and processing of produce for the market, does groundnut differ essentially from the rest. For the case of groundnut these operations are not only time-consuming but also expensive. In spite of these handicaps, farmers prefer this crop because it is easy to sell and fetches a fair return.

Groundnut is the fourth most important source of edible oil and the third most important source of vegetable protein. It contributes significantly to the diet of people in many developing countries. Populations in rural areas largely depend upon subsistence agriculture, as there is low consumption of food of protein-rich animal products. The consumption of groundnut can minimize dietary deficiency. It has high caloric value from oil, proteins, minerals and vitamins. Protein content does lack lysine and methionine. Self-sufficiency in these two amino acids can be achieved through genetic improvement in cultivated groundnut. Please see Figure 37.

**Figure 37. In a village of Saurastra (Gujarat) groundnut haulms as animal fodder are stored in the room the remaining space is being utilized for educating the new generation.**

The smallholder producing groundnut as a food crop for their traditional farming practices have been little affected by improvements in agricultural technologies. Thus strategies to benefit smallholder farmers means more work opportunities for ever-increasing members of underemployed rural poor.

Groundnut as a source of protein and oil can play a major role in improving the calorie and protein value of the diet available to poor men and school children. This is particularly true in the developing countries, where malnutrition is a major problem. The harsh fact is that over more than half a billion people in the world are malnourished. Mozambique is the largest producer of groundnut in southern Africa. The crop is grown almost throughout the country, with the largest concentration in Nampula Province in the northern region. Groundnut plays an important role both as food and cash crop for smallholder farmers. It is a key component of the rural diet and provides supplementary cash income to women farmers. The crop is grown and managed mostly by resource-poor farmers, especially women.

The haulms at the harvest and cake after extraction of the oil are a major source of nutrients for animals. On small farms, they form the principal fodder and feeds for the ruminant livestock during dry season. Wild perennial Arachis species are also potential source of green fodder, chiefly in the dry season. In drought prone areas of Gujarat (India), farmers prefer groundnut crops because of its drought tolerant character, lower water requirement

(especially during the vegetative phase) and fodder value. Concerns about inadequate utilization of available feed in the developing countries have lead to the establishment of research programmes to improve the nutritive value and utilization of crop residues as ruminant feed. Despite this, farmer uptake of research findings has been limited.
Farming system research may be an essential tool to enhance the relevance of research on groundnut production and utilization in the semi-arid tropics. At the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), village level agricultural studies in India and in West Africa were conducted in the millet/groundnut zone. On the face of it, groundnut as a cash-food crop should blend well into drought tolerant food production systems. When the price is right more groundnuts can be grown for sale enabling the purchase of food requirements when groundnuts are in greatest demand. The crop fits well into nutritional subsistence food production systems.
The significance of groundnut as fodder and feed may vary in different production systems. Diversity of production goals, resource endowments and socio-economic conditions create assorted opportunities for the use of crop residue. Consequently, in designing research and extension projects that seek to improve its use as livestock feed, it is pertinent to identify the main livestock production systems, farmers' production objectives, resource endowments and determine the appropriate crop-residue-based diet for each system. Groundnut has several qualities and utilities that also fit well in the sustainable food production system. For instance, groundnut possesses the ability to maintain or increase food production over the long term without damaging or depleting the resource base in the fragile ecosystem.

## 5.1 Overview of costs and losses

Farming is a business proposition like industry and costs are accounted for against returns. The data on the production costs provide the basic framework to analyse the economic viability of the crop. The awareness of the farmers about increases in the prices of inputs such as fertilizers and pesticides has made them more cost conscious. As a result they resort to enterprise budgeting before raising the crop. Detailed study of the cost components of production and distribution may help to cut down excessive costs on less productive components. Analysis can also guide decisions to increase investment on more productive components. Study of cost price structure may form the basis for minimizing costs and increasing profitability. Hence, there is a need for data collection relevant to the crop production costs on a comprehensive basis in the developing countries.
The high cost of production for groundnut is mainly due to the heavy seed-rate adopted and the large labour force employed for harvesting and threshing. As groundnut have large seeds and low multiplication ratio, collecting the seed costs about 40 percent of the total cultivation outlay. The expenditure on these and other cultivation operations varies largely between groundnut-growing countries. Farming expenses are conditional on the variety grown, soil and climatic conditions, cultivation practices, implements used for field operations, rate of hire charges for work bullocks, wages of mazdoors plus other factors.
Note: The cost of cultivation increases with the use of technology. Examples include tilling with the help of tractor, sowing by seed drill and inter-culture by mini-tractor. Tractors and other farm machinery provide pay back in timesavings from faster execution of these operations. Details of current cultivation practices in Gujarat, India are furnished in Table 25.

**Table 25. Assessment of the cost of cultivation of groundnut during rainy and summer seasons in Junagadh district of Gujarat, India.**

| Details of field operations | Rainy season Bunch type | Rainy season Runner type | Summer season Bunch type |
|---|---|---|---|
| 1. Preparatory tillage | | | |
| i.) Ploughing with country plough 2 men (@ US$2 per person and US$3 per 2 bullock pair) | 10 | 10 | 10 |
| ii.) Harrowing (1 man, 1 bullock pair) | 5 | 5 | 5 |
| iii.) Planking (1 man and 1 bullock pair) | 5 | 5 | 5 |
| 2. Seed and sowing | | | |
| i.) Runner (100 kg $h^{-1}$ and Bunch 120 kg h-1) | 65 | 54 | 65 |
| ii. Seed treatment (500 g Dithane M 45) | 2 | 2 | 2 |
| iii. Sowing (2 men and 2 bullock pairs) | 10 | 10 | 10 |
| iv.) Manure (FYM 10 t $h^{-1}$, 4 tasks) | 7 | 7 | 7 |
| v.) Fertilizer (N as urea and P as SSP) | 12.5 | 12.5 | 25 |
| vi.) Irrigation (7 tasks) | rainfed | rainfed | 27 |
| 3. After care | | | |
| i.) Intercultivation (2 men and 2 bullock pairs) | 10 | 10 | 10 |
| ii.) Weeding (thrice in rainy and twice in summer seasons) | 39 | 39 | 26 |
| iii.) Pesticides spray | 5.4 | 5.4 | 3.2 |
| 4. Harvesting | | | |
| i.) Digging with blade (2 men and 2 bullock pairs) | 5 | 5 | 5 |
| ii. Drying, cleaning and threshing (10 tasks with one motor thresher run for 5 hours) | 34 | 34 | 34 |

| Details of field operations | Rainy season Bunch type | Rainy season Runner type | Summer season Bunch type |
|---|---|---|---|
| 5. Interest on working capital @ 10% for 4 months | 10 | 7 | 8 |
| 6. Supervision charges @ 10% of working capital | 30 | 28 | 32 |
| 7. Repairing and depreciation charges of implements @ 3% per annum for 4 months | 3 | 3 | 3 |
| 8. Depreciation charges of buildings @ 2% approximate cost of building US$1 086. | 22 | 22 | 22 |
| 9. Total fixed capital (1+ 8) | 356 | 344 | 385 |
| 10. Interest on fixed capital @ 6% for 4 months | 7 | 7 | 8 |
| 11. Land rent @ 16% of gross income for 4 months | 130 | 148 | 148 |
| 12. Total cost of cultivation | 494 | 498 | 540 |
| 13. Total income | | | |
| i.) Main product | 587 | 652 | 652 |
| ii.) By product | 228 | 271 | 271 |
| 14. Profit = income- cost | 321 | 425 | 373 |

Source: Department of Agronomy Gujarat Agriculture University, Junagadh campus, Junagadh. Cost of cultivation has been calculated in US$ per hectare.

The cost of raising the rain-fed crop ranges from US$450 to 550 ha-1 depending on local conditions. It is generally more expensive in Tamil Nadu where most of the field operations are carried out manually. The comparatively low cost in Andhra Pradesh and Gujarat is mainly due to the use of labour saving implements and adoption of low seed-rate. In spite of the high cultivation cost in Tamil Nadu the return from the crop compares favourably with those obtained in other states because of the higher yields obtained. Even in this State, the production cost is perhaps the highest in the Pollachi area as a result of the thorough preparatory cultivation given to the fields and the very heavy seed rate used. The rental charges for work bullocks and mazdoors wages are also substantial.

Groundnut cultivation employing irrigation is done extensively in Tamil Nadu, Andhra Pradesh, Maharastra and Gujarat states. Cultivation of the irrigated crop is generally more rigorous as it receives special attention such as preparing the land, manuring and other tasks.

The cultivation costs for the irrigated crop in Gujarat is identified in Table 25. As the irrigated crop offers better yield and economic returns, a large area should be devoted to this method. Rain-fed crop as well should be supplemented by irrigation during dry periods wherever facilities are available. These steps would help to boost the area under cultivation and the crop yield in India. In Saurastra, India best returns may be achieved at the start of the monsoon, if the farmers are able to sow the runner crop variety in the first fortnight of June. However; if the onset of monsoon is delayed and sowing is not possible during June, farmers should always sow the short duration bunch types instead.

Ways to reduce cultivation costs: The need for reducing the cultivation costs of this crop has not been realized by growers in the developing countries. The problem arises out of two important considerations: i.) ensuring optimum return from the crop even under conditions of low prices, ii.) facing competition from the other groundnut growing countries.

Thus cost of cultivation may be reduced by mechanization with the hand operated or power operated implements as suited to the location and specific area.

1. Implements to be used for reducing expenditure on sowing, intercultivation and harvest of the crop have been demonstrated widely by various agricultural universities. The volume of work required to strip groundnut pods may be reduced considerably, using a mechanical stripper. A drum-type groundnut stripper developed by the Tamil Nadu Agricultural University can strip about 150 kg of pods in 8 hours by engaging only one women worker.
2. Use of a hand-operated oscillating type or pedal-operated decorticator would diminish the shelling cost considerably without serious damage to kernels. Even in separating healthy seed from the shrivelled, broken and diseased ones, the process of handpicking can be avoided by the use of a grader.
3. It is now widely recognized that line sowing with seed drills helps to regulate seed-rate and cover large areas within a short time.
4. Farmers are reluctant to invest in fertilizer and pesticides because of the risks involved in raising rain-fed groundnut crops. This is due to the uncertainty regarding quantity and distribution of rainfall during the crop period. Doubt concerning rainfall leads to instability in production, productivity and widely fluctuating price patterns due to extreme speculative trade in groundnuts. If price support is offered to the farmers, they may invest in quality seed, fertilizers, pesticides and thereby increase productivity.

Thus there is a wide scope of activities to reduce the cost of cultivating the groundnut crop in the developing countries. The state Departments of Agriculture should undertake large-scale tests with the various labour saving implements and machinery available. Further they should standardize the operations in each case with a view to reducing expenses to the minimum. Extensive use of such labour saving devices would only enable farmers of the developing countries to realize a better return from the crop. Appropriate crop growing techniques also makes developing nations more competitive compared to other groundnut-growing countries, especially those which are fully equipped for the cultivation of groundnut in mechanized farming.

Competition with other crops: In India groundnut is grown primarily as rain-dependent crop and usually competes with jowar, bajara, cotton and paddy. In spite of the higher cost of cultivation and several risks, including drought during the pod-fill phase, the farmers prefer groundnut. For example, in Gujarat groundnut competes primarily with bajara. However, following the introduction of bajara in the mid 1960s, groundnut lost its relative share in gross crop area until the mid 1970s. Since than, there has been an upward trend in groundnut acreage accompanied by a decline in bajara`s area. Price Commission, the agency responsible for recommending support and procurement prices conducted a survey "The impact of India’s grain revolution on the pulses and oilseeds" for the groundnut crop. Table 26 summarizes information given in the project report on the cost, revenue and income for the cultivation of groundnut and Bajara.

**Table 26. Cost of cultivation of groundnut and its competing crops (US$ $ha^{-1}$).**

| | | | | | | |
|---|---|---|---|---|---|---|
| Gujarat | | | | | | |
| | Groundnut | | | Bajara | | |
| | Cost | Revenue | Income | Cost | Revenue | Income |
| 1973-74 | 29 | 37 | 8 | 18 | 26 | 9 |
| 1974-75 | 28 | 28 | 1 | 22 | 30 | 8 |
| 1975-76 | 32 | 47 | 15 | 21 | 25 | 4 |
| 1978-79 | 38 | 41 | 4 | 34 | 44 | 10 |
| Tamil Nadu | | | | | | |
| | Groundnut | | | Bajara | | |
| | Cost | Revenue | Income | Cost | Revenue | Income |
| 1973-74 | 40 | 49 | 9 | 38 | 47 | 10 |
| 1974-75 | 39 | 34 | (-) 5 | 54 | 85 | 31 |
| 1975-76 | 39 | 37 | (-) 1 | 29 | 76 | 47 |
| 1978-79 | 45 | 44 | (-) 1 | 68 | 80 | 12 |

Source: Ministry of Agriculture and Irrigation, Directorate of Economics and Statistics, Indian Agriculture in Brief (Delhi, 1983). Referred by Meenakshi et al. 1986.

Note: a. revenue includes the values of the main crop and the values of by-products. b. Cost include values of: hired labour, family labour, bullocks, machines, seed (both owned and purchased), manure and fertilizer, insecticides, pesticides, depreciation, irrigation charges, land and other taxes, interest on working capital, interest on owned capital, owned land and rent for leased land.

A lost trade

The area devoted to groundnut has fallen to low levels in Western Africa. The key to recovery is restoring farmers' confidence that they can grow the crop without losing their harvest to a divesting disease. Kano's "groundnut pyramids" used to be proudly pointed out to visitors. The huge piles of sacks that tapered to a point higher than most of the city’s buildings were a symbol of Northern Nigeria’s abundance in this important cash crop. Today the dusty yards where the groundnut marketing Board stocked-piled farmers' harvest lie almost empty in Nigeria. As in other major producer countries of Western Africa, groundnut production has never recovered from the disaster that struck in 1975. An epidemic of rosette disease destroyed nearly three-quarters of a million hectares of the crop and wiped out regional trade worth estimated US$250 million. Combined with aflatoxin contamination, rosette disease is a major region why buyers turned away from Africa to other, more reliable suppliers. Transmitted by aphids, rosette disease remains a major constraint to groundnut production across Western Africa. Yield losses of 10 to 30 percent are common, but rise to 100 percent when the disease reaches epidemic proportions. Many of the farmers who suffered financial ruin in 1975 have since limited their cultivation to safer crops such as cowpea, sorghum and pearl millet.

## 5.2 Major problems

### 5.2.1 Lack of suitable farm equipment and facilities

Bullock drawn seed-drills are used in most of the developing countries to sow the seed. Regulation of spacing within and between the seed rows is not perfect using this method. Still this technology will go a long way in increasing productivity. At present seeders, diggers, strippers, shellers and graders are available in the market, but most of them are power operated. The economic condition of small-scale farmers in the developing countries is so bad that they cannot afford such expensive equipment. For small landholders, power drawn equipment is not economical. Groundnut is a labour-intensive crop. New design and introduction of appropriate indigenous low-cost bullock drawn implements would increase the efficiency of operation, thereby reducing the time necessary for each operation and cost of cultivation.

The groundnut plant is unique in the world as its pods remain in the soil, absorbing calcium directly through the pod surface. Calcium in groundnut plays a major role in determining the quality of seed or kernels. Since the pods are located underground, the challenge is the absence of suitable implements for harvesting. Non-implementation of the manually or power operated tools, lack of knowledge and attitude to the production of quality produce seems to underlie other principal post-harvest problems. The curing/drying and storage facilities at the farmers' level also contribute much to the deterioration of seed or kernel quality in storage. Under the present status of groundnut cultivation in the developing countries, equipment and methodologies are required for various harvest and post-harvest operations. For example:

- Harvesting equipment and methodologies need to be modified to lift the groundnut plants and the leftover pods in a single operation. This minimizes the harvest losses and increases the quality of groundnuts,
- Suitable drying methods are required to avoid the excessive heat in the windrows or heap drying plus reduction in quality due to the rains immediately after harvest,
- To maintain the seed and milling quality the drying procedures must be standardized,
- Farmers' storage facilities are very poor. Low cost technology is required to store seed at the farm level,
- Various power and manually operated equipment used in the post-harvest operations such as threshers, decorticators, shellers and product processing equipment either need to be improved or their efficiency must be increased.

### 5.2.2 Gap in the processing industries

Four types of processing methods for extraction of oil are being used in India. Oil is obtained by crushing in village ghanis, rotaries, expellers and solvent extraction plants. It is necessary to launch a programme for improving the efficiency of the large number of processing units, particularly in the rural sector. Considerable improvement in the processing of oil by mills in India could be achieved through the addition of balancing equipment. Small-scale industries for preparing groundnut butter, milk and various other items need to be encouraged in the rural areas.

### 5.2.3 Seed production

Low productivity may be explained by noting that groundnut seed contributes about 40 percent of the total input cost, has a large size and low multiplication ratio compared to cereals. Consequently the production of quality seed and timely supply affects a bottleneck in popularizing the new released varieties. The situation observed today in India clearly warns that groundnut productivity can be increased substantially improving cultivation practices. These enhancements comprise integrated crop management and post-harvest practices, rather than breeding the new faster maturing varieties alone. Groundnut seed are also prone to loss of viability during storage plus losses due to very serious insect and pest damages. Timely availability of the quality seed and expense are the major constraints in the cultivation of groundnut by the small land-holders.

Poor quality of seed continues to be one of the major problems limiting the spread of summer or winter season groundnut in the states of Maharastra, Karnataka, Andhra Pradesh, Tamil Nadu, Gujarat and Orissa. Prevailing weather conditions, improper drying and post-harvest practices currently adopted by the farmers in the summer groundnut growing areas make the produce unfit for the use as seed in the next rainy or winter/summer seasons. Accordingly, farmers cultivating groundnut in the winter/summer season in the paddy fallow are compelled to depend on poor quality seed brought from the neighbouring states. The consequences lead to considerable delay in sowing and poor emergence evidenced by patchy crop stand.

As far as possible seed production programmes in various developing countries need to be organized on cluster basis for selected varieties in high demand and where shortfalls are anticipated. In case of a self-pollinated crop like groundnut, farmers may have to be advised to retain sufficient seed for next year's sowing. A preliminary assessment of benefits accrued from producing and marketing groundnut seed at the farm level in Maharastra showed that seed production activity at village appears to have several advantages over existing centralized large scale production and procurement by state owned organizations. The immediate benefit is timely seed supply to farmers at their doorstep. Elimination of intermediate agencies appears to allow larger profits for seed producers.

Greater communication of experiences is required if farmers' aspirations are to be raised regarding the outcomes of adopting new post-harvest technologies. Key positive factors were found to be higher annual farm income and education levels. Groundnuts required for seed purposes must be handled with much more care than enabled by normal commercial operations. When groundnuts are a major cash crop in an area, special crops should be grown specifically to provide seed. The extent of mechanical damage and its effect on germination and seedling vigour are not always appreciated, since damage to kernels may not be obvious visually. Hand-harvested seed can give twice the final stand and twice the yield of mechanically harvested seed (Roy et al., 1978).

Widespread and severe drought conditions have given a serious jolt to seed production programmes in India. The production of basic, breeders, foundation and certified seed of groundnut crop, therefore require highest priority in the winter/summer, if the availability of adequate seed supplies at the right time and place for rainy season sowings is a constraint. The winter/summer season provides ideal conditions for production of quality seed required for rainy and winter/summers. All our efforts should therefore, be made to take full advantage of the assured moisture and irrigation facilities available in various areas and launch massive seed production programme in groundnut to ensure that seed does not become limiting factor for subsequent rainy season sowings (Ranga Rao and Mangla Rai, 1987).

Is a better life possible for smallholder farmers? Good science is not enough. It must be backed by good extension work. A good example this is found in Malawi, where the national programme, the United Nations Children's Fund (UNICEF) and ICRISAT are working together on a package deal for CG 7, a variety that could be major success story for groundnut in Africa. A number of simple factors like cost and availability of technology as well as more complex factors such as the social and culture milieu and compatibility of the new technology with traditional farming practices governs adoption. ICRISAT-Malawi NARS teams helped the adoption of CG 7. Two major problems were inadequate extension and lack of seed. In response to these problems, ICRISAT and NARS introduced a new scheme during the 1993/94 crop season involving over 300 women farmers as most groundnut farmers in Malawi are women. The object was to deliver affordable, high-quality CG 7 seed to farmers and simultaneously improve awareness of this variety by establishing on-farm demonstration/evaluation plots. Each farmer in the scheme was given 1 kg of seed. She could retain whatever she harvested, but had to return 1 kg of seed, which would be distributed to other farmers.

In 1981 a report on the Oilseed Growers Cooperative Project by the CLUSA/USAID project assessment team was submitted with the following recommendations on the improved seed supply to the farmers in India:

"Of the project’s input supply constraints by far the most crippling is the absolute scarcity of improved seed. The crux of the problem involves the limited acreage available to the project for seed multiplication activities. The recent experience of other developing countries with seed multiplication programmes clearly demonstrates that successful operations depend on two essential prerequisites: i.) seed farm and their required seed treatment facilities must be fairly large-scale undertakings run on a centralized basis and ii.) These operations are best managed by private sector enterprises in oilseeds it must be able to make available to growers genetically improved seed on a massive scale, seed of a sufficiently consistent quality that growers will entirely abandon the shortage of their own seed stocks. The team feels that for the project as a whole there will eventually arise the need for perhaps four seed plants of about 100 tonnes daily capacity each. On the other hand, in the absence of sufficient farm properties available to the project for seed multiplication activities, stop-gap strategies for seed supply may have to include village level schemes where one growers of every ten will specialized in the production of improves seed for his neighbours. The team is fully aware that the latter approach would create complex problems of local-level training and supervision to guarantee high seed quality; the team only endorse it as a strictly temporary activity conducted with already-selected grower demonstrators until such time as more adequate seed farm acreage and seed treatment plants have become operational".

**5.2.4 Economic and social considerations**

The economic and social considerations vary among the countries due to variation in the agriculture policies and the priorities. The problem and impact of government policies has been discussed taking the example of India, where groundnut is cultivated on the largest area in the world. Department of Agricultural Economics, New York State College of Agriculture and Life Sciences, submitted a survey report Cornell/International Agricultural Economics Study "The Impact of India’s Grain Revolution on the Pulses and Oilseeds" (Meenakshi et al., 1986). The highlights of the report on groundnut are mentioned below:

"Much of the interest in the Indian oilseeds economy has estimated from India’s large imports of vegetable oils recently. From being an importer of cereals and an exporter of vegetable oils in the 1960s, India has become an occasional and minor exporter of cereals and a regular and major importer of vegetable oils. This trade shift has occurred because the green revolution, which primarily benefited the cereals, did not extended to oilseeds and per capita consumption of oilseeds has declined". Please see Figure 38.

**Figure 38.Groundnuts are very popular in Saurastra (Gujarat), India and small farmers usually take it to their home to eat after roasting where as city dwellers purchase it from the market.**

The demand for vegetable oils in India is driven primarily by that of edible oils. Domestic utilization of oilseed cakes and meals is low and exports are restricted. In fact, oilseeds in India are produced in order to satisfy vegetable oil demand, rather than oilcake demand. In the case of groundnut only a minor portion of oilseed production is used as seed or for snacks. In 1990s, demand pressures and the resultant skyrocketing of vegetable oil prices forced the government of India to liberalize its vegetable oil import policy to insure availability to the economically weaker section of the population. Nearly 400 000 tonnes of vegetable oil were imported in 1967 to 1977, constituting a 400 percent jump over levels in previous years. The value of imports has gone up correspondingly and averaging over seven billion rupees during the three years ending in 1984 comprising approximately half the value of agricultural imports. This expenditure drained India's foreign exchange reserves. Until the late 1970s, vegetable oils could be imported free of custom duty. However, the Government of India felt the benefits from such a policy "were not fully accruing to the consumers" and that private traders were making large profits by maximizing domestic price through hoarding. Consequently in 1978 it channelled virtually all imports of vegetable oils through the state trading Cooperation of India. This directive has enabled the State Trading Cooperation of India to monitor the international market effectively and immediately take advantage of any downward price change. (FAO, 1982). Please see Figure 39.

**Figure 39.A camel cart from the field to the farmhouse for threshing is transporting groundnut vines.**

The green revolution in India, which entailed the adoption of high-yielding varieties together with an appropriate combination fertilizer application and water and pest management techniques, has, in fact, been a grain revolution. Its impact on Indian agriculture has been uneven for while the cereals have benefited from it, the oilseeds have not (Meenakshi, et al., 1986). No counterparts of the high-yielding varieties of cereals were developed for the oilseeds. The grain revolution acted to increase the relative profitability of cereal in comparison with the competing oilseed crops. In view of India's noted Agriculture Economist "the high yielding varieties, typically increased the profit per unit of the output, i.e. they led to a reduction in the unit cost of production as a proportion of output" (Hanumantha Rao, 1975). Therefore, while cereal production kept up with population growth, oilseed production did not.

At present the major responsibility of groundnut research lies with the All India Coordinated Research Project (Groundnut). In addition to the AICRP and research carried out in the State Agricultural Universities, several programmes exist under the auspices of the Indian Council of Agricultural Research (ICAR) to undertake groundnut research. Noteworthy among them is the National Research Centre for Groundnut, Junagadh. The International Crop Research Institute for the Semi-arid Tropics (ICRISAT), Hyderabad, India, also has a major groundnut research programme. The first groundnut cultivar (Spanish improved) in India was released in 1936. After that about 80 varieties have been released, averaging 2 to 3 varieties per year. Nevertheless, not much has been achieved to increase productivity by developing new technologies and varieties.

The processing and marketing of oil is in the hands of a few traders who are in the position to exploit the farmers. Partially as a response to this fact, the Gujarat Cooperative Oilseeds Growers' Federation (GROFED) was set up in 1979 in major groundnut-producing districts of Gujarat, in the belief that "by organizing farmers around a commodity system and resting with this farmer's organization the management and control of technically superior processing and marketing facilities, so that a greater proportion of the consumer rupee can be paid to the producer in comparison to what the traditional trade can pay". Unfortunately the GROFED has stopped functioning since 1993. Such cooperative organizations need to be established and strengthened with a strong political will in the developing countries.

### 5.2.5 Groundnut production constraints in Ghana

Groundnut is the most widely cultivated crop in Ghana and is featured prominently in the crop systems of the Savannah and Forest-savannah transitional agro-ecological zones. The major production limits identified by farmers, extension workers, researchers and other stakeholders include:

- diseases such as rosette, cercospora leaf spots, rust and aflatoxin contamination,
- inadequate supply of improved seed,
- high cost of labour especially for picking and shelling (manually) pods,
- pre-harvesting of seed, soil pest (termites and millipeds).

National Agricultural Research Project (NARP) is currently funding 16 research projects on groundnuts. Other areas of research cover socio-economic studies, development of cleaning and dehulling machines for small-scale processors in addition to some technology transfer activities on groundnut cultivation, processing and utilization. There is a need for future investigation to target breeding for high nitrogen fixing and drought-tolerant varieties. Further it is crucial to prioritize specific quality traits, for example oil and protein for the processing industries. There is also a need to develop simple harvesting and shelling machines for small-scale farmers (Asafo-Adjei, et al., 1998).

## 5.3 Gender aspects

Most of the post-harvest activities like picking, drying, threshing and shelling are traditionally performed by the farmwomen. The techniques used by them are extremely arduous, involving a large investment of time for few results. Two categories of women are engaged in this type of activity. The first, farmwomen, process their own crop for family consumption while the second known as landless women or wives of marginal farmers, process other people's crops as a way of supplementing family income. The introduction of crop processing equipment has different implications for these dissimilar sectors of society. Farmwomen may find they are released from tiring, unproductive work so that they can devote more time to childcare. If it is available, they may involve themselves in more remunerative kinds of activities, which would help them pay for the use of machinery. Landless women may find themselves relieved of their only means of earning a living. Indeed, the introduction and spread of Engleberg mills in countries such as Indonesia and Bangladesh has destroyed millions of part time jobs for the poorest individuals in society. Estimates show that 7 to 8 million women lost their jobs following mechanization of rice milling in Java (Carruthers, 1985). Please see Figure 40.

**Figure 40. Harvesting and picking groundnut pods done by female labourers in experimental plots at the National Research Centre for Groundnut, (ICAR) Junagadh, India.**

Participation of women in agriculture especially in developing countries has been appreciated silently, without much recognition and documentation of their contribution. They have not been prepared for active involvement in the development process. By and large, they have remained "invisible workers". Since 1970s, a global concern for the emancipation of all women with special emphasis on rural and farmwomen has been expressed in numerous ways aimed at improving the working environment of women along with raising their standard of living. Limited efforts have been made in scientific organizations and institutions for creating appropriate technologies for women acknowledging the nature and extent of their environment in various enterprises plus considering their work culture and milieu (ICAR, 1988).

Groundnut contributes significantly to household food security. Since many smallholder farmers in the developing countries are women, it has an important bearing on the gender issue. Gender-related Iissues impact labour allocation and activity patterns. It further affects labour requirements for groundnut production, use of hired labour, decision making for resource allocation and decision making for distribution of benefits. As indicated by user perceptions in developing countries like India, technology adoption increased the workload of women farmers and expanded the employment prospects of female wage-labourers.

Development of technologies enhanced the unequal power relationship between men and women, therefore reinforcing stereotyped responsibilities within households. Women tended to lose in resource allocations, but marginally gained in benefits distribution. Still, there was a inclination to push women into the domestic sphere and men into marketing.
The women's participation in agriculture is a multifaceted area for research. It is difficult to clearly understand and appreciate their role and contribution unless all the major data are studied in depth. Information must be analyzed individually as well as through a systems approach. A critical look into the micro-level studies conducted so far revealed the following:

i. participation in agricultural and allied activities;
ii. decision-making in farm and home-related matters;
iii. impact of new technology on employment and income;
iv. time use pattern;
v. access to development inputs and services including technology, credit and training;
vi. participation in rural-agricultural development programme; and
vii. role expectation and role performance.

There is a lot to be done to improve socio-economic conditions, while increasing active participation of women in the developing countries.
ICRISAT has conducted a survey on "An ex-post gender analysis of impact of groundnut crop production technologies in the India SAT". The following summarize the major research results (ICRISAT Annual Report, 1995):

- Demand for female labour had gone up with the introduction of technology. Labour use patterns show that women play an important role in groundnut production.
- Groundnut production technologies created a positive impact on the yields and income form groundnut for the farm households and helped to create an informal farmer-to-farmer seed market, boosting their income considerably.
- High cash inflow from groundnut crop increased the decision-making power of men regarding uses of output and household expenditure pattern. Women do not have input and output markets. Hence policies have to address these issues. New technologies create a gap between men and women in household decision-making power.
- Women are equipped with less information to express their preferences and to increase their decision-making powers.
- Perceptions of men and women farmers revealed that the criteria, as well as number of criteria for evaluation of groundnut varieties, were different for men and women. The criteria used by women were very closely related to the operations performed by them.
- Women's concerns were centred on harvesting and processing problems.
- Factors for consideration in technology development are high capital cost, increase in labour requirement, workload associated with practices and longer duration of the crop.
    - Intra-household dynamics of technology intervention: A gender analysis approach
- In another study on "Intra-household dynamics of technology intervention: A gender analysis approach" conducted at ICRISAT, Hyderabad, India (ICRISAT, Annual report 1995), showed overall higher benefits for the technology village (Umra). The difference between access and control clearly speaks of the disadvantageous position of Umra women. The benefits analysis revealed that new technology led to creation of new markets for different groundnut products. For example, before the technology intervention, the market was for groundnut pods only, while the introduction of new technology and its quick adaptation created a new seed market.

- The group discussion conducted with men and women of farm and labour households to ascertain their performances and specific needs after experiencing technology intervention is marked by contradictions. The dialogue points out a clear polarization between farmers and labourers as revealed in Table 27.

**Table. 27. Effects of technology intervention: preferences and perceptions, Umra, Maharastra, India 1991 to 1992.**

| Component of technology | Effects of technology intervention | | | |
|---|---|---|---|---|
| | Farm households | | Labourer households | |
| Supplied | Men | Women | Men | Women |
| ICRISAT varieties | +[1] | + | + | + |
| Broadbed and furrow system | -[2] | + | + | + |
| Dibblg | + | - | + | + |
| Sprinkler | + | + | + | NA[3] |
| Demanded | | | | |
| Broadbed and furrow marker | + | + | - | _ |
| Dibbler | + | + | NA | _ |
| Harvesting equipment | + | + | - | _ |
| Ultra low volume sprayer | + | NA | + | NA |
| Sheller | + | + | NA | - |
| Short-duration drought resistant varieties | + | + | NA | NA |

1. += Positive response, 2. - = Negative response, 3. NA = Not applicable; Source: ICRISAT Annual Report, 1995.

- The most interesting aspect of this are the conflicting preferences found between farmers and labourer groups of women. For example, the demand for a groundnut sheller shows the needs of women farmers for labour-saving equipment, which directly clashes with the interests of women of agricultural labourer households. The women from labourer households expressed support for continuing ‘dibbling’ sowing groundnut as it increased their employment prospects. Women from cultivator households opposed this recommendation as it not only increased physical drudgery, but also increased their supervisory responsibilities, as they had to supervise several hired women labours at the time of sowing.

- Technology intervention on the whole led to further demand for new technologies, as the farmers enjoyed the benefits of higher yields and economic returns from technology intervention. The survey revealed that both men and women farmers demanded labour saving machinery, indicating the pressure created by new technology on labour. Women farmers enhanced participation in groundnut production in Umra, combined with their demand for dibblers and shellers, indicating that technology intervention led to an increase in their workload. The resource and benefit analysis clearly indicates that, control over resources and benefits in the household were guided by traditional patterns of responsibilities assigned to different genders. As a result, any new changes that have occurred in resource use, benefits accruing due to new technology gave an advantage to the men as they gained more control over these. Owing to this, the gap between men and women seemed to have widened in decision-making. This gap is likely to alienate women from technology development process, constraining wider adaptation of technologies. The report emphasizing the demand for "short-duration" groundnut varieties' by men and women farmers suggests that households have difficulties in fitting the long-duration varieties into their cropping systems.

## 5.4 Proposed improvements

In spite of the release of several cultivars in the developing countries, cultivars suitable for specific situation are still not available. For example early maturing cultivars with fresh-seed dormancy is requirement for the cultivation of groundnut in intercropping in various agro-ecosystems. The yield losses due to diseases and pests need to be assessed for integrated pest management (IPM). About 80 percent of the groundnut in the developing countries are cultivated under rain-fed situations a water use efficient genotype is the most urgent requirement. Genotypes possessing resistance or tolerance to drought and high temperature stresses need to be identified. The wild species of groundnut offer a vast reservoir of valuable genes that are not available within the cultivated species.

Several efforts in developing countries are being made to improve the quality of groundnuts by employing traditional plant-breeding techniques, but met with little success. The advent of biotechnological tools including marker-assisted selection and gene transfer across the species barrier has opened up novel opportunities for enhancing the seed-quality. The transformation protocols for groundnut are now well established and development of transgenic groundnut expressing desirable foreign genes is on the anvil. Misra (1997) has briefly reviewed the topic and suggested following biotechnological approaches to improve the quality of groundnut seed. The information provided might be useful in conceiving and formulating research projects aimed at improving quality of groundnut through genetic engineering.

***Improvement in quality of oil***

The long chain saturated fatty acids (LSFAs)-amyl arachidic (20:0), behenic (22:0) and lignoceric (24:0) present predominantly in sn-3 position have been reported to contribute to atherosclerosis. If further elongation of stearic acid can be prevented, groundnut oil would be free from these hazardous fatty acids. The elongation of chain behind C18 is catalysed by membrane bound enzyme steoryl-Co-A-: α-ketoeicosanoyl-CoA synthetase. Engineering a gene coding for antisene RNA in groundnut may help reduce activity of this enzyme and hence of LSFA. For enhancing self-life of groundnut products, a higher oleic/linoleic (O/L) ratio is considered desirable. Increasing the protein of oleic acid in groundnut oil can attain this. The introduction of the first double bond in the plant fatty acids occurs by the action of enzyme stearoyl-ACP desaturase. Expression of additional copies of gene for this enzyme may enhance the content of oleic acid and hence O/L ratio.

***Improvement in quality of protein***

Groundnut protein is considered poor in sulphur-containing amino acids besides lysine, threonine and isoleucine. A Brazil-nut polypeptide with 18 percent methionine has been identified. The gene for this polypeptide has been successfully transferred to tobacco and expressed in developing seed resulting in a 30 percent increase in methionine content of transgenic tobacco seed. Thus the gene encoding Brazil-nut methionine rich polypeptide has the potential to improve the quality of groundnut protein.

***Improvement in composition of carbohydrates***

When a galactose moiety is linked to a sucrose molecule, raffinise is synthesized and when another galactose moiety is linked to raffinose, stachyose is obtained. Thus, obstructing the synthesis of the former alone will be enough to check production of both the oligosaccharides. The enzyme galactinol: sucrose-6-galactosyl transferase (GST), catalyses the crucial step in the synthesis of raffinose, can be obstructed by engineering expression of gene encoding antisense RNA of GST.

***Reduction in aflatoxin load***

Groundnut produces stilbene phytoalexins in response to fungal infection. Stilbenes inhibit fungal growth and spore germination of Aspergillus species and aflatoxin contamination does not occur as long as kernels have the capacity to produce stilbenes. Stilbene synthesis has been identified as the key enzyme for the biosynthesis of stilbene backbone. The gene encoding of this enzyme has already been characterized and even successfully expressed in tobacco. Organ specific expression of multiple copies of gene for stilbene synthesis is likely to enhance production of stilbenes in groundnut kernels and hence make them less prone to colonization by *Aspergillus flavus.*

### 5.5.1 Pod moisture-related studies

Improvement in future designs of the processing equipment for groundnut requires a more complete knowledge of the pod physical properties including the interaction with environmental moisture content. Dickens and Pattee (1972) reviewed the impact of drying practices on final product quality. More advanced work on internal vapour diffusion in groundnut and on alternative methods of drying such as use of radio-frequency and spouted beds (Nelson and Gay, 1971) will, however require additional knowledge of moisture related properties as experiment approaches application. Another example of the determination of such properties includes dielectric constant, specific heat, heat of respiration and other thermal properties (Suter, *et al.*, 1972). They are primarily concern with densities, volumes and void fractions of whole groundnuts, whereas shell and kernels are related to moisture content. The shell or hull moisture content (HMC) appears to be about 6 percent greater than the kernel moisture content (KMC) at any equilibrium moisture level. This indicates that for typical forced convection, drying the shell could remove some moisture from the kernel after drying operation ceased (Beasly and Dicken, 1963). Rapid drying rate and high cured moisture content increases proportion of extra large kernels (ELK) in some of the groundnut cultivars (NC-2) and cause the whole groundnuts to have a lower density. Presumably, rapid drying distorts the cotyledons and increases the void space between the cotyledons.

### 5.5.2 Attention to post-production system

Little attention has been given in the developing countries to examining the impact of various handling methods used by the farmers in on rate of loss and reabsorption of moisture. Local methods of harvesting, curing, drying, threshing, marketing and storage are crucial factors in the aflatoxin problem. Local governments, with the help of International Organizations like FAO/UNDP, are considering the need of analyses to improve the efficiency of local handling methods. A workshop organized at ICRISAT identified various areas of concern about aflatoxin contamination of groundnut and made recommendations that were covered in detail in the group discussions. The overall guidance of the workshop follows (ICRISAT, 1987).

a) Information and training:The workshop emphasized the need to increase awareness of the danger of aflatoxin contamination of groundnut and groundnut products among international groups, national governments, the groundnut industry, the producers and ultimately the consumers. Organizations such as FAO, WHO, the EEC, etc. could do more in this respect and could cover the problem of aflatoxins in all commodities. It was also suggested that ICRISAT could act as a clearinghouse to inform all concerned with the aflatoxin problem of proposed training courses, workshops etc.
b) Strategies:The concerned groups, AGC, EEC, FAO and Codex Alimentarius, should continue to work towards a standard international legislation on regulatory levels of aflatoxin in groundnuts and groundnut products for human and animal consumption. At the national level, countries are recommended to set up interdisciplinary working groups to coordinate the evaluation of the aflatoxin problem in their country. They should identify a responsible agency, organize monitoring of aflatoxin levels in foods plus feeds and initiate the coordinate research with a view to preparing recommendations for control at all levels.
c) Research needs: Research needs should be clearly identified in the light of each country's problem and capabilities. Work should be carried out by the most relevant organizations using the most appropriate technologies. In developing countries, where large areas of groundnut are grown, specialized equipment is desirable and may require the adaptation of traditional agriculture methods for most profitable use, i.e. a change from runner to bunch types or a modification of individual planting dates to ensure optimum soil moisture at the time of harvest for efficient use of digging and threshing implements or machines.

### 5.5.3 Assessment of post-harvest losses

In the literature there is no systematic information on the post-harvest losses in groundnut under the developing countries' production system. In groundnut post-harvest losses are substantial, thus there is urgent need for the assessment of post-harvest losses. Farmers need to be educated regarding the post harvest losses in the quality and weight of groundnuts assisted by application of better equipment and methods for the harvest. The need for drying and storage must be suggested and demonstrated.

### 5.5.4 Policy formulation

In the international workshop organized by the ICRISAT in 1991 "Groundnut- A Global Perspective" (Nigam, 1992) and in other ICRISAT literature most of the post-harvest, marketing, socio-economic and policy aspects seem to be closely related among various developing countries in the Asia and South Africa. Therefore, proposed improvements have been suggested using India as an example, which can also be implemented, suitable in other developing countries. In 2000 a report "Technological Forecasting of Future Oilseeds Scenario in India" (Rama Rao, *et al.*, 2000) was conducted in ICAR-AP Cess fund Project by

National Academy of Agricultural Research Management (ICAR), Hyderabad, India. The abstract of the report follows.

"This study investigates the future scenario of oilseeds in India. It is intended to help policy makers to effectively plan and utilize the oilseed resources in the country. The study uses out put from brainstorming sessions, workshop, expert consultations, survey, historic data and system dynamic analysis. By 2010 AD, the oilseed production in the country is forecasted to reach 37 million tonnes as against the requirement of 44 million tonnes. The study identifies the shortcomings in the present production system and evaluates opportunities for improvement. R and D strategies to improve oilseeds situation hinge upon developing efficient technologies. Agency-specific recommendations are made to realize the strategies. The study recommends special focus on rain-fed oilseeds research through changed mandate coupled with resource reallocation. To improve the supply of quality seed, the study recommends association of NGOs and young agriculture graduates entrepreneurs for contract mode commercial seed production with priority finance and business partnership with research institutes and agricultural universities".

Following improvements in cultivation, policies and R and D are proposed:

1. Major competing oilseeds crops by 2010 AD would be paddy, sunflower and millets for groundnut.
2. Slow results of the dry land research, insufficient resources, uncertain rainfall, lack of access to germplasm, lack of appreciation for basic research and lack of interest in the researchers were observes as the major factors in the order affecting dry land oilseed research.
3. The subsystems associated with oilseeds that are likely to have more impact on overall oilseeds situation by 2010 AD in the order of importance is TOT (development), research and education, marketing and trade and processing.
4. Medium level farmers are likely to give more preference for oilseed crops cultivation. The reasons for their preference are: commercial nature of crop, crop rotation and exposure to improved technologies and local market demand.
5. The present market share of less than 5 percent for blending edible oils in total edible market is expected to increase to 8 percent by 2010 AD. The basis for blending of oils in future would be health, cost, keeping quality and taste, in that order.
6. The possible technical improvements in oilseeds processing that could be envisaged by 2010 AD are increased use of solvent extraction and production of pesticide-free by-products.
7. The government policies on futures trading, liberalization of seed import, efficient inland handling and transport, stock decontrol and development of infrastructure facilities are expected to overcome the constraints faced by processing units in next ten years.
8. To exploit high yield potential of oilseed crops in summer season, the government may encourage special tariffs for electricity and water under command areas.
9. The import duty on edible oils need to be kept above 40 percent. This would protect the interests of the farmers while taking care of domestic demand to protect the interest of consumers.
10. Poor consumers buy unbranded oil in low volume on daily basis but at very high price. To meet the nutritional demand of this group, States may encourage (low excise duty) supply of blended oils in small pouches of about 20 ml, sufficient for one use.
11. The technology to be followed can be made available to the farmers in the printed form along with seed bags. This would help farmer to adopt technology for realizing the full potential of high yielding cultivars.

12. Lack of quality seed availability is one of the major causes of low productivity. Reputation of seed co-operations on seed quality is at stack and there is need to look for new modes of seed production and distribution.
13. There is tremendous scope for value addition in oilseeds both for domestic use and export. The R and D projects on value addition in oilseeds (such as recycling of protein rich defatted flour) should be given priority funding and other assistance.
14. Farmers need to educate on post-harvest processes and production technologies. Private sector need to be encouraged produces quality material.

The potential dietary role of groundnut butter in semi-arid tropics of African countries has been determined, as has the assessment post-harvest practices that impact the supply and utilization of crop. It was determined that there is a need for research to:

- increase use of groundnut in refined/processed form,
- prevent or minimize aflatoxin contamination,
- improve packaging to increase the self life of groundnut products,
- produce flour to increase the value of cereal and legume-based foods, and
- improve methods of handling groundnuts and their products.

Presented next are the highlights of the Proceedings of the Working Group on Post-harvest Technology and Utilization "Regional Groundnut Meeting for West Africa" held 18 to 21 November 1996, in Bamako, Mali.

1. In view of the increasing demand of groundnut products by producers, processors and consumers, the group expressed satisfaction to the importance of postharvest technology outlined in the Fifth Regional Groundnut meeting.
2. The reflection areas of the Working Group covers all agricultural and related activities from groundnut harvest to end products or partially finished products and their delivery to processors, distributor or consumer. The group has identified four types of products, which justify a research intervention:

- Home-made products for direct human consumption,
- Improved seeds,
- Edible groundnut and confectionery nuts,
- Enhancement of sub-products in the rural areas (haulm, oilcake, pods).

Common problems in these sectors depend on the following principal themes:

- Storage and conservation of products,
- Quality control, particularly of aflatoxins,
- Socio-economic evaluation of recommended technologies or those in practice,
- Technology transfer, training and information extension.

This grid of analysis led the Group to formulate the following recommendations:

3. Homemade products for direct human consumption, notably unrefined oil from hand kneeing is technologically poor in quality and hygiene. Generally it does not allow for any aflatoxin contamination control; research in this area is very inadequate whereas considerable efforts have been devoted to the control and detoxification of products made for export. The Group recommends that the diversification of home made products, improvement of manufacturing techniques and improvement of their hygienic and nutritional quality is made a subject for coherent research programme with adequate support.
4. Availability of good quality seeds in sufficient quantity constitutes a major constraint to the improvement and extension of groundnut production to farmers. Research conducted in Senegal on this subject should be reactivated and their results brought to the knowledge of other producing countries. Special attention should be given to seed production and on-farm conservation, in view of the implementation of the new

agricultural policies which will result in the breakdown of the rural supply channels in western and Central Africa.

5. Edible groundnut represents a very interesting diversification of groundnut production. The group recommends that research conducted in Senegal, should be activated and be carried out in other countries. This work should not only have the objective of production for international market but should also consider production for local and regional consumers.
6. Groundnut haulms are sub products in high demand for livestock feed in dry and peri-urban zones. After shelling, pods can be used for soil amendment and as fuel. Traditional utilization technologies exist here and there; these should be registered, improved and spread in all production zones.
7. Adoption of improved technologies is linked to their feasibility and profitability in traditional rural areas. Research recommendations should be carefully assessed in socio-economics terms. The farmer on other hand should be sensitized to produce good quality products. This necessity implies that sampling criteria be developed to quickly evaluate the quality of products and to pay realistic prices for them. The group recommends that economist collaborate closely with agronomists and technologist to study this problem.
8. The group recommends that work on post-harvest technology is based on an inventory of existing technologies and a research programme adapted to regional level. This approach greatly enhances technology transfer and development of relationships between producers, researchers, processors and consumers. Spread of information, (academic and professional training) and user initiation to improved technologies is of fundamental importance for new technology utilization.
9. On a general note, Group recommends that account should be taken of the diversity of situations and producers' freedom of acceptance in traditional rural zones. Thus, research should provide them with tools for decisions and recommendations adjustable and adaptable to the various constraints encountered and to the diversity of strategies implemented of which the farmers remains the only judge.
10. In conclusion it can be said that large scope exist to improve groundnut production and processing in the developing countries, if the gaps in research, extension and seed production and post-harvest processing are remedied. Finally, success does not lies only making the improvements, the ultimate technologies should find its way to the farmers fields, which is the ultimate goal of our endeavours.

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### Acronyms and Abbreviations

| | |
|---|---|
| AGC | African Groundnut Council |
| AOAC | Association of Official Agricultural Chemists |
| AICRP (G) | All India Coordinated Research Project on groundnut |
| ADMARC | Agricultural Development and Marketing Corporation |
| PCM | Protein Calorie Malnutrition |
| APREA | The America Peanut Research and Education USA |
| USD | United States of America |
| CAC | Codex Alimentarious Committee |
| CAB | Common Wealth Agricultural Bureaux |
| cm | Centimetre |
| CIAE | Central Institute of Agricultural Engineering, (ICAR) Bhopal, India |
| DOR | Directorate of Oilseed Research (ICAR) |
| DMI | Department of Marketing Inspection |
| EEC | European Economic Comm unity |
| EMS | Ethyl Methane Sulphonate |
| FDA | Food and Dairy Administration |
| FAO | Food and Agriculture Organization of the United Nations |
| FAA | Free Fatty Acids |
| fpm | Feet per minute |
| FAME | Fatty Acid Methyl Easter |
| GROFED | Gujart Groundnut Growers Federation |
| GATT | General Agreement on Tariffs and Trade |

| | |
|---|---|
| GOI | Government of India |
| GPMB | Ghana Produce Marketing Board |
| GFDC | Ghana Food Distribution Corporation |
| hp | Horse Power |
| ha | Hectare |
| hr | Hours |
| HPS | Hand Picked and Selected |
| ILO | International Labour Organization |
| IOPEA | Indian Oilseeds Producers Export Agency |
| ICRISAT | International Crop Research Institute for Semi-Arid |
| IMF | International Monetary Fund |
| ICAR | Indian Council of Agricultural Research |
| IPM | Integrated Pest Management |
| IFTM | Instron Food Testing Machine |
| Kg | Kilogram |
| LDL | Low Density Lipoproteins |
| LSK | Loosed Shelled Kernel |
| m | Metre |
| Mt | Metric tones |
| NRCG | National Research Centre for Groundnut, Junagadh, India |
| NSPRI | Nigerian Stored Product Research Institute |
| NGOs | Non Government Organizations |
| NARS | National Agriculture Research Scientists Team |
| NARP | National Agriculture Research Project |

| | |
|---|---|
| NDDB | National Dairy Development Board, Anand, India |
| NASA | National Aeronautics and Space Administration |
| O/L | Oilec and linolic acids ratio |
| RNA | Ribonucleic acid |
| rpm | Revolution per minute |
| Sec | Second |
| SAT | Semi-Arid tropics |
| SONACOS | Société Nationale de Commercialisation des Oléagineux du Sénégal |
| TMOP | Technology Mission on Oilseeds and Pulses |
| UK | United Kingdom |
| UNIDO | United Nations Industrial Development Organization |
| UNDP | United Nations Development Programme |
| UNICEF | United Nations and International Children's Education Fund |
| WHO | World Health Organization |
| W.b. | Wet weight basis |