SOYBEANS

Post-harvest Operations

INPhO - Post-harvest Compendium

Food and Agriculture Organization
of the United Nations

SOYBEANS: Post-harvest Operations

Organization: Centro de Investigación y Desarrollo, A.C. (CIAD) (http://www.ciad.mx)
Authors: A.R. Islas-Rubio, PhD, I. Higuera-Ciapara, PhD, General Director
(aislas@cascabel.ciad.mx and higuera@cascabel.ciad.mx)
Edited by AGSI/FAO: Danilo Mejia, PhD (Technical), Beverly Lewis (Language & Style)
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Preface

The flow of grains from the field to consumers includes several operations, whose sequence and interactions contribute to the formation of a complex system named "the post-harvest system". All of these operations should be appropriately done in order to reduce the risk of altering negatively the condition of the grain, that is, its quality. Soybeans growers do their jobs cultivating the land and harvesting the crop at optimum maturity. Sometimes, it is necessary to pre-dry the produce before the subsequent threshing or shelling operation. Afterwards, the grain must be cleaned and dried, so that it can be stored or undergoes further processing. Soybean, as any other grain, can be stored in bulk or in bags, on the farms where it is produced, in collection centres, or with storage agencies. Finally, soybean is sent from the warehouses to markets for sale to consumers, to small-scale food processors, or to agro-food industries.

In the past, the gathering and storing of ripened crops was generally a slow and arduous task, today the reverse is usually the case, because of the availability of harvesting machinery and handling and loading equipment. Harvesting should be done in the shorter time possible to avoid grain condition changes that might affect its conservation and storage. In developing countries, there are still many farms, often the small farms, where insufficiency of knowledge and of machinery, equipment, labour and storage facilities, make it difficult to proceed in the right manner, with the result that storage is not always successfully accomplished and the quantitative and qualitative losses are high.

In some regions of Africa and Latin America, overall post-harvest losses of cereals and grain legumes between 25 and 50 percent of the quantities harvested are estimated. Grain losses in the tropical and subtropical regions are also high since the tropical conditions accelerate the growth of insects, fungi, mites and rodents and provide optimum conditions for their development through most of the year. In addition, the lack of economical resources in these regions to invest in constructing the appropriate storage facilities contributes to higher grain losses. There is a lack of reliable data on the level of soybean post-harvest losses.

It is possible to increase the amount of soybeans available for the market without increasing the number of hectares dedicated to this important crop. There are several ways to do it, but none of them is easy. One of them is reducing soybeans post-harvest losses by improving the actual post-harvest systems. Another is increasing yield by implementing an integrated pest management to control plant diseases and insects, or by using disease-resistance and insect-resistant cultivars, or by using transgenic seeds conferring tolerance to a certain herbicide or resistance to insects.

This chapter entitled *Soybeans Postharvest Operations* as a part of the INPhO Compendium on Post-harvest Operations intends to provide up-to-date information regarding one of the most important crops in the world, as well as the traditional and improved techniques used to carry out the operations in the post-production chain. Whenever possible, losses and work division within the family associated to soybean post-harvest operations will be provided.

Chapter 1 (Introduction) gives a general overview of the importance of the post-harvest system, economic and social impact of soybeans, world trade (production and marketing), primary, secondary and derived products, requirements for export and quality assurance and consumer preferences. Chapter 2 gives the post-production operations, including pre-harvest and harvesting operations, transport, threshing, drying, cleaning, packaging, storage and processing of soybeans. Chapter 3 discusses overall losses distinguishing among quantitative and qualitative losses whenever possible. Chapter 4 describes pest species more frequently found in soybean after harvesting, prevention and control. Chapter 5 is devoted to economic and social considerations with emphasis on costs and losses at different stages, major problems facing small and medium-scale farmers. References are listed in Chapter 6.

Chapter 7 includes an Annex containing a complete list of pesticides used to control soybean pests during its cultivation, handling and storage. A good number of traditional recipes and other recipes that include soybeans exclusively or in some extent are provided in the Annex, whenever possible the country in which the recipe originated is given. Also, the Annex contains the list of figures and tables.

Soybeans Postharvest System intends to be a reference for anyone interested in soybeans, food technologist, nutritionist, academic and governmental professionals, students and for people dealing with soybean at any stage of the post-harvest system.

We wish to express our sincere appreciation to Food and Agriculture Organization of the United Nations (FAO) for selecting our Institution (CIAD, A.C.) and particularly to us, to write this chapter for the InPhO Compendium on Post-harvest Operations. We also express our gratitude to those who kindly accepted our interviews and shared with us their experience in any of the multiple activities that have to be done to make soybeans or soy-base foods available to consumers. We are grateful for the support provided by our families and Q.B. Elsa Bringas Taddei to carry through this commission.

1.1 Economic and social impact of soybeans

Soybean crop is undoubtedly of a great economic and social importance worldwide. Soybean provides about 64 percent of the world's oilseed meal supply and is the major source of oil, accounting for about 28 percent of total production (USDA, 2000). In 1999, soybeans represented 52 percent of world oilseed production and 46 percent of those soybeans were produced in the United States on a surface of about 30 million hectares, representing a crop value of US$ 12.3 billion. Fully 60 percent of the world's soybean trade originated from the United States.

For countries with surplus soybean production this crop represents an important source of foreign currency, such is the case of Brazil and Argentina in Latin America. In Argentina, the soybean complex contributes with more than 50 percent of the export currency (Ploper, 1997), whereas in Brazil the soybean complex generates yearly US$ 24.5 billion in income and earning about US$ 5.7 billion in foreign exchange (Duque, 1999). On the other hand, for countries with a consolidated soybean crashing industry but insufficient amount of domestic soybeans to produce the soybean meal demanded for the broiler, pork and aquaculture industries, soybean exports are indispensable for keeping the actual labour force and remaining in business. Mexico has been in this situation for several years. In 1998, Mexico imported about 4 million metric tonnes of soybeans and 150 thousand tonnes of soy meal with a value of 754.2 and 27.9 million dollars, respectively (Feedstuffs, 1999).

In some developing countries, especially in rural areas, soybean represents the best protein source available for improving the nutritional value of traditional foods (Bressani, 1974; Vaidehi *et al*, 1985; Verma *et al.*, 1987; Seralathan *et al.*, 1987; Akpapunam *et al.*, 1996; Sheralathan and Thirumaran, 1998). Also, the crop has revolutionized the rural economy by raising the living standards of soybean farmers, especially the women and children (Paroda, 1999). In some regions of Asia, soybean crop sales represents between 30 percent and 60 percent of the average cash income, which is used to buy material inputs for the next crop (rice cultivation), Lancon (1997).

In the Far East countries and some other countries with a large Oriental population, soybean is an essential part of the diet. In 1994, the worldwide market for food beans was estimated at least at one million metric tonnes (Shurtleff, 1994; Motoki and Seguro, 1994). Research findings in the last decade about the benefits of soy-based foods to prevent and treat cancers and heart disease may contribute to higher soy-based food consumption, especially in the West.

The introduction of soybean crop to several countries have led to a shift in their cropping systems from a monocrop (post-rainy wheat or other crop) to a soybean-wheat or soybean-other crop system. This cropping system change has resulted in an enhancement in the cropping intensity and resultant increase in the unit area profitability from the land use (Paroda, 1999). Soybean crop is seen to be useful for the sustainability of the major cereal based cropping systems in the world.

1.2 World trade

World soybean market data are shown in Tables 1 through 6. From 1992 to 1997, the annual average world soybean production was about 125.7 million metric tonnes (Table 1), corresponding 50 percent of this amount to North America, 31.5 percent to Central and South America, 16 percent to Asia and the remaining 2.5 percent to Africa, Europe and Oceania (Soya Bluebook Plus, 1998), Table 2. The world soybean market is dominated by a reduced number of countries. The leader soybean producer countries in each region were the United States in North America, Brazil and Argentina in South America, China and India in Asia, Italy and France in Europe, South Africa and Zimbabwe in Africa and Australia in Oceania. Soybean has been the United States second largest crop in cash sales and the number 1 value crop export. The United States has been losing competitiveness in the world soybean market (Hill *et al.*, 1997). On the other hand, Brazil and Argentina have been gaining position in the soybean international trade. The world soybean area harvested by region from 1992 to 1997 is shown in Tables 3. The total soybean area harvested has increased from 54.99 to 63.08 million hectares. 42 percent of the land cultivated with soybean corresponded to North America, 30 percent to Central and South America, 25 percent to Asia and the remaining 3 percent to Africa, Europe and Oceania.
Soybean meal is a highly demanded product worldwide (see Table 4). A continuous increase in the production, exports, imports and consumption of soybean meal has been observed each year. The world production and consumption of soybean oil has had the same trend in the last years.

Table 1. World soybeans: supply and distribution (million metric tonnes), 1992 to 1997.

PERIOD	PRODUCTION	EXPORTS	IMPORTS	CRUSH[a]	ENDING STOCKS
1992-1993	117.4	29.8	30.4	96.7	20.3
1993-1994	117.8	28.2	28.4	102.1	17.3
1994-1995	137.6	32.1	32.8	109.8	23.7
1995-1996	124.4	31.9	32.1	112.1	16.7
1996-1997	131.7	35.5	35.7	114.8	13.1
AVERAGE	125.8	31.5	31.9	107.1	18.2

[a] Soybean industrial processing to obtain meal and oil.
Split years shown refers to years of harvest. Northern Hemisphere crops which are harvested in the first
part of the split year (for example September to October 1988) and Southern Hemisphere crops
which are harvested in the first part of the following year (for example March to April 1989).
Source: Soya Bluebook Plus (1998).

Table 2. World soybeans: production by region and world total (1000 metric tonnes), 1991 to 1997.

PERIOD	REGION						WORLD TOTAL
	North America	Central & South America	Africa	Europe	Asia	Oceania	
1991-1992	56 243	32 314	351	2 047	15 549	63	106 567
1992-1993	61 639	36 388	314	2 215	16 712	5	117 273
1993-1994	53 267	39 969	339	1 673	22 416	82	117 746
1994-1995	71 269	41 797	321	1 777	22 435	34	137 633
1995-1996	61 726	39 853	373	1 607	21 008	73	124 640
1996-1997	67 067	42 288	365	1 925	20 482	100	132 227
AVERAGE	61 869	38 768	344	1 874	19 767	60	122 681
PERCENT[a]	50	31.5	0.2	1.5	16.1	0.04	

[a] Contribution to the world soybean production.
Split years shown refers to years of harvest. Northern Hemisphere crops which are harvested in the first part of the split year (for example September to October 1988) and Southern Hemisphere crops which are harvested in the first part of the following year (for example March to April 1989).
Source: Adapted from Soya Bluebook Plus (1998).

Table 3. World soybeans: area harvested by region and world total (1 000 hectares), 1991 to 1997.

PERIOD	REGION						WORLD TOTAL
	North America	Central & South America	Africa	Europe	Asia	Oceania	
1991-1992	24 415	15 750	299	1 526	12 981	21	54 992
1992-1993	24 494	16 896	220	1 555	13 531	32	56 728
1993-1994	24 166	18 389	243	1 220	16 341	39	60 398
1994-1995	25 737	19 055	279	1 176	15 943	17	62 207
1995-1996	25 898	18 613	276	1 017	15 442	32	61 278
1996-1997	26 581	19 849	288	1 112	15 202	50	63 082
AVERAGE	25 215	18 092	268	1 268	14 907	33	59 780
PERCENT[a]	42	30	0.4	2 1	25	0.05	

[a]Contribution to the total soybean area harvested.
Split years shown refers to years of harvest. Northern Hemisphere crops which are harvested

in the first
part of the split year (for example September to October 1988) and Southern Hemisphere crops
which are harvested in the first part of the following year (for example March to April 1989).
Source: Adapted from Soya Bluebook Plus (1998).

Table 4. World soybean meal: supply and distribution (million metric tonnes), 1992 to 1997.

PERIOD	PRODUCTION	EXPORTS	IMPORTS	CONSUMPTION	ENDING STOCKS
1992-1993	76.4	27.4	27.9	76.1	4.1
1993-1994	81.3	29.9	29.3	80.7	3.9
1994-1995	87.2	30.9	31.2	87.0	4.4
1995-1996	89.1	33.8	32.0	87.6	4.2
1996-1997	91.2	33.3	33.0	91.2	3.9
AVERAGE	85.0	31.0	30.7	84.5	4.1

Split years shown refers to years of harvest. Northern Hemisphere crops which are harvested in the first part of the split year (for example September to October 1988) and Southern Hemisphere crops which are harvested in the first part of the following year (for example March to April 1989).
Source: Adapted from Soya Bluebook Plus (1998).

Table 5. World soybean oil: supply and distribution (million metric tonnes), 1992 to 1997.

PERIOD	PRODUCTION	EXPORTS	IMPORTS	CONSUMPTION	ENDING STOCKS
1992-1993	17.2	4.2	3.9	17.3	2.0
1993-1994	18.2	4.9	4.7	18.4	1.7
1994-1995	19.7	5.9	6.1	19.5	2.1
1995-1996	20.2	5.3	5.1	19.6	2.5
1996-1997	20.4	5.7	5.6	20.4	2.4
AVERAGE	19.1	5.2	5.1	19.0	2.1

Split years shown refers to years of harvest. Northern Hemisphere crops which are harvested in the first part of the split year (for example September to October 1988) and Southern Hemisphere crops which are harvested in the first part of the following year (for example March to April 1989).
Source: Adapted from Soya Bluebook Plus (1998).

The world's three major soybeans and products producers: average supply and distribution from 1991 to 1996 are presented in Table 6. The United States was the leader in soybean production, exports and consumption. This country also produced and consumed more soybean meal than any other country. Most of the soybean oil produced in the United States is domestically consumed (89 percent). The major United States soybean importer countries were Netherlands, Germany and Spain in Europe; Mexico in North America; Japan, China and Korea in Asia. From 1991 to 1996, United States exported annually about 20.5 million metric tonnes of soybeans. Most of the soybean meal (31.3 million metric tonnes/year) was produced in the United States. This country exported annually about 6.1 million metric tonnes of soybean meal, being the third exporter country, after Brazil and Argentina. The major United States soybean meal importer countries were Venezuela and Colombia in South America; former Soviet Union, Ireland, Germany and Italy in Europe; China and Japan in Asia. The major United States soybean oil importer countries were Peru, Colombia and Equator in South America; former Soviet Union, Germany and Netherlands in Europe; China and Korea in Asia. The United States exported annually about 721 736 metric tonnes of soybean oil. Brazil exported soybeans mainly to EC, soybean meal to EC and Asia and soybean oil to China, Iran and Bangladesh.

In 1999, United States soybean and product exports totalled US$ 6.066 billion. The European Community was the number one United States market for whole soybeans (US$ 1.033 billion). Japan was the largest single country customer for United States soybeans (US$ 775 million) and US$ 47 million worth of soybean meal. The Philippines became the largest customer for United States soybean meal at US$ 137 million, US$ 2 million more than Canada. Korea was the largest customer for United States soybean oil with purchases of US$ 61 million in addition to US$ 224 million in whole soybean purchases. Mexico was the third United States export customer for soybeans (US$ 659 million) and soybean oil (US$ 48 million) and the fifth customer for soybean meal (US$ 57 million).

Domestically, soybeans provided 82 percent of the edible consumption of fats and oils in United States. The domestic soybean industrial processing to elaborate meal and oil increased to 43.14 metric tonnes, while United States ending stocks of soybeans decreased to 8.1 million metric tonnes.

In 1999, soybeans represented 52 percent of world oilseed production and 46 percent of those soybeans were produced in the United States. The world soybean exports totalled 43.3 million metric tonnes, corresponding 60 percent of this amount to the leader, United States, 21 percent to Brazil, 9 percent to Argentina, 5 percent to Paraguay, 0.2 percent to China and 5.1 percent to other. The world soybean meal exports totalled 38.7 million metric tonnes, Argentina was the leader with 36.2 percent of that amount, followed by Brazil (26.3 percent), United States (16 percent), European Comunity-15 (13.4 percent), India (5.4 percent) and other (3.1 percent). The world soybean meal consumption was 107.4 million metric tonnes. The world soybean oil consumption during 1999 was 24.5 million metric tonnes.

The increasing population and consumption of animal products, especially poultry, swine and aquaculture-produced species, ensures expanding markets for soybean and soybean products. It is expected that Argentina, Paraguay and India continue gaining position in the soybean international trade. On the other hand, Mexico will continue its dependence of the United States to satisfy the soybean needs. Human health benefits attributed to the consumption of soybean and soy-based foods may contribute to strengthen the market of this important crop.

Table 6. Major soybeans and products producer countries - Supply and distribution (million metric tonnes) Average from 1991 to 1996.

COUNTRY	PRODUCT	PRODUCTION	IMPORTS	EXPORTS	CRUSH[a]	CONSUMPTION	END STOCKS
United States	Soybeans	57.5	0.12	20.5	36.4	38.4	7.6
	S. Meal[b]	30 804	68.8	6 120	-	24 771	235
	S. Oil[c]	14 389	34.7	1 508	-	12 798	1 640
Brazil	Soybeans	21.4	0.90	4.7	18.5	20.1	0.62
	S. Meal	14.5	0.05	10.0	-	4.5	0.45
	S. Oil	3.5	0.17	1.2	-	2.4	0.18
Argentina	Soybeans	11.3	0.03	2.2	9.2	9.7	0.27
	S. Meal	7.5	-	7.2	-	0.3	0.18
	S. Oil	1.6	-	1.5	-	0.09	0.05

[a]Soybean industrial processing to obtain meal and oil.
[a] Million short tonnes.
[b] Million pounds.
Source: Adapted from Soya Bluebook Plus (1998).

1.3 Primary products

Soybeans are grown primarily for their meal. Meal is the primary product and oil is secondary. Soybean oil accounts for slightly less than 19 percent of total product weight. About two thirds of total crop return to soybean producers has long come from soybean meal (Asbridge, 1995). In 1999, soybean provides about 64 percent of the world's protein meal supply and simultaneously is the major source of oil, accounting for about 28 percent of total production. World soybean meal production totalled 107.4 million metric tonnes. The average annual production (1991 to 1996) was 85 million metric tonnes of meal.

1.4 Secondary and derived products

Secondary products generally are functionally interchangeable with alternatives and require competitive marketing to move them in the trade (Lusas, 2000). For our purpose, secondary products are those by-products obtained by the soybean crushing industry. Derived products are those made from soybeans or soybean meal, or any soybean by-product.

Secondary products

As mentioned above, oil is a secondary product in the soybean crushing industries. Lecithin is another secondary product obtained after degumming the crude soybean oil.

Derived products

The most important soybean derived products are the traditional soy foods, which include the no fermented and fermented Oriental soy foods. Among the no fermented soy foods, tofu is the most popular, followed by soymilk and soy sprouts. Other includes okara, roasted soy nuts or flour, yuba, fresh immature soybeans, sweet beans and mature whole soybeans. Among the popular fermented soy foods are soy sauce, miso, tempeh and natto. Most of these soy foods are inexpensive, nutritious and easy to make. They serve as an alternative source to nourish people with protein, oil and other nutrients. In recent years, there has been an increasing

interest in the West in exploring the food values of these products. Some of them have shown great potential for being incorporated into Western diets.
Soybeans can be partially used for the production of tortillas, refried beans, soups or salads. Also, in many regions where soybean was not consumed at all, soybeans have been partially used to fortify staple foods. Some of these products will be discussed in the section related to processing and/or in the section of the Annex related to recipes.
If soybean is not directly used, it can be processed to obtain several products differing in protein content. These soy-based products are: whole grain and grits flours (40 percent protein), defatted flour (50 percent protein), soy protein concentrate (70 percent protein) and isolated soy protein (90 percent protein).
Other soybean derived products such as soy ice cream, soy yoghurt, soy cheese, soy burgers and other meat analogues comprise the new generation soy foods.
Salad oil, cooking and frying oils, shortenings and margarine are also derived products since they are made from soybean oil exclusively or in some extent.

1.5 Requirements for export and quality assurance

The quality factors usually included in soybean export contracts are oil, protein, foreign material, moisture and free fatty acid content (Hill *et al.*, 1997). The requirements for export of the top three exporter countries are reviewed in this section. In addition, the grades and grade requirements for soybeans in two countries, the United States and Mexico, are provided. These grades and grade requirements are similar to those of other countries.
Brazil and Argentina have an export grade for soybeans, Grade No. 1. Brazil's Grade No. 1 limits foreign material to 1 percent. The base limit for Argentine soybeans is 1 percent, although discounts may be applied up to 3 percent. Their definition of foreign material excludes small pieces of broken beans that are included in United States definitions. The United States does not have a specific export grade for soybeans, practically, soybean is exported at any requested specification for foreign material and since its soybean handling technology allows them to meet any specification. Brazilian grades specify 14 percent moisture content as the maximum limit for export quality; Argentine grades use a base of 13 percent. In the United States, 14 percent is the most common maximum for export.
Comparison of United States average soybean quality with that of Brazil and Argentine from 1986 to 1992 showed that the level of free fatty acids in soybeans shipped from the United States is nearly 0.4 percent points lower than soybeans shipped from Brazil and 0.12 percent points higher than soybeans from Argentine. Argentine had the lowest value (0.87 percent) (Hill *et al.*, 1997). The average oil content of Brazil soybeans over the six-year period was 1.2 percent higher than that of soybeans from the United States (20.2 percent vs. 19.0 percent). Protein content of Brazil soybeans was 0.6 percent higher than those from the United States and Argentine (35.9 percent vs. 35.3 percent). United States origin soybeans had higher oil content than Argentine soybeans (19.0 percent vs. 18.7 percent).
Quality factors of great importance for soybeans handling and storage are moisture content, foreign material and free fatty acids. The lower the moisture content, the greater the breakage and the higher the expected foreign material level after unloading. Seemingly, low moisture contents are a disadvantage, but it is not true since for safe soybean storage moisture content should not exceed 13 percent. On the other hand, moisture content affects the quantity of oil and meal that can be obtained per tonne of soybeans as well as quality deterioration in the market channel. Foreign material affects the efficiency of the oil extraction process and the quality of the final products (meal or oil). Soybeans containing certain foreign material level should be cleaned to enable the production of high quality soy products. Foreign material removal is necessary to protect the processing equipment. Levels of free fatty acids above 1

percent create serious problems for processors, decreasing oil quality and increasing refining costs.

United States Grades and Grade Requirements for Soybeans

United States Standards define soybeans as grain that "consists of 50 percent or more of whole or broken soybeans (*Glycine max* L. Merr.) that will not pass through an 8/64 round-hole sieve and not more than 10 percent of other grains for which standards have been established under the United States Grain Standards Act". There are five classes of soybeans: yellow, green, brown, black and mixed soybeans. The first four classes are described as soybeans which have seed coats of their respective colour (yellow and green are permitted for the yellow class) and which are of the same colour in cross section and contain not more than 10 percent of soybeans of other classes. Mixed soybeans, the fifth class, are any soybeans that do not meet the preceding requirements, including bi coloured soybeans. There are two special grades for soybeans. Garlic soybeans contain five or more garlic bulblets per 1 000 grams. Weevily soybeans are those infested with live weevils or other insects injurious to stored grain. The words "garlic" or "weevily" are added to the grade designation of soybeans in cases where applicable.

Soybean grades are based on the minimum test weight per bushel, maximum percent limits of damaged kernels, foreign material, splits and colours other than yellow and maximum count limits of other materials.

Damaged kernels are divided into two classifications: total and heat damaged. Other types of damage include weather damage, frost damage, germ damage, immature soybeans, insect damage, mould damage and sprout damage.

Foreign material refers to all matter, including soybeans and pieces of soybeans that pass through a 1/8 in. (0.32 cm) sieve. It also includes all materials other than soybeans that remain on the sieve after sieving. Among the foreign material normally seen during inspection are: whole or parts of corn kernels or other grains, weed seeds, vegetable parts such as pods, leaves, or stems and dirt or other inorganic materials.

Splits are those soybeans with more than one-quarter of the bean removed and that are not otherwise damaged. They result mainly from mechanical damage during handling of soybeans. In addition, some splits may result from excessively lowering seed moisture.

The most current standards for soybeans are shown in Table 7.

Table 7. U.S. Grades and grade requirements for soybeans.

Grading Factors	Numerical Grades			
	US No.1	US No. 2	US No. 3	US No. 4
Minimum limits of Test weight (lbs/Bu)	56.0	54.0	52.0	49.0
Maximum percent limits of Moisture Damaged kernels Heat damaged Total damaged Foreign material Splits Soybeans of other coloursa	13.0 0.2 2.0 1.0 10.0 1.0	14.0 0.5 3.0 2.0 20.0 2.0	16.0 1.0 5.0 3.0 30.0 5.0	18.0 3.0 8.0 5.0 40.0 10.0
Maximum count limits of Other materials Animal filth Castor beans Crotalaria seeds Glass Stonesb Unknown foreign substance Totalc	 9 1 2 0 3 3 10	 9 1 2 0 3 3 10	 9 1 2 0 3 3 10	 9 1 2 0 3 3 10

Source: Liu (1997), Scott and Aldrich (1970), taken from Official United States Standards for Grains, Item No. 810.1604 (1995).

The US sample grade soybeans are those that:
Do not meet the requirements for US Grades 1 to 4, or
Have a musty, sour, or commercially objectionable foreign odour (except garlic odour), or
Are heating or distinctly low quality.
a Disregard for mixed soybeans.
b In addition to the maximum count limit, stones must not exceed 0.1 percent of the sample weight.
c Includes any combination of animal filth, castor beans, crotalaria seeds, glass, stones and unknown foreign substances. The weight of stones is not applicable for total other material.
Sampling is the first and critical step for grading soybeans. Some guidelines have therefore been established.
Sampling from a container.
In general, if soybeans to be sampled are already in a container, such a truck, railway car or barge, five samples from different placed need to be obtained by use of a double-tube trier that can remove soybeans from several depths in the container.
Sampling when soybeans are being loaded or unloaded.
A "pelican" sampling device is used to obtain cuts from the stream.
Sampling when soybeans are shipped in sacks.
A sufficient number of sacks need to be sampled. Regardless of how samples are obtained, the size of the sample must be at least 2 quarts (about 1.4 kg or 3 lb). All samples need to be protected from any changes that may affect the grade before the actual grading is carried out.

Mexican Grades and Grade Requirements for Soybeans

Comision Nacional de Subsistencias Populares (CONASUPO) since 1992, Table 8, established the current Mexican grades and grade requirements for soybeans commercialization. Some differences between United States and Mexican standards for soybeans are the number of grades (5 vs. 3); soybeans exceeding maximum limits are qualified as "sample grade" in the United States system whereas those soybeans are rejected in the Mexican system. Test weight is not a grading factor in the Mexican system. In addition, the Mexican system applied penalties when soybeans exceed the maximum limit allowed for a given grade provided not exceeding the minimum limit for rejection. Penalties consist of discounting one kilogram per metric tonne for each decimal point exceeding the percent limit established for "no penalties". Acid value is a grading factor in the Mexican system whereas in the United States system is not taking into account.

Table 8. Mexican grades and grade requirements for soybeans.

Grading factor	Mexico No. 1	Mexico No. 2	Mexico No. 3
Maximum percent limits of	12.0	12.0	12.0
Moisture[a]	0.5	0.5	0.5
Damaged kernels[b]	2.0	3.0	5.0
Heat damaged	1.0	3.0	5.0
Total damaged	10.0	20.0	30.0
Foreign material[c]	1.0	1.5	2.0
Splits[d]			
Acid value			

[a] Penalties due to excess moisture are as follow: □ 12 percent no penalty; between 12.01 and 14 percent the penalty is to discount one kilogram per metric tonne for each decimal point exceeding 12 percent. Samples with moisture content higher than 14 percent are rejected, except those commercialized in the states of Chiapas and Tamaulipas, whose allowed moisture content is 16 percent and penalties are applied when moisture content is between 12.1 and 16 percent.

[b] Penalties for damaged kernels are as follow: □ 2 percent no penalty, between 2.1 and 5 percent the penalty is to discount one kilogram per metric tonne for each decimal point exceeding 2 percent. Samples containing more than 5 percent damaged kernels are rejected as well as those containing more than 0.5 percent heat damaged kernels.

[c] Penalties for foreign material are as follow: □ 1 percent no penalty; between 1.1 and 5 percent the penalty is to discount one kilogram per metric tonne for each decimal point exceeding 1 percent. Samples with more than 5 percent foreign material are rejected.

[d] Penalties for splits are as follow: □ 10 percent no penalty; between 10.1 and 20 percent the penalty is to discount one kilogram per metric tonne for each decimal point exceeding 10 percent.

Samples containing more than 20 percent splits are rejected.

In Mexico, the operations of sampling, analyzing and certification of soybean quality are carried out as follows:

Farmers take soybeans to the reception centre or the processing plant. Sampling is carried out by the lab-technician. Results of the analyses are displayed on each truck properly identified, in case of meeting the established requirements for soybean reception.

The lab-technician must return the grain samples taken for analyses.

In case of disagreement with the results of the analyses, the farmer (s) could require the analyses were redone under his vigilance and the results should be taken as definitive for rejection or reception of the soybeans.
Once the above is done, the grain is weighed.
Next, the lab-technician fill out a special form (Form C-1) called "unique document".
The farmer(s) receives the unique document as proof of being in agreement with the analyses and volume of grain sold signs the original and copies of the document. At this point, it is ready to receive the payment.

Other specifications

Specifications for typical food grade soybeans (Table 9) were reported by Wilson (1999). Constituents are important in processing soyfoods, extracting components for food, feed and industrial uses, for nutritional value, health, functionality and sensory properties in foods.

Table 9. Typical food grade soybean specifications.

Seed size, seed coat colour, cleanliness and number of hard beans (germination test or soaking test)
Proximate composition- some companies also requires calcium and phosphorous levels (phytic acid).
Total sugar (free)
Total sugar (fermentable sugar-Japanese specifications)
Peroxide Value or TBA
Acid Value (US or Japanese methods)
Free Fatty Acid (US or Japanese methods)
Nitrogen Solubility Index (NSI) or Protein Dispersibility Index (PDI)
Organically grown
Genetically Modified Organisms (GMO) free
Identity Preserved (IP)

Source: Wilson (1999).

1.6 Consumer preferences

In the Far East, traditionally, soybeans are made into various foods for human consumption, whereas in the West, most soybeans are crushed into oil and defatted meal. Due to this difference in soybean use, two different types of soybeans have emerged; food beans and oil beans (Liu *et al.*, 1995; Orthoefer and Liu, 1995; Wilson, 1995). Annually, the United States exports 10 to 15 percent of the soybean production estimated at 6 to 7 million metric tonnes, to Japan, Korea and Taiwan. Most of this portion is used for whole bean applications (Motoki and Seguro, 1994).
The traditional soyfoods include the nonfermented and fermented Oriental soyfoods. Among the nonfermented soyfoods, tofu is the most popular, followed by soymilk and soy sprouts. Other includes okara, roasted soy nuts or flour, yuba, fresh immature soybeans, sweet beans and mature whole soybeans. Among the popular fermented soyfoods are soy sauce, miso, tempeh and natto.
In recent years, there has been an increasing interest in the West in exploring the food values of soyfoods. Some of them have shown great potential for being incorporated into Western diets.

Tofu

Tofu (Japanese), Dan fu (Vietnamese), Teou fu or Tou fu ho (Chinese) or bean curd is a cottage cheese-like product formed into a cake, which is precipitated from soy milk by a calcium salt or, in some instances, by concentrated sea water. Tofu can be prepared for the table in many different ways; the most important are in soup and by deep fat frying, the latter called aburage in Japanese and Yu Tou Fu in Chinese. Tofu compares with cheese or meat, it is much lower in calories because of its higher protein/fat ratio. It is also cholesterol free, lactose free and lower in saturated fat. Composition of tofu and annual per capita consumption in some countries is shown in Tables 10 and 11, respectively. The annual consumption of tofu is between 100 to 150 g in countries other than those of Asian origin. Throughout East Asia, tofu has been the most popular way to serve soybeans as a food. In 1997, tofu and tofu derivatives were dominant in China, Korea and Japan. About 60 percent of total soybean consumption in Japan corresponded to Tofu and tofu derivatives (Saio, 1999).

Germany is the most important market for tofu in the European Community, followed by United Kingdom, France and Holland (Kerntke, 1992). In India, soypanner (the Indian name for tofu) is acceptable to the consumers (Bhatnagar *et al.*, 1991).

Table 10. Composition of tofu on wet and dry matter basis.

Item /100 g	**Wet matter basis**[a]	**Dry matter basis**[b]
Water	85	-
Protein	7.8	50
Lipids	4.2	27
Carbohydrates + Minerals	3.0[c]	~ 23
Calcium (mg/g)	2	

a Adapted from Wang et al. (1983); Schaefer and Love (1992).
bAdapted from Wang et al. (1983).
c Estimated by difference.

Table 11. Tofu annual per capita consumption.

Country	**Per capita consumption (g)**
Holland	110
United States	150
European Community	50 - 100
Japan	< 4 000

Source: Kerntke (1992).

Soybean milk

Soymilk is a water extract of soybeans, closely resembling dairy milk in appearance and composition. Soymilk contains total solids of 8 to 10 percent, depending on the water: bean ratio in its processing. Protein is about 3.6 percent; fat, 2 percent; carbohydrates, 2.9 percent

and ash, 0.5 percent. Soymilk composition compares favourably with those of cow's milk and human milk, Table 12. It contains the highest amount of protein, iron, unsaturated fatty acids and niacin, but the lowest amount of fat, carbohydrates and calcium. It is lactose and cholesterol free. Soymilk provides proteins and other nutrients to people in regions where the supply of animal milk is inadequate. It is especially important for infants and children who exhibit allergic reactions to dairy milk or have a particular need for adequate protein in their diets (Liu, 1997). Progress in reducing beany flavour by researchers at Cornell University and the University of Illinois, has made soymilk popular as a beverage in the Far East. It is steadily spreading to the Western world.
Soymilk is quite popular en China and Korea, but its consumption is insignificant in Japan (Saio, 1999). The United Kingdom is the main European market for soymilk, followed by Germany, France and Holland (Kerntke, 1992). In many other countries, soymilk is being produced and commercialized under different names, for example "A de S" in Mexico; soy-milk in India; "Soja drink" in Brazil.

Soy sprouts

Consumption of soy sprouts is large in China and Korea (14.2 percent) (Saio, 1999). In the Western world, the most common use of soy sprouts is cooked with vegetables and meat, poultry or fish. In Mexico, the main, if not the unique, dish prepared with soy sprouts is called "chop suey". In the Orient, soy sprouts are consumed cooked as vegetable or in soup. There is no consumption data available in the literature for soy sprouts.

Soy paste

Soy paste is one of the most important fermented Oriental soyfoods in China and Japan, where it is called "Jiang" and "Miso", respectively. Miso is a paste resembling peanut butter in consistency. It is made from soybeans mixed with rice or barley or soybean alone, whereas Jiang is often made from soybeans and wheat. In China, jiang is used as a base for sauces served with meat, seafood, poultry or vegetable dishes. In Japan, miso is mainly dissolved in water as a base for various types of soups. Miso and natto are dominant in Japan; about 165 metric tonnes of soybeans were used for miso manufacturing. In Korea, 82 metric tonnes of soybeans were utilized for miso and soy sauce (Saio, 1999).

Soy sauce

Among all fermented soyfoods, soy sauce is now the most widely accepted product, not only in the Far East but also in Western countries. Soy sauce is a dark-brown liquid extracted from a fermented mixture of soybeans and wheat.

Tempeh

Tempeh is one of the most popular fermented foods in Indonesia, New Guinea and Sumatra. Because of its meat like texture and mushroom-like flavour, tempeh is well suited to Western tastes. It is becoming a popular food for vegetarians in the United States and other parts of the world. Tempeh serves as a main dish or meat substitute.

Natto

Natto is one of the few products in which bacteria predominate during fermentation. When properly prepared, it has a slimy appearance, sweet taste and characteristic aroma. In Japan, it is often eaten with soy sauce or mustard. It is served for breakfast and dinner along with rice. In 1997, Japan used 122 metric tonnes of soybeans for natto manufacturing (Saio, 1999).

Vegetable soybeans

Immature green soybeans are being marketed in the United States as a frozen vegetable by SunRich (Weingartner, *et al.*, 1999).

In the United States, six companies dominate the soyfood market. The retail values of soyfood sales in the United States are shown in Table 13. Soymilk sales increased from US$2 million in 1980 to US$207 million in 1998 and it is the fastest growing soyfood. Soy proteins and soy sauce were the most demanded soyfood during 1998; together these soyfoods totalled 70 percent of the United States soyfood sales.

Table 12. Composition of soymilk, cow's milk and human breast milk.

Item/100g	**Soymilk**	**Cow's milk**	**Human milk**
Calorie	44	59	62
Water	90.8	88.6	88.2
Protein	3.6	2.9	1.4
Fat	2.0	3.3	3.1
Carbohydrates	2.9	4.5	7.1
Ash	0.5	0.7	0.2
Minerals (mg) Calcium Phosphorus Sodium Iron	15 49 2 1.2	100 90 36 0.1	35 25 15 0.2
Vitamins (mg) Thiamine (B1) Riboflavin (B2) Niacin	0.03 0.02 0.50	0.04 0.15 0.20	0.02 0.03 0.20
Saturated fatty acids (%)	40-48	60-70	55.3
Unsaturated fatty acids (%)	52-60	30-40	44.7
Cholesterol (mg)	0	9.24-9.9	9.3-18.6

Source: Taken from Liu (1997), adapted from Chen (1989).

Table 13. Retail value of soyfood sales in the United States during 1980 and 1998.

Soyfood	**Retail value (million US$)**	
	1980	1998
Soymilk	2	201
Tofu	38	207
Tempeh	1	18
Miso	6	76
Soy sauce	126	490
Soy nuts	3	19
Soy proteins	218	753
Total	394	1 764

Source: Wilson (1999).

2. Post-Production Operations

A lot of work is behind the million tonnes of soybeans produced by farmers. The effort of farmers to produce soybeans has to be complemented with the effort and care of those who handle the beans after harvesting. Once the soybeans are mature, they are subjected to several operations whose purpose is to keep as much as possible the original quality of the beans. The goal is to maintain the quality at harvest and ensure a continuous supply to processing industries or consumers.

The following operations are mostly carried out in the sequence in which they are mentioned. Sometimes, some of them have to be repeated if the beans are in risk of spoilage or deterioration. The post-production operations include harvest, pre-drying, threshing (this operation is done simultaneously with harvesting when the beans are harvested by combines), transport, pre-cleaning, drying, cleaning and sorting, packaging, storage and processing.

2.1 Pre-harvest operations

This section describes crop preparation for harvesting including cultural practices, diseases and pests associated to soybean cultivation. Among the cultural practices in soybean cultivation are soil preparation and fertilization, planting, irrigation, weeds, diseases and pests control.

Preparation of the land and fertilization.

It is very important to plough and level the soil before planting soybeans (Figure 2). These labours acquire a major importance when soybean crop is mechanized. When the surface is in good condition it is much easier to make downer cuts and harvest more seeds. On the contrary, on uneven soils, not levelled, with hillocks, etc, losses due to excessive height cuts may be of concern because of head machine (combine) swinging, which requires the combine operator's constant care to avoid uneven cuts and platform sticking. It is recommended to use planks to flatten the soil before planting. Flat and not deeper than 10 cm scratches are convenient cultural practices in soybean cropping.

Figure 2. Soil ploughing and levelling.

When soybean is grown after other crop, it often can be planted without further preparation of the soil, once the preceding crop has been harvested or the soil has been ploughed two or three times until free from grass and other plants. Some farmers in the northwestern part of Mexico use to crop soybean after wheat harvesting. Wheat stubbles are burned and the furrows previously used are immediately irrigated without further land preparation. This practice reduces soybean production costs.

Fertilizing soybeans is not a common practice, unless the soil is known to be deficient in phosphorus and potassium. Phosphate and potash granules are spread over the fields before planting begins. Nitrogen is important for soybean cultivation. But soybeans, like other legume crops, have the capacity to "fix" nitrogen in the soil, thanks to certain bacteria contained in the nodules that form their roots. These bacteria convert nitrogen from the air and convert it to metabolized ammonium N, thus reducing soy's need for a nitrogen fertilizer. Soybeans perform nitrogen fixation by establishing a symbiotic relationship with the bacteria, *Rhizobium japonicum*, in root nodules. This symbiotic nitrogen fixation system results from nodule formation known as nodulation (Liu, 1997). To ensure this process takes place, soybean seeds are inoculated with *R. japonicum* before planting. But as with any bean, adding inoculants to your soy crop will both allow plants to better fix nitrogen in the soil and improve the yield. Inexpensive inoculants may be purchased from seed catalogues and in hardware stores. Besides the inoculant, the soybean seed is sometimes added with a fungicide. Some farmers in rural areas cannot afford the use of fertilizers even their lands have nutrient deficiencies, consequently, soybean yields are very low. Soybean, yielding 3 000 kg/ha, is able to extract 205 kg of nitrogen, 55 kg of phosphorus and 135 kg of potassium. Taking into accounts these numbers and the previous chemical analyses of the soil, the fertilizer needs for this crop can be calculated. In deficient soils in phosphorus and potassium, it is recommended to apply at least 300 kg/ha of a formula 5-20-20. When the soils are only deficient in phosphorus, it can be applied from 100 to 200 kg/ha of a fertilizer composed of 10-30-10 (Sánches-Potes, 1982).

Planting

The seeds are planted 1 1/2" deep, unless they are being planted late. (In that case, since the ground will be much drier, push them to twice that depth). This may sound a bit close, as the soybean plants are quite large; but this close spacing allows the floppy plants to hold each

other up and the beans will produce excellently. In wetted soils, soybean is less deep planted than in dried soils. In light soils, it is deeper planted.
Seed planting density is between 60 to 80 kg/hectare, although there is a tendency to sow 80 kg/ha that is from 32 to 38 plants per linear metre to produce plants with thinner stems and pods at a higher height, which facilitate cutting. When soybean is going to be planted in soils never cultivated with soybean, it is highly recommended to inoculate soybean with the specific strain of *R. japonicum*. Distance between furrows depends on soybean varieties, plant height and its ability to grow. For high plant and late maturity varieties, it is recommended plant densities between 27 and 30 plants per square metre in rows spaced 60 cm. For short and early maturity varieties, a plant density between 40 and 60 plants per square metre in rows spaced 30 or 45 cm is recommended (Sánchez-Potes, 1982).
The beans can also be planted broadcast-style, then worked into the ground with a tiller. But this stand will be much weedier, as you will be unable to till it. If, however, the last crop you grew on the same spot was weed-free, weed control may not be such a problem.
Hand planting a hectare of land with soybeans often takes two workdays (Thuy, 1998). Farmers plant soybeans by inserting 7 or 8 seeds in each hole.

Irrigation or rainfed

Some moisture is necessary for germination, of course and during early development. Indeed, it is most important that the plants receive rainfall (or artificial watering) at the time of their seed-filling period. However, soybeans can withstand some drought once they are well established.

Weeds and their control

Soybean plants face a challenge from both broadleaf and grass weeds, particularly early in the growing season. If left after mid-season, weeds will seriously affect yields. In fact, weeds constitute the greatest hazard to soybean production in terms of the magnitude of losses they can cause. Weeds compete with plants for moisture, nutrients and sunlight. They also interfere with harvesting machinery and its presence in the harvest significantly reduces the trading value of the crop.
During the first days, soybean growth is slow and the crop must be kept weeds free. Some weeds may invade it, even though at the later stages of development. In each region specific weeds are predominant. It is necessary to recognize and identify them for a better control, especially if herbicides are used. Several systems must be integrated for getting weed control. An adequate land preparation allows eliminating a lot of weeds. The use of improved aggressive varieties and good coating, optimum plant spacing and an adequate fertilization, will provide advantages to soybean plants over weeds. Once the soybean seed is germinated, weeds can be eliminated by hand (Figure 3), commonly used by small-scale growers, or mechanically (Figure 4) as done by large-scale growers. The chemical control by means of herbicides is carried out before planting, as a pre-planting application, or after planting but before germination, as a pre-emergence application. Pre-planting herbicides are incorporated to the soil during the second tillage. There are many pre-emergence herbicides. These are applied by means of a sprayer machine (Figure 5) following the manufacturer's instructions. Most large-scale growers are forced to use herbicides for weed control. Herbicides most currently used to control weeds in pre- or postemergence treatments are imazaquin, imazethapyr, chlorimuron-ethyl, flumetsulam and fomesafen. Glyphosate is the world's most popular herbicide due to its excellent weed control capabilities and environmental safety. This herbicide cannot be applied over the top of the crop because it causes severe plant injury. Since 1996, a new weed control system for soybeans crop has been commercially available (Monsanto, Co.) through the glyphosate-tolerant soybeans called "Roundup", a transgenic

plant developed in the United States (Duke, 1996). In the last years, the "Round-up" soybean has been tested worldwide. In Italy, the efficacy and total cost of weed control based on glyphosate (Round-up) were quite similar to those of good traditional control techniques (Sartoroto and Zanin, 1999).

Figure 3. a. Agricultural tool used for weed control. b. and c. Agricultural workers eliminating weeds in a field.

Figure 4. Equipment used to eliminate weeds.

Figure 5. Apparatus for herbicide application (left), attached to a tractor for weed control (right).

Diseases and pests control

Soybean plants are susceptible to many diseases and pests worldwide. More details on this matter are provided in Section 4. Strategies for a better control of diseases and pests include the use of resistant cultivars developed by plant breeders.

Disease resistant cultivars

The cultivar Tracy M has been reported to have two dominant genes for resistance to stem canker disease (*Diaporthe phaseolorium* f. sp.*meridionalis)*, either of which can confer resistance (Kilen and Hartwig, 1987). Other sources of resistance to this important soybean disease are the cultivars BR-1, Doko, CAC-1, Dourados, EMGOPA 302, FT-Estrella, IAC-13, IAC-17, MTBR-45 and UFV-9 (de Toledo *et al.*, 1997).

Insect resistance cultivars

Only four accessions, PI 171444, PI 171451, PI 227687 and PI 229358 have shown varying levels of resistance to bean flies, leaf feeders and stink bugs and pod borers in Asia and elsewhere (Telakar, 1997). The Asian Vegetable Research and Development Centre (AVRDC) uses only PI 227687 in its insect resistance-breeding program. Insect-resistant PI accessions are available free of charge to any breeder interested in breeding insect-resistant soybean cultivars. Recently, a soybean cultivar with resistance to white fly, the devastating insect that caused severe yield losses in the northwestern part of Mexico, was developed (Castillo *et al.*, 1998). Soybean varieties or germplasms possessing field resistance to stem fly infestation, to seed maggots, to green slug caterpillar, to leaf miner, to girdle beetle and to leaf folders have been developed in India (Khundu and Srivastava, 1992). The cultivar "Hartwig", the result of two backcrosses to "Forrest" using the PI 437654 as the donor parent, with broad resistance was released (Anand, 1992). Hartwig is probably the best source of resistance to the cyst nematode, *Heterodera glycines* (de Toledo *et al.*, 1997). Duyn *et al.* (1971) reported genes for insect resistance in PI 229358, PI 227687 and PI 141451. In the last decade, scientists have successfully isolated a gene from the bacterium *Bacillus thuringiensis* (Bt) and inserted it into soybeans and other crops (Stewart *et al.*, 1994). The transgenic soybean with *Bt* gene has been shown in the field to be effectively immune from attacks of the caterpillar larvae of lepidopteran insects, moths and butterflies, the two major insect pests (Liu, 1997).

2.2 Harvesting

The length of the growing season varies from 50 to 200 days, depending on the variety, weather, latitude, etc. For dry harvest, soybeans should be allowed to stand in the field while the pods dry and mature, turning a buff to yellow colour, Figure 6. During this time, the leaves will first turn yellow and then drop off. The fully ripe beans are left to dry in the fields; the old brown stems and pods are left standing until dry, with the moisture content falling to about 13 percent. Some small farmers check seed moisture by just cutting few pods, moving them in the air to listen to its dry sound. Others remove the seeds from the pods and apply some pressure with their teeth.

Figure 6. Soybean field ready for harvesting in the Yaqui Valley, Sonora, Mexico.

Soybeans are harvested over a relatively short period of time. In the United States, Mexico and some other countries, soybeans are harvested in the fall of the year. Therefore, the initial soybean marketing is a highly seasonal activity with the result that the beans are gathered and placed in storage for utilization over the entire year. Depending on circumstances, the grower may hold the beans in storage, either on the farm or in private storage space, or sell his beans for cash.

Most of the soybeans are mechanically harvested. In the fall, combines (Figure 7) run day and night to bring in the harvest before the fall rains. The machine moves down one to several rows (depending on the size of the combine) and pick up leaves stalks and pods. The seeds are threshed out from pods into a hopper and moved into a transport truck. All other parts of the plants are blown back out onto the field. In the less developed countries, harvesting is done by a two- or four-row cutter (Figures 8 and 9). The plants are cut 1 to 2 in. above the surface of the soil, usually in the early morning when the presence of dew prevents shattering. Hand cutting by sickles (Figure 10) is another way to harvest soybeans, particularly for beans grown in a small field. The harvested plants are collected, dried and finally threshed (Figure 11). Thresher machines similar to that of Figure 11 are commercially available in the United States **http://www.Almaco.com** or Brazil **http://www.Industriascolombo.com.br**. The price oscillates between US$ 5 000 and US$ 7 700. See the Annex (page 87) for technical specifications of these type of machines.

Figure 7. Modern combine for soybean harvesting, left; front view; right; back where all other parts of the plants are spread onto the field.

Figure 8. Equipment used for soybean harvest in the less developed countries.

Figure 9. Agricultural implement used with the equipment in Figure 8. to reduce harvesting loss.

Figure 10. Hand cutting by sickles.

Figure 11. Equipment for soybean threshing.

Harvesting a backyard crop of soybeans for home use is a little more labour-intensive. If you are growing a small quantity of beans, you can cut and thresh them by hand. Cut the stalks, stuff them in a burlap bag, then trample them, beat them or run them over with your pickup. The resulting tangle can be winnowed by pouring the beans from one bucket to another, either outdoors in a brisk breeze, or in front of a large fan.

The beans may also be harvested in the green stage, you can gather, cook and freeze them, as you would garden peas. Steam the green, still-tender pods for about ten minutes, pour off the water and remove the hull. This will be a slow process. Some folks simply pull the green shell between their teeth and pop out the green seeds that way. Green soybean harvest may be stretched over several weeks, as the beans at the base of the stalks dry first, then gradually the ones higher up--very much like garden peas.

Reliable data on the true level of soybean postharvest losses are not available. It is really a difficult task to evaluate losses that occur during all phases of the postharvest system. Postharvest losses must include both quantitative (weight loss) and qualitative (nutritional, functional, or hygienic) losses caused by various physical, biological and mechanical factors, which the beans are exposed to.

In general, losses of food grains through spillage and breakage are reported to be lesser in manual harvesting than in the use of mechanical devices (FAO, 1984). Soybean harvesting loss data are scarce throughout literature. A study carried out in Monte Alegre de Minas, MG, Brazil (Reis *et al.*, 1989) reported losses due to mechanical harvesting of soybeans in the range of 2 to 4 percent, depending on the type of cylinder attached to the combine and the hour of harvesting, Table 14. Manual harvesting caused less seed damage than mechanical harvesting, Table 15. In this study, losses were measured by collecting the pods and beans scattered on the ground and, separately, the pods and beans left on the plant stumps. They used two types of cylinders in the combine: a toothed cylinder for threshing out the grain and one with steel bars mounted longitudinally on the cylinder. The toothed cylinder provoked a higher seed loss (1.17 percent) and less damage than the cylinder with the steel bar, Table 14. Seed losses increased as the hour of harvesting progressed and seed moisture decreased. Seed damage (cracked and split seeds) increased during the day as levels of humidity reduced, Table 15.

Table 14. Results of seed loss in soybeans due to mechanical harvesting, in Monte Alegre de Minas, MG, Brazil, 1986 to 1987.

Type of cylinder	Hour of harvesting	Scattered seed (%)	Scattered pods and branches (%)	Seed left on plant stumps (%)	Total (%)
Barred	11 13 15 17	1.17 1.14 1.76 1.67	0.91 1.01 0.76 1.40	0.11 0.18 0.10 0.11	2.19 2.33 2.62 3.18
Toothed	11 13	1.31 1.34	1.25 2.42	0.32 0.22	2.88 3.98

Source: Reis *et al*. (1989).

Table 15. Results of seed damage in soybeans due to mechanical harvesting, in Monte Alegre de Minas, MG, Brazil, 1986 to 1987.

Type of threshing	Hour of harvesting	Moisture (%)	Seedcoat cracking (%)	Normal sprouts (%)	Necrosis (%)	Soaking (%)
Manual	10	13.65	0.0	96.6	15.6	60.3
Beating sacked plants with a stick	10	13.65	0.0	94.8	19.0	51.5
Barred	10 11 12 15 16 17	13.65 13.21 13.01 13.03 12.30 11.97	5.2 10.8 9.0 12.8 14.0 15.2	86.2 93.4 84.6 80.4 87.4 83.4	24.0 16.8 23.4 25.0 13.4 12.0	59.0 63.9 67.6 71.4 70.8 69.5
Toothed	**11** 12	**13.21** 12.91	**2.8** 6.8	**91.6** 96.0	**12.0** 12.8	**59.1** 60.7

Source: Reis *et al*. **(1989).**

The harvesting losses estimated by a soybean grower (medium-scale farmer) in Culiacan Valley, Sinaloa, Mexico (Godoy, 2000), using the equipment shown in Figure 8, was 150 kg per hectare (about 7 percent). If the agricultural implement shown in Figure 9 (with a value of US$ 12 000) is attached to the equipment illustrated in Figure 8, harvesting losses are reduced significantly (almost to 1 percent). Kowalczuk (1996) reported soybean harvesting losses ≤ 6 percent when harvesting was carried out with the Z056 "Bizon Super" grain combine harvester equipped with a floating cutting bar. Scott and Aldrich (1970) reported harvest losses between 5.4 and 12.2 percent depending on the height at which the combine cutterbar was operated. The lower loss corresponded to a height of cut of 3.5 inches and the higher to 6.5 inches.

It is estimated that the average time spent cutting the plants by sickles runs from 80 to 100 man-hours per hectare, that is, 10 to 12 work-days per hectare (Godoy, 2000).

Mechanical harvesting with combine-harvesters spent between 1 to 2 hours per hectare, depending on the machine capacity and how well the land was levelled and weeded. The combine works efficiently if the plants stand erect and reach maturity simultaneously. If the grower does not own a combine and wants to harvest with rapidity his beans, then he contracts the service of harvesting, which includes the rent of the combine and the operator's salary, at a rate of US$ 40 per hectare (Godoy, 2000).

2.3 Transport

Soybeans have to be moved throughout the postharvest system. This includes soybeans transport from the harvest fields to the threshing or drying site, from there to storehouses or to collection centres, from there to the processing industries or to bigger central storage buildings, from these industries or storage buildings to wholesalers or retailers for final marketing. The type of transport used to move soybeans depends on the amount of beans and distance travelled.

2.3.1 Traditional transport

In places where the road network is undeveloped and agriculture is traditional, people, donkeys and sometimes horses generally transport soybeans. Otherwise, small trucks are used to transport small quantities of beans, generally packed in bags. Big trucks (Figure 12) are most commonly used since more beans are transported per trip. Most of the times these trucks transport the beans in bulk.

Figure 12.Truck used to transport soybeans.

It is especially important to transport the beans from the field to storage centres as soon as possible to avoid deterioration.

Losses during transport must be reduced to a minimum. Loss means the difference in weight between the quantity loaded and the quantity unloaded. In addition, there is a loss in quality when the beans undergo changes during transport. To avoid transport losses, bags must be checked before putting beans in, since they are reused and can tear during loading or unloading, causing leakage of beans during transport. Care must be taken to load and arrange bags properly in the truck, avoiding crushing the lower layers and placing bags on pallets to permit air to circulate. Also, soybeans must be protected while being transported in the rainy season.

In Mexico, the average transportation rate is about US$7 per tonne of beans in a maximum distance of 60 km. If the truck has to go over a longer distance, the transportation cost has to be agreed between the parts.

In some cases transport costs may represent a considerable amount of money for the farmers. Soybean farmers in Northwestern Argentina have to ship their soybeans to processing plants located in the southern part of the country. These transportation expenses in some years have accounted for as much as 20 percent of the total production costs (Ricci and Ploper, 1997).

Barge transportation of grains is a tradition in the Midwestern part of United States. Agriculture in Midwestern United States is the world’s most efficient and lowest cost producer of many crops, soybean is one of them (Fruin, 1995). The inland waterway system is the major transportation route to export ports in the Gulf of Mexico. Over 25 percent of world grain and oilseed originate on this waterway. In the US, although the water route means extra miles, the rates are much lower than rail rates.

2.3.2 Other means of transport

Large quantities of soybeans are also transported by railcars (Figure 13). This transportation mean has the advantage of generally being cheaper than road transport. Over great distances and where the means exist, it is preferable to transport beans by rail or by ship. Ocean grain freighting services are often contracted several months before shipment.

Figure 13. Soybeans and soybean meal transport by rail (left); bottom unloading by gravity (right).

It is very important to clean and fumigate the railcars before loading the beans. The moisture content of the beans must be checked and kept between the desirable range for safe storage and handling. Moisture contents lower than 12 percent are desirable for safe storage. In general, moisture contents not lower than 10 percent are desirable to avoid seed damage during handling.

The rate of transporting beans or soybean meal by rail from the United States border to Ciudad Obregon, Sonora, Mexico, a city located at 500 km from the United States border, is US$9 per tonne.

2.4 Threshing

Threshing consists of separating the beans from the portion of the plant that holds them. Nowadays, most of the soybeans are harvested and threshed simultaneously by using modern combines. Threshing can also be done by hand, with simple tools, with the help of vehicles, or with simple handy machines or motor operated, Figure 11. Whatever the system used, it is very important that threshing be done with care. Otherwise, this operation can cause breakage of the beans or protective hulls thus reducing the product's quality and fostering subsequent losses from the action of insects and moulds.

2.5 Drying

"Drying" is the phase of the postharvest system during which the beans are rapidly dried until they reach the "safe-moisture" level. After threshing, the moisture content of the beans is sometimes too high for good conservation (13 to 15 percent). The purpose of drying is to lower the moisture content in order to guarantee conditions favourable for storage or for further processing or handling of the product.

Moisture content

Moisture content of a product is a numerical value, expressed in percentage, determined by the relationship between the weight of the water contained in a given sample and the total weight of that sample.

Moisture content of the sample (	Weight of the sample's water	x

%)=	Weight of (sample's dry matter + sample's water)	100

Therefore, to say that soybeans have 15 percent moisture content means within a sample of 100 g of raw product there are 15 g of water and 85 g of dry matter.

Relative humidity

Soybeans, as all grains, are "hydroscopic", meaning that in ambient air they can either give off or absorb water in the form of vapour. At a given temperature, the air cannot absorb unlimited quantities of water vapour. The air is "saturated" when it is unable to absorb water vapour at a given temperature, that is, it has a relative humidity of 100 percent. Air containing a given amount of water vapour tends to become saturated if its temperature is lowered. Contrary, if it is desirable to increase the "drying power" of this air, that is its capacity for absorbing more water vapour, it is necessary to heat it.

The relative humidity (RH) of the air, expressed in percentage, is defined as the relationship between the weight of the water vapour contained in 1 kg of air and the weight of the water vapour contained in 1 kg of saturated air, at a given temperature.

Relative humidity of the air (%)=	Weight of water vapour in 1 kg of air	x 100
	Weight of water vapour in 1 kg of saturated air	

The term equilibrium relative humidity (ERH) simply means RH in the adjacent air after allowing sufficient time for moisture in the seed to equilibrate with the air and can be determined by analyzing the headspace in a sealed equilibrated container.

Table 16 shows moisture-relative humidity equilibrium values for soybeans at 25° C. The higher the RH of the air, the greater amount of vapour absorbed by the beans. At 35 percent RH, the beans contain 6.5 percent of moisture, whereas at 85 percent RH, the moisture content of the beans is 18.4 percent.

Table 16. Moisture-Relative humidity equilibrium values for soybeans at 25° C.

Relative humidity (%)	Moisture in soybeans (%)
35	6.5
50	8.0
60	9.6
70	12.4
85	18.4

Source: Barger (1981).

2.5.1 Drying process

Drying of beans can be done by circulating air at varying degrees of heat through a mass of beans. As the air moves through the beans, it imparts heat to the beans, while absorbing the

humidity of the outermost layers. The exchange of heat and humidity between the air and the beans takes place as follows:
Heating of the beans, accompanied by cooling of the drying air,
Reduction in the moisture content of the beans, accompanied by an increase in the RH of the drying air. Unfortunately, this process does not take place uniformly.
The water present in the outer layers of the beans evaporates much faster and easily than that of the internal layers. Thus, it is much harder to lower the moisture content of the beans from 17 to 12 percent than from 22 to 17 percent. Some farmers have the erroneous belief that rapid drying at high temperature overcomes this situation, but these drying conditions create internal tensions and produce tiny cracks that can lead to rupture of the beans during subsequent handling.
There are essentially two methods of drying natural and artificial drying.
Natural drying consists of exposing the threshed beans to the sun, mostly in the field. To obtain the desired moisture content, the beans are spread in thin layers on a drying-floor, where they are exposed to the air (in sun) between 1 to 2 weeks. The beans must be stirred frequently to encourage uniform drying. As a rule of thumb, the relative humidity of the ambient air must not exceed 70 percent for drying to be effective. This is the reason why grains must not be exposed at night. The cold of the night fosters rehumidification of the grains. This method should not be used in humid regions or during the rainy season. Insufficient or excessively slow drying can bring about severe losses of beans during storage from the self-generated heat of "green" beans. Also, prolong exposure of beans to atmospheric factors (insects, rodents, and birds) and microorganisms (moulds) can cause losses of the product. In China, considerable losses are incurred annually during storage and transportation of grain, as a result of inadequate drying (Ren and Graver, 1996).
Despite these disadvantages, natural drying is recommended in the following situations: when atmospheric conditions favour a reduction in moisture content over a reasonably short time-span, when the amounts of beans to be dried are modest, when the production organization and socio-economic conditions do not justify the cost of installing artificial drying equipment.
Artificial drying is unavoidable in humid tropical and subtropical regions, given unfavourable weather conditions at harvest time. In these regions, it is often difficult to safeguard the quality of the beans. With the introduction of high-yielding soybean varieties and the agriculture mechanization it is possible to harvest large quantities of soybeans in a relative short time. The need of using the land for cultivating other crops forces farmers to harvest soybeans with high moisture content. Consequently, it is necessary to dry the beans artificially. This method of drying consists of exposing the beans to forced ventilation of air that is heated to certain degree in special equipment called "dryers".

The dryer consists of 3 basic elements (Figure 14):

- the body of the dryer, which contains the beans to be dried,
- the hot air generator, which permits heating of the drying air,
- the ventilator, which permits circulation of the drying air through the mass of beans

Figure 14. Grain dryer, capacity 20 tonnes/day; left: body, middle: air generator, right: ventilator.

There are two types of dryers: static or discontinuous and continuous dryers. The dryer shown in Figure 14 is a continuous dryer. The discontinuous dryer is relatively inexpensive and can treat only modest quantities of grain; then it is better adapted to the needs of small- and medium-scale collection centres and processing of products. Small-scale dryers used in South East Asia have a drying capacity between 1 to 6 tonnes per 8 hour operating day (Tumambing, 1996). In Thailand, continuous-flow dryers locally made are used for soybean drying (Bovornusvakool, 1996).

The continuous dryers are high-flow dryers that require a more complex infrastructure, complementary equipment and special planning and organization. They are more appropriate for big centres, silos or warehouses, where very large quantities of product are treated. One disadvantage of artificial drying is that it is fairly costly (purchase of dryers, use of fuel). In Mexico, the cost of drying a tonne of beans or any other grain depends on the original and desired moisture content of the grain. Table 17 shows the charge of grain drying at different original and desired moisture contents. It is estimated that 10 percent of the charge represents the profit for the owner of the drying facility.

Table 17. Average cost of drying grain in Mexico.

Original grain moisture (%)	Desired grain moisture (%)	Average cost (US$/ tonne)
16.0	14.0	3.5
18.0	14.0	4.0
20.0	14.0	4.5
25.0	14.0	5.5 – 6.0

The amount of water to evaporate per tonne of grain, Qr, with an initial moisture Wi (%) to be set at a final moisture Wf (%), is calculate by the following equation:

$$Qr = \frac{Wi - Wf}{100 - Wf} \; 1\,000 \text{ (kg/tonne)}$$

If 5 tonnes of beans harvested at 28 percent moisture were dehydrated to final moisture of 14 percent, the amount of water eliminated would be:

Qr =	28 – 14	1 000 x 5= 162.8 x 5= 813.95 kg
	100 – 14	

It may be interesting to know the amount of water evaporated per tonne of dried grain Qr' to a final moisture Wf. In this case the result would be:

Qr^3 =	Wi – Wf	1 000 (kg/tonne)
	100 – Wf	

For the same moisture content and amount of grain of the previous example, the water eliminated would be:

Qr^3 =	28 – 14	1 000 x 5= 972.22 kg
	100 – 28	

It would be eliminated a higher amount of water since 5 tonnes of beans correspond approximately to 6 tonnes of humid beans.

Table 18 shows the amount of water to be removed per tonne of grain (humid or dried) as a function of the original moisture and final moisture of 14 percent.
The drying rates of 25 Argentinean varieties of soybeans were determined by Giner *et al.* (1994). Variability in seed size and diffusion coefficient accounted for 93.8 percent of variation in soybean seed drying rates.

Table 18. Amount of water to be eliminated from the grain to take it from the harvesting moisture to 14 percent.

Grain moisture (%)	Amount of water evaporated per tonne of humid grain Qr (kg/tonne)	Amount of water evaporated per tonne of dried grain Qr' (kg/tonne)
28	162.79	194.44
27	151.16	178.08
26	139.53	162.16
25	127.91	146.67
24	116.28	131.58
23	104.65	116.88
22	93.02	102.56
21	81.40	88.61
20	69.77	75.00
19	58.14	61.73
18	46.51	48.78
17	34.8	36.14
16	23.25	23.81
15	11.63	11.76

Adapted from De Zanche (1991).

2.6 Cleaning

Cleaning operations consist of eliminating impurities from the grain mass. Sometimes it has to be done more than once through the postharvest system. It may be accompanied by a sorting of the beans according to quality. Cleaning is necessary before artificial drying, storage, marketing or further processing of the beans. After threshing, soybeans are contaminated by earth, plant and insect waste, small pebbles, etc. The beans are susceptible to physical damage during threshing and harvesting, resulting in seed breakage. The broken kernels and all kind of impurities hinder drying operations and make them longer and more costly. In addition, these impurities lower the quality of the product and are also the target for potential infestation during storage.

In the United States, generally, grain is not cleaned when it comes from off the farm. It is placed in bins according to quality so that it can be blended with grains of different quality when loaded out. In Argentina, since there is a premium for No. 1 soybeans, most soybeans are cleaned to less than 1 percent foreign material. In Brazil, soybeans that exceed Brazilian export quality (foreign material 1 percent) are cleaned. In Canada, very little cleaning is done at first point of receipt (Krischik, 1995).

The simplest cleaning method consists of tossing the beans into the air and letting the wind carry off the lightest impurities. This cleaning method does not eliminate the heavier impurities. Cleaner-separator machines (Figure 15) are used when large quantities of beans have to be cleaned. They are motor-driven and consist mainly of a reception hopper, a fan and set of vibrating sieves. Cleaning is done by repeated suction of the lightest impurities, followed by siftings of the beans.

Aspiration cleaning of soybean samples containing 0.5 to 4.0 percent foreign material and 3 to 22 percent splits was reported by Hurburgh *et al.* (1996). Air velocities of 19 m/s (3 500 ft/min) and 10 m/s (1 970 ft/min) were used to clean the samples. The high airflow rate removed 1.1 percent of whole soybeans compared with 0.4 percent at low airflow rate. At either airflow rate, the aspirator removed less saleable material and more non-grain material than previously reported for screen cleaning.

Figure 15. Grain cleaning equipment, left: overall view; right: close-up.

2.7 Packaging

Soybeans are generally packed in bags made of fibres (jute or cotton) or plastic. Bag packaging is little used in developed countries but it is widespread in developing countries because it is economical and well adapted to local grain-transport and marketing conditions. The type of bag determines the height of the stacks. Generally, the bags are stacked on wooden platform called pallets, in order to prevent direct contact of bags with the floor, Figure 16. The free space between the top layer of the stacks and the top of the storehouse should be at least 1 metre. Sometimes, small-farmers keep small quantities of soybeans in sealed containers for self-consumption.

Figure 16. Pallets of soybean packed in bags.

2.8 Storage

Storage is an important phase of the postharvest system. During this phase, the soybeans are kept in such a way as to guarantee soybean availability other than during periods of its agricultural production and conserve its quality as long as possible. The main objectives of soybean storage are to permit deferred soybean use, to ensure seed availability for the next crop cycle, to guarantee regular and continuous supplies of raw soybeans for processing industries and to balance the supply and demand of soybean, thereby stabilizing its market price.

Soybeans, as all grains, begin to lose quality at some rate as they are harvested, stored, or processed. Factors responsible for soybean quality losses during postharvest handling include biological ageing, microbial infection and or insect attacks (Liu, 1997). The control of environmental factors such as temperature, moisture and pests, as well as inventory control (trough proper stock rotation) are needed to minimize these changes in soybean quality during storage. Quantitative losses also occur during soybean storage and handling. Freefall is a major cause of damage to soybeans during handling and shipping, which not only rebound on quantitative losses but also on qualitative losses, since the resulting splits are more susceptible to moisture absorption and enzymatic and mould damage. Shippers in the United States have estimated an average cumulative breakage of about 3 percent each time soybeans are moved (Lusas, 2000).

Temperature and moisture

Temperature and moisture of the beans during storage are determining factors of the quality of the beans at the end of the storage period. Grain temperature is the major stored-grain management tool that regulates insects and moulds. Grain moisture is the other critical grain management factor that regulates storability. The moisture content of soybeans harvested in United States and other countries where soybean cultivation is done in the dry season, normally is low enough for safe handling and storage without artificial drying. The majority of the soybeans harvested in Brazil and Argentina is artificially dried for safe storage. Allowable storage time for soybeans at different moisture contents and temperatures are shown in Figure 17. The higher the moisture and temperature of the beans, the shorter the allowed storage time.

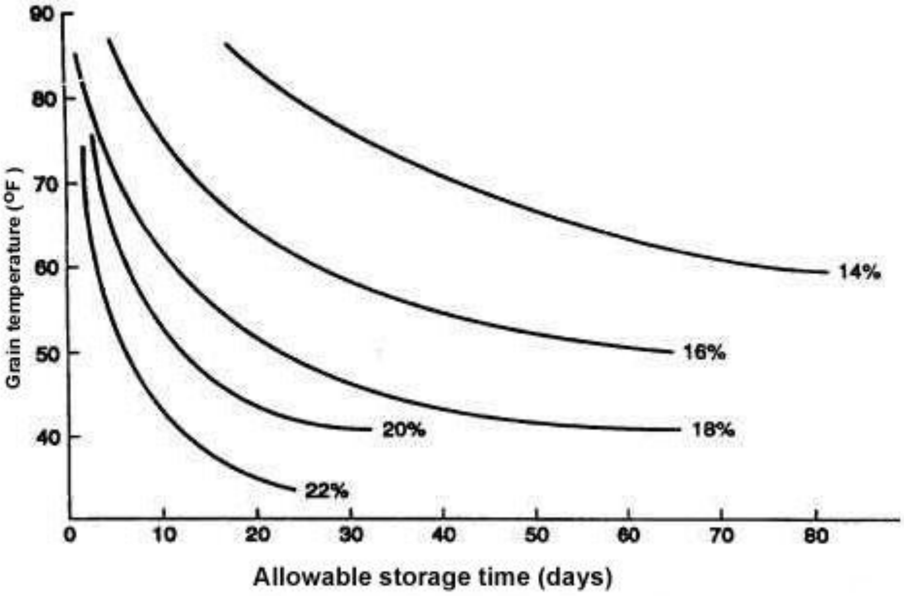

Figure 17. Relationships between temperature, moisture content and allowable storage time. Source: Spencer, 1976.

Temperature and moisture content need to be monitored frequently to watch for heat and moisture build-up. Cooling grain by aeration can reduce temperature and moisture content and limit insect population development (Cuperus *et al.*, 1986; 1990). Drying free-flowing seeds at low moisture levels can be continued in silos or storage buildings by aeration from the bottom. Aeration at 0.1 m^3/min/mtonne (0.1 ft^3/min/bu) is typical for soybeans (Woerfel, 1995). Nowadays, most of the silos are constructed including the aeration system, however, the aeration system in storage buildings (storehouses) in developing countries is commonly implemented by putting several fans (Figure 18) outside the buildings connected to galvanized ducts, which convey the ambient air to the bottom of the mass of grain to be aerated. Considerations explained in section 2.5 with respect to natural drying also apply for aeration. When beans are stored at safe moisture levels but they are not aerated, moisture movement, commonly called "moisture migration", can develop from one part of the storage to another. It is recommended not to aerate soybeans when the relative humidity of the air after reduction of the temperature of the beans is lower than that of the exhaust air. Moisture in high-humidity warm air can condense on cold beans. Reductions in relative humidity as air is heated are shown in Table 19. Increases in relative humidity as air is cooled can also be interpreted from the same table.

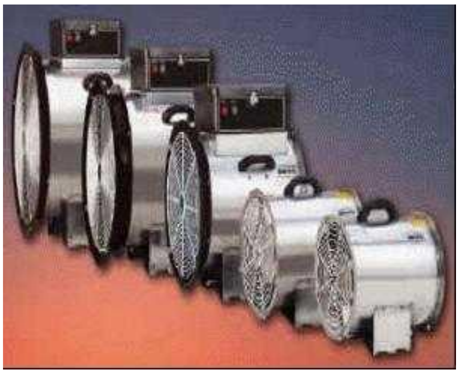

Figure 18. Fans used to aerate grains.

Table 19: Reduction in relative humidity resulting from an increase in temperature.

Air temperature (° C)	Temperature increase (° C)											
	0	6	11	17	22	28	33	39	45	50	55	61
43	95	72	55	42	33	26	21					
38	95	71	53	40	31	24	19	15				
32	95	70	52	40	30	23	18	14	12			
27	95	70	50	38	29	22	17	13	10	8		
21	95	69	49	36	27	21	16	12	9	7	6	
15	95	67	49	36	26	19	14	11	9	7	5	4
10	95	66	47	32	24	18	13	10	8	6	4	4
4	95	64	45	31	22	16	12	9	7	5	4	4

Source: Patterson (1989).

Storage Systems

Soybeans can be packed and stored in bags for further utilization. Generally, this storage system is used for short-term storage. The bags can be stacked outdoors on concrete platforms protected from bad weather and against termite and rodent attacks. They can also be placed on wooden platforms inside storehouses or warehouses. The specific volume, that is, the space occupied by a tonne of soybeans stored in bags is 2.0 m^3/tonne (de Lucia and Assennato, 1994). By multiplying the tonnes of soybeans to be stored by 2, the volume (in m^3) occupied by the bags in the storehouse can be obtained. Another storage system consists of storing soybeans in bulk inside warehouses (storehouses), or in bins (silos) made of concrete or corrugated steel (Figure 19). The amount of beans and the desired storage time, among other factors, determine the type of storage facility to be used, acquired or rented. As an example, the construction costs for round, corrugated-steel, flat-bottom bins of various capacities are shown in Table 20. This type of bin is mainly used for on-farm storage. These costs include the aeration system and the unload auger.

Table 20: Construction costs for round, corrugated-steel, flat-bottom bins of different capacities.

Total Construction costs (US$)	Bin capacity (Bushels)			
	3 000	5 000	10 000	20 000
	4 915	6 629	9 509	16 675

Source: Anderson et al. (1995).

Figure 19. In bulk storage system, left: storehouse used mainly in developing countries, middle: concrete silos used in storage centres, rigth: corrugated-steel silos for on-farm storage.

Designs of storage facilities are dictated by needs for aeration of seed and its angle of repose, that is, the minimum angle in degrees at which a pile maintains its slope (Appel, 1973). This sometimes is reflected in the pitch of conical roofs on storage bins. Similarly, downspouts and the conical bottom of bins must have pitches steeper than the angle of repose for soybean or meal to flow smoothly. Higher moisture and oil contents increase the angle of repose. The angle of repose and bulk density of soybean and soybean products are shown in Table 21. Different on-farm storage structures to those of Figure 19 exist in rural areas of developing countries. In these areas, local available materials are used for their construction. Some examples are the enclosed earthen granaries of the dry zones and the ventilated granaries made of plant fibre and wood that are used in humid zones (de Lucia and Assennato, 1994). Osunade and Lasisi (1995) compared the performance of metal silos with laterized concrete silos in Nigeria. The laterized concrete is concrete in which some, or all, of the fine aggregate is from lateritic soils. Laterized concrete silos maintained a uniform temperature of about 26° C, whereas there were high temperature fluctuations within the metal silos and outside both silos. The results of this study suggest that laterized concrete silos are better than metal silos and that they can be used for grain storage in tropical regions. Oti-Boateng (1995) presented traditional and improved storage methods in developing countries. Construction materials, costs, capacity and appropriate crops and storage time for each storage method was presented.

Table 21: Approximate angle of repose and bulk densities of soybean and soybean processing intermediates.

Soybean product	Angle of repose (°)	Bulk densities	
		kg/m^3	lb/ft^3
Whole	35	720-800	45-50
Hulls, unground	45	96-112	6-7
Meal (solv. ext., 44%)	35	560-610	35-38
Mean (solv. ext., 50%)	32-37	657-673	41-42
Meal (expeller oil)	35	575-640	36-40

Source: Gustafson (1976) and Appel (1973).

Whatever grain storage system requires ventilation. Sometimes, unventilated silos are used for storing grain but they are limited to zones with low relative humidity and protected form outside temperature variations (concrete bins). To use this type of silo, the grain must be completely clean, dry and treated with long-lasting insecticides. In addition, the grain temperature needs to be monitored by thermocouples distributed within the bin.
Small weed seeds and broken kernels (fine material) tend to accumulate in spoutlines, pockets and layers whenever soybeans are transferred. The spoutline material in bins of soybeans may consists of 80 percent weed seeds and it is in this material that spoilage first starts in bins and tanks of stored soybeans. The first indication of spoilage is a rise in temperature. When the temperature in the bin or in the storage facility is not monitored spoilage progress to the final stages of heating. There was a report on discolouration of 10 000 bushels of soybeans of the 90 000 bushels stored in a bin for 3 months due to severe heating.
Turning the mass of grain with motorized equipment or by hand is another way of providing ventilation to the grain. It is not an efficient way of cooling grain but it helps to dissipate heat accumulated in certain areas of the mass of grain called "hot spots" and disperse insects capable of growing and/or surviving under the mass of grain.

Soybean storage studies

It has been observed that soybean genotypes differ in their capacity to maintain viability and vigour during storage (Coelho *et al.*, 1978; Fernandez, 1970; Kueneman, 1982; Herrera and Rosales, 1987). Twenty five soybean genotypes were stored under four storage conditions: (1)

bunches of plants were hanged up at 2 m in a well-ventilated rustic warehouse and dusted with malathion (4 percent) and captan (3 g/kg of seeds) to avoid weevil attacks, (2) seeds were placed in cloth bags in a well-ventilated warehouse at ambient conditions, (3) seeds were placed in sealed containers (jars) at ambient conditions and (4) seeds were placed in cloth bags kept in a chamber at 15° C and 60 percent relative humidity. The storage period was 8 months, the normal storage period from soybean harvesting to the next planting date in Costa Rica. The genotypes' capacity to maintain their viability and vigour varied with the type of storage. After 8-month storage at 15° C and 60 percent RH, soybeans showed the best conservation with an average germination of 95 percent and low variability among genotypes (Herrera and Rosales, 1987). Seeds kept in cloth bags and in plant bunches stored in warehouse at ambient conditions showed the lowest germination values.

Three different threshing methods were used with Indian soybean cultivars, PK-327, PK-416 and PK-564. Seeds were threshed by hand beating, machine threshing, or tractor treading and kept under ambient storage conditions and then tested for percentage germination, electrical conductivity and the effect of ageing. Hand beating resulted in higher percentage germination levels and less deterioration of seed than the other two techniques at all stages of storage (Jha *et al.*, 1995). PK-327 maintained the maximum standard percentage germination and lowest electrical conductivity value after 8 months of storage.

The effect of storage period on germination and health of 8 soybean cultivars grown in Brazil was determined (de Resende *et al.*, 1995). Seeds were stored for 3.5, 9 or 14 months under ambient conditions in the laboratory. Average germination percentage decreased from 91.4 percent to 65.6 percent after 3.5 and 9 months, respectively. Average fungal contamination decreased from a peak of 10.4 percent after 9 months to 1.0 percent after 14 months with the dominant fungus, *Phomopsis* sp. disappearing completely by the end of the storage period.

The effect of ethylene oxide and methyl formate fumigation on seed microflora and germination of stored soybeans in Nigeria was reported (Bankole, 1996). The fumigated seeds were stored in airtight metal bins for a year and the microflora and *in vitro* germination then determined. While 8 genera and 29 species of fungi were isolated from untreated seeds, only *Aspergillus flavus* appeared on the fumigated seeds. *A. niger* and *Penicillium citrinum* appeared on soybeans fumigated with methyl formate. Seeds treated with fumigants recorded significantly higher *in vitro* germination than untreated seeds.

In Pakistan, nine fungal species were isolated from 20 soybean seed samples collected from grain markets (Ali *et al.*, 1995). Of the nine species, *M. phaseolina* was the most pathogenic in germination tests. Thiophanate-methyl (Topsin-M) and benomyl (Benlate) were effective in controlling *M. phaseolina*. In a separate study, Anwar *et al.* (1995) reported high incidence of storage fungi *Aspergillus*, *Penicillium and Rhizopus* spp., which reduced seed germination potential *in-vitro*.

In Nigeria, the effect of temperature and relative humidity on the storability of five soybean cultivars was examined (Nkang *et al.*, 1997). Germinability differed significantly after six-month storage among the cultivars. Optimum storage conditions were found to be at temperatures of 25 to 30 ° C and relative humidities of 55 to 65 percent.

Chemical and biological changes during storage

Soybean seeds are living tissues and undergo physicochemical and biological changes. Many of these changes can lead to both nutritional and functional deterioration and ultimately to losses of commercial value. Among the changes found during postharvest handling is the one associated with seed proteins, a major component of soybeans (Yoshino *et al.*, 1977; Saio *et al.*, 1980, 1982; Nakayama *et al.*, 1981; Yanagi *et al.*, 1985; Narayan *et al.* 1988a,b; Thomas *et al.*, 1989; Lambrecht *et al.*, 1996). Changes in extractable proteins from defatted soy meal and whole beans during six months of storage were reported by Saio *et al.* (1982). They kept the products at any of four storage temperature and relative humidity conditions (25° C, 50 percent RH; 25° C, 85 percent RH; 35° C, 50 percent RH; and 35° C, 85 percent RH) and found that the percentage of extractable protein from either defatted meal or whole beans decrease with time. The decreasing rate depends on storage conditions. The higher the temperature and the higher the humidity, the higher the decreasing rate in protein extractability. The moisture content (or RH) appeared to have a stronger effect than the storage temperature. In addition, under identical storage conditions, defatted meal showed a more rapid decrease of protein extractability with time than whole beans. When extractability of each protein component was followed, all components decreased with storage time except for the 2S component. Among protein components, the 11S component decreased most rapidly. Later, Yanagi *et al.* (1985) found that sedimentation pattern of water extract from stored soybeans exhibited a decrease in peak height for the 11S fraction and increases in peak height for both smaller fractions (2S and 7S) and larger fraction (15S). The rapid decrease of 11S found by both researchers could be explained by its degradation and aggregation during storage (Liu, 1997).

Besides storage protein, other components in soybeans also undergo changes during storage. These include increases in non-protein nitrogen, free fatty acids and peroxide value, decreases in sugars, trypsin inhibitor activity, available lysine, pigments and lipoxygenase activity (Narayan *et al.*, 1988a) and decomposition of phospholipids (Nakayama *et al.*, 1981). Increases in total ash, various minerals, sugars and reducing constituents in soaking water of stored beans were reported (Saio *et al.*, 1980).

Important indicators of biological changes during soybean storage are darkening in bean colour, a decrease in water absorption rate, an increase in leakage during soaking and an increase in acid value of extracted crude oil as well as in the acidity of beans (Saio *et al.*, 1980, 1982; Thomas *et al.*, 1989). This last change indicates that the neutral fat in fresh beans had been hydrolyzed to free fatty acids during storage (Liu, 1997).

Several studies (Yoshino *et al.*, 1977;Narayan *et al.*, 1988b; Thomas *et al.*, 1989; Lambrecht *et al.*, 1996) have shown that the reduction in overall production yields and organoleptic properties is a function of storage time and become severe when storage temperature and relative humidity are both high. Apparently, most of the effects can be attributed to decreased protein functionality as a result of storage (Liu, 1997).

The effect of storage on the nutritional values of soybeans has not been addressed. However, studies with other legume species, particularly dry beans (*Phaseolus vulgaris*), showed that adverse storage leads to decreases in protein efficiency ratio, protein digestibility and availability of sulphur amino acids (Atunes and Sgarbieri, 1979).

2.9 Processing

The soybeans are cracked to remove the hull and rolled into full-fat flakes. The rolling process disrupts the oil cell, facilitating solvent extraction of the oil. After the oil has been extracted, the solvent is removed and the flakes are dried, creating defatted soy flakes. The defatted soy flakes can be ground to produce soy flour, sized to produce soy grits or texturized to produce textured vegetable protein (TVP). The defatted flakes can be further processed to produce soy protein concentrates and isolated soy protein.

Primary and secondary products

Soybeans are grown primarily for their meal. Meal is the primary product and oil and lecithin are secondary.

Meal and oil

The early oil mill processing of soybeans was on a small scale using a hydraulic and screw presses (Goss, 1944). Gradually the screw press replaced the less efficient hydraulic press and in 1934 the first countercurrent solvent extraction was introduced. Improvements in oil extraction are continuously evolving. Major changes during the last two decades have included reduced energy purchases by introduction of the expander, installation of heat recovery systems and co-generation (making steam and electricity on site by burning waste by-products like hulls), improved working conditions for employees (dust and sound control), reduced contamination of the environment and automation of equipment, introduction of computer control of the processes and reduction of manual labour (Lusas, 2000).

Direct solvent extraction, "full" pressing or prepress-solvent extraction can accomplish separation of oil from soybeans. Some crushing industries combine these extraction methods to maximize oil extraction and its quality. Solvent extraction is the most widely used method for oil extraction in the Western world. However, mechanical extraction is often preferred by small extraction plants throughout the world to remove the oil. A flow sheet of soybean oil solvent extraction process is shown in Figure 20. Some of the soybean oil extraction by-products are shown in Figure 21.

Soybean meal and oil can also be produced by the ExPress System, where the whole or de-hulled soybeans at field moisture are fed continuously to a dry extruder. Within the extruder barrel, the material is subjected to friction, shear and pressure whereby heat is generated. The temperature profile within the extruder barrel can be varied depending upon the intended use of the processed meal. This process does not require external heat source. Typically, the top temperature at the exit of the extruder barrel is 150 ° C. Lower temperature profiles are used when the meal is intended for use as a functional ingredient in food applications (Wijeratne, 1999).

Soy meal is mainly used as animal feed. Only a small portion is processed into soy protein ingredients including soy flour, concentrates, isolates and textured soy proteins. These ingredients have functional and nutritional applications in various types of bakery, dairy and meat products, infant formulas and the so-called new generation soyfoods. Due to this difference in soybean use, two different types of soybeans have emerged: food beans and oil beans (Liu *et al.* 1995, Orthoefer and Liu 1995; Wilson, 1995). Annually, the United States exports 10 to 15 percent of the soybean production estimated at 6 to 7 million metric tonnes, to Japan, Korea and Taiwan. Most of this portion is used for whole bean applications (Motoki and Seguro 1994).

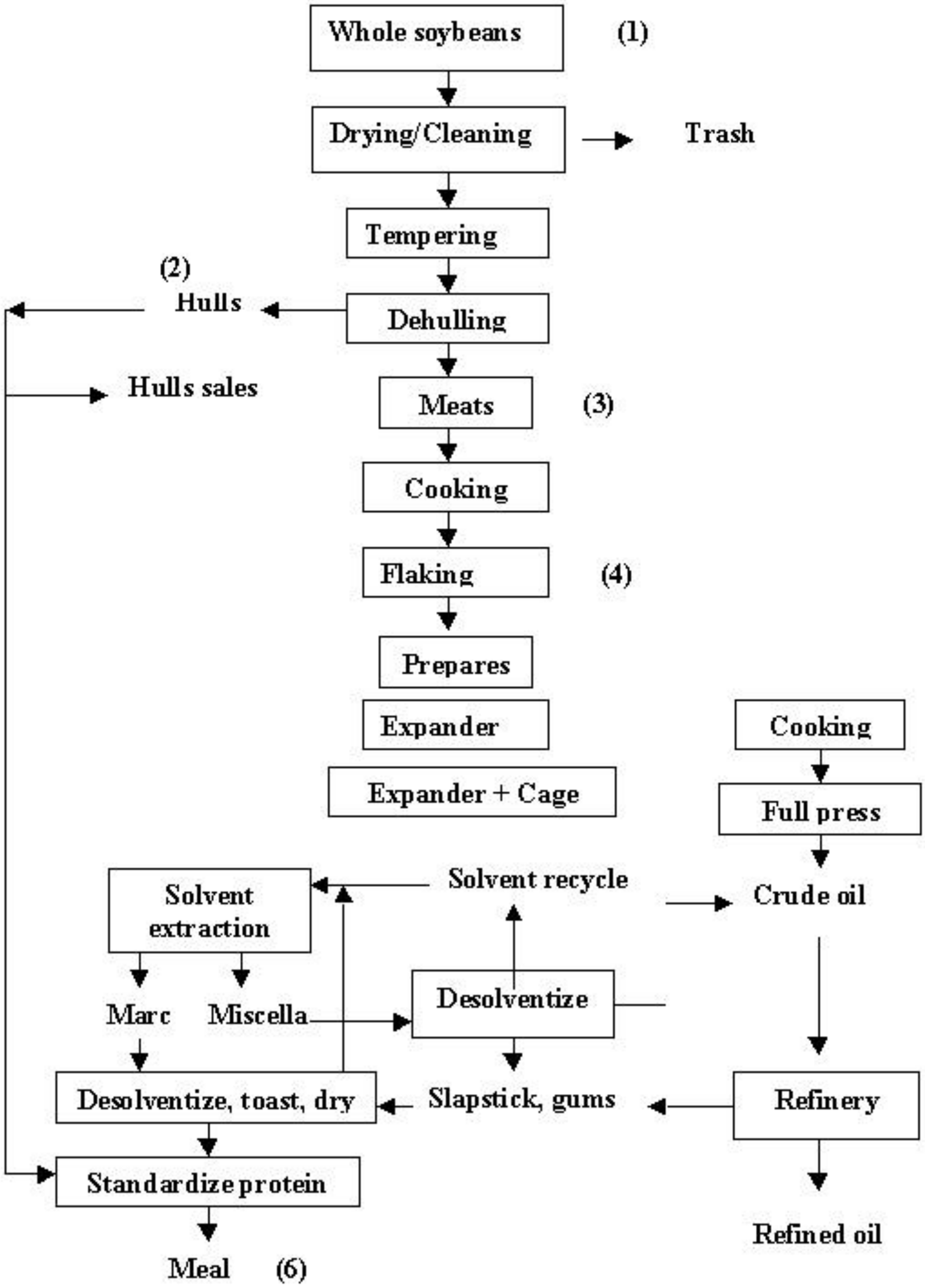

Figure 20. Flowchart of soybean oil extraction process.

Figure 21. Some of the soybean by-products obtained during oil extraction: (1) Whole soybeans, (2) hulls, (3) meats, (4) flakes, (5) collets or pellets and (6) meal.

Lecithin

Lecithin is produced by degumming the crude oil, followed by drying and cooling. Lecithin is modified to produce speciality lecithin. Soy lecithin is a very effective emulsifier that is added in small amounts to chocolates (0.25 to 0.35 percent), cookies, peanut butter (1 to 2 percent), confectionery coating, power mixes, baked products and dietary food. Two types of lecithin are generally recognized in the trade: crude soybean lecithin and refined lecithin. Emulsifiers or emulsifying agents are surface-active substances that increase stability of an emulsion when added. They usually contain both polar and non-polar groups, with one group being slightly dominant. Among the most commonly used emulsifying agents approved for food uses are lecithin and mono- and diglycerides of edible oils (particularly those from soybean oil). At levels of 0.1 to 0.5 percent in combination with other emulsifiers, usually mono- and diglycerides, lecithin is added to the fat in manufacturing margarine as well as some shortenings. When added to margarine, lecithin prevents "sweeping" or "bleeding" of the moisture present, reduces spattering during frying, increases the shortening effect for baking and helps protect the vitamin A in fortified margarine from oxidation. When used in baked goods, lecithin helps bring about rapid and intimate mixing of the shortening in the dough, improves the fermentation, water absorption and handling of the dough, gives a more tender and richer product after baking and prevents baked goods from staling.
Refined lecithin or vegetable oil, at 0.5 to 30 percent levels, is combined with extracted soy flour to make lecithinated/refatted flours. Dustiness is reduced and the products disperse more readily in beverages, dry mixes and during food processing (Soy Protein Council, 1987).

Derived products

The most important soybean derived products are the traditional soyfoods. The most popular soyfood is tofu, followed by soymilk and soy sprouts. Other includes okara, roasted soy nuts or flour, yuba, fresh immature soybeans, sweet beans and mature whole soybeans. Among the popular fermented soyfoods are soy sauce, miso, tempeh and natto.

Soybean milk

A traditional Chinese method for preparing soymilk is shown in Figure 22. The whole soybeans are soaked in water overnight, then washed and ground with fresh water at a water: bean ratio between 8:1 and 10:1. The slurry is then filtered through a cloth. The residue, known as soy pulp or okara, is separated and the filtrated is boiled for a few minutes before serving (Liu, 1997). Several modifications to the traditional Chinese method have been made in order to increase soymilk acceptability by consumers, especially Western consumers. This has to do mainly with the characteristic flavour associated with soybean products, known as bean-like flavour. One of these modifications consists on preventing the bean-like flavour formation through heat inactivation of lipoxygenase (LOX). Two-well known methods were developed in the 60's and 70's. They are the so-called hot-grinding method (Cornell method) and the pre-blanch or Illinois method. In the Cornell method, unsoaked, dehulled soybeans are ground in a preheated grinder with hot water. The slurry is maintained at temperature between 80 to 100 ° C in the grinder to completely inactivate LOXs and then boiled in a steam-jacketed kettle before filtering into soymilk and okara (Wilkens *et al.*, 1967). In the Illinois method, the process starts with blanching pre-soaked soybeans in boiling water for 10 min. The beans are then drained and ground with sufficient cold water to make soy slurry and then into soymilk (Nelson *et al.*, 1976). Another alternative is to strip off the volatile bean-like compounds once they are formed. During commercial production of soymilk, a deodorization step is sometimes added. The process involves passing cooked soymilk through a vacuum pan at high temperature in the presence of a strong vacuum (Liu, 1999).

Tofu

Tofu (Japanese), Dan fu (Vietnamese), Teou fu or Tou fu ho (Chinese) or bean curd is a cottage cheese-like product formed into a cake, which is precipitated from soy milk by a calcium salt or, in some instances, by concentrated sea water. Tofu can be prepared for the table in many different ways; the most important are in soup and by deep fat frying, the latter called aburage in Japanese and Yu Tou Fu in Chinese. Figure 22 shows the flowchart for tofu preparation. Conditions and yield were taken from Smith and Circle (1980).

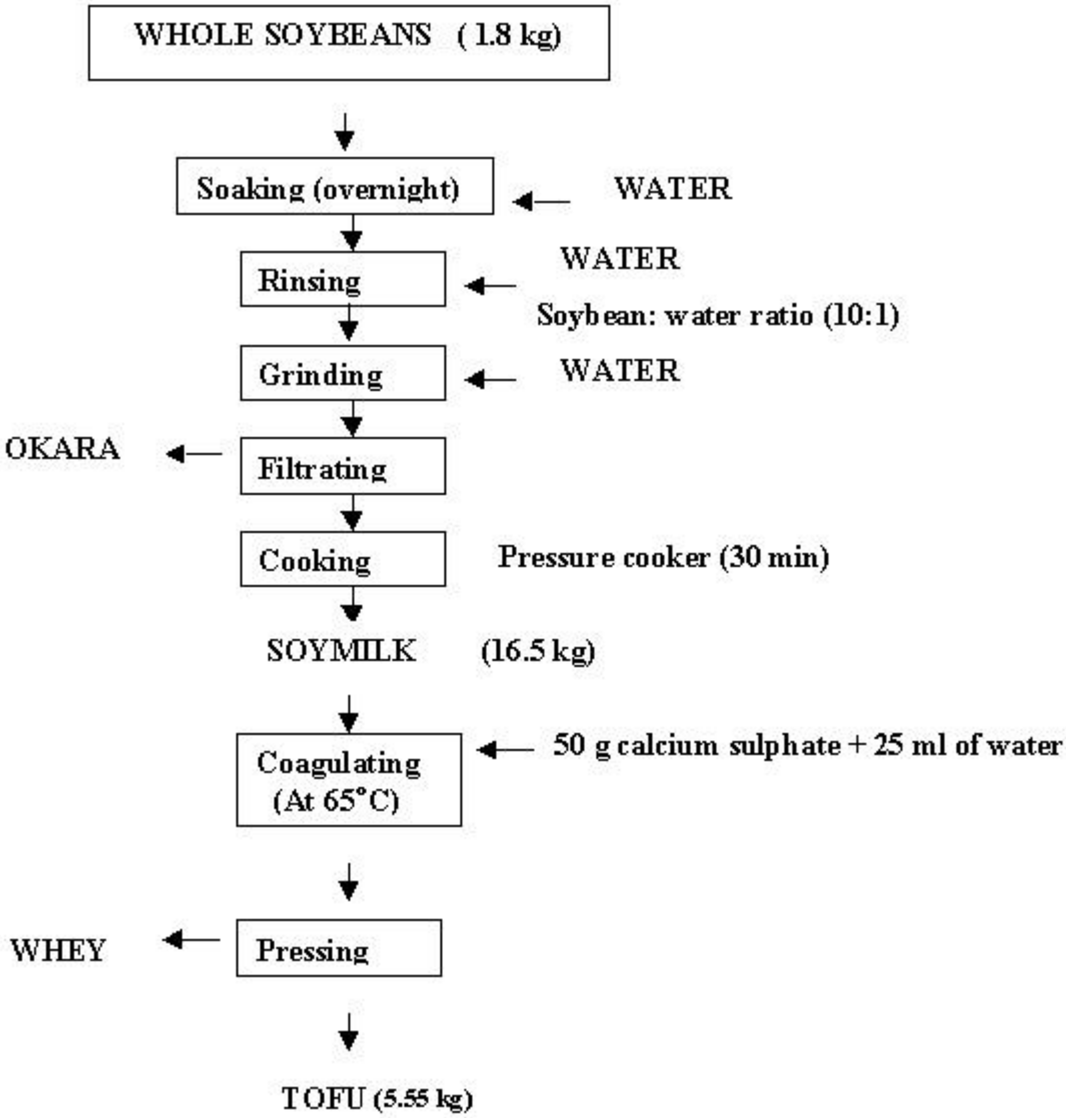

Figure 22. Flowchart for preparation of soymilk and tofu according to the Chinese method.

Food-grade full-fat soy flours and grits

There are three types of full-fat soy flours: enzyme-active, toasted and extruder-processed (Lusas and Rhee, 1995). Typical specifications for enzyme-active flours are moisture, 10 percent maximum; and on moisture free basis (mfb): protein, 42 percent; fat, 21 percent; and ash, 4.7 percent. Enzyme-active full-fat soy flours are preferred for bleaching wheat flour (by lipoxygenase activity) in making bread in Europe and enzyme-active defatted flours are preferred in the United States (Lusas, 2000). Toasted soy flours ("heat-treated full-fat soy flours") pass U.S. No. 100 or 200 mesh screen, have a protein digestibility index (PDI) in the 20 to 35 range. Grits are available in various granulation, for example, coarse (through No. 10 screen on No. 20); medium (through No. 20 on No. 40); and fine (through No. 40 on No. 80). Full-fat soy flours have been made using extruders to inactivate lipoxygenase. This type of flour is reported to have 89 percent trypsin inhibitor inactivation, a protein efficiency ratio (PER) of 2.15, urease activity of 0.1 pH change and a product nitrogen solubility index (NSI) of 21 percent (Mustakas *et al.*, 1970). Full-fat soy flours contain approximately 40 percent protein (N x 6.25).

Extracted flake products and flours

Extraction of soybeans for food protein uses differs from processes where the meal is used for animal feeds (Witte, 1995). A cleaner United States No. 2 soybean, or a United States No.1, is used. Splits removal is emphasized since may harbour early lipoxygenase activity that produces bean-like flavour. In processing soybean food proteins, a solvent-extracted "white flake" is made first. It may be sold as a food ingredient, ground into flour or grits, extracted to produce soy protein concentrate, or solubilized in preparation of soy protein isolate (Lusas and Rhee, 1995). NSI of white flakes before toasting are in the 85 to 90 range. The Soy Protein Council (1987) has defined flakes as "white," NSI>85, "cooked," 20 to 60 NSI and "toasted," NSI<20.

Soy protein concentrates

Soy protein concentrates are basically flour from which sugars (sucrose and the nondigestible oligosaccharides stachyose and raffinose) and other soluble materials have been removed (Lusas and Rhee, 1995). Soy concentrates have a medium level of protein (65 percent-72 percent) and a similar high level of crude fiber to soy flour (3.5 percent-5 percent).

Soy protein isolates

In making isolates, essentially all solubles, including sugars and fibre are removed from the starting flour. Preparation of soy protein isolate takes advantages of solubility characteristics of proteins at different pHs. Soy isolates have a higher level of protein (90 percent-92 percent) and lower carbohydrate content (3 percent-4 percent) than soy concentrates.

Composition of commercial soy protein products mentioned above is shown in Table 22. Fat content in all of them is similar since all are made from defatted soybean. The carbohydrate content is low in isolates, intermediate in concentrates and high in flours and grits. The opposite occur in protein content, that is, isolates contains the highest amount of protein (90 to 92 percent), followed by concentrates (65 to 72 percent), flours and grits (56 to 59 percent). On the other hand, isolates had the lowest fibre content (0.1 to 0.2 percent), followed by defatted flours and grits (2.7 to 3.8 percent) and concentrates (3.4 to 4.8 percent).

Textured soy protein products

Soy flour and concentrates may be further processed by thermoplastic extrusion (Atkinson, 1970) to impart meat like texture to these products. Similarly, soy isolates may also be textured by a spinning process that involves solubilizing soy isolates in alkali and then forcing it through a spinneret into an acid bath to coagulate the proteins. The fibres formed are stretched and combined into bundles or tow. The tows are then used to produce meat analogues.

Table 22. Chemical composition (%) of soy protein products

Constituent	Defatted flours and grits		Concentrates		Isolates	
	As is	Dry basis	As is	Dry basis	As is	Dry basis
Protein (Nx6.25)	52-54	56-59	62-69	65-72	86-87	90-92
Fat (petrol. ether)	0.5-1.0	0.5-1.1	0.5-1.0	0.5-1.0	0.5-1.0	0.5-1.0
Crude fibre	2.5-3.5	2.7-3.8	3.4-4.8	3.5-5.0	0.1-0.2	0.1-0.2
Ash	5.0-6.0	5.4-6.5	3.8-6.2	4.0-6.5	3.8-4.8	4.0-5.0
Moisture	6-8	0	4-6	0	4-6	0
Carbohydrates (by difference)	30-32	32-34	19-21	20-22	3-4	3-4

Source: Soy Protein Council (1987).

Other uses

Soybeans are also used in the manufacture of many industrial products such as resins (John Deere is testing it now), plastics, varnishes and paints, caulking compounds, disinfectants, insecticides, oiled fabrics, printing inks (Danbury Printing and Litho uses soy-based ink), soap, crayons, paints, graffiti remover, fire extinguisher foam, wallpaper, glycerine, lubricants, soft soaps, waterproof goods, oilcloth, rubber substitutes, artificial petroleum, gasoline, cardboard, grocery sacks, linoleum, enamel, copy toners (for use in printers), hydraulic oil (performs as well as petroleum-based), wood adhesives (replacing petroleum-based products), concrete, wax polish (outperforms other waxes, easier to apply), solvent to remove grease, oil, asphalt, paints, etc. with no damage to surfaces, SoyDiesel, an alternative mixture of diesel fuel and soybean oil used to power small boats.

3. Overall Losses

The soybean seed is at its optimum quality when it reaches physiological maturity in the field. The subsequent handling (transport from the field to the reception centre or to elevators, conditioning, seed packaging, storage, processing, etc.) results in a gradual, sometimes rapid, reduction of its quality.

What does loss mean?

Sometimes it is not clear whether losses are expressed on a wet or dry weight basis and the use of accumulated percentages is dangerous. Reports often do not make clear how accumulated losses have been derived. If losses in each of harvesting, threshing, transport, storage and processing are 10 percent, the total loss may not be 50 percent; if the losses were a percentage of the quantity left at each stage then the total loss is only 41 percent (Wright, 1995). Another feature of the common methods of assessment is that they are concerned only with physical weight loss rather than loss of quality, nutritional value, seed viability or commercial value (Boxall, 1986). Different aspects and types of quality loss were reviewed by FAO (1984). In Africa, where demand exceeds production, quality issues are less relevant than in food surplus situations (Wright, 1995). Nutritional loss, in terms of nutritional value per unit weight, is often a major factor. Many pest species are selective feeders; bruchids feed on the cotyledons (Haines, 1991); rats, mites, *Ephestia* and *Plodia* larvae feed on the grain germ, thereby removing much of the protein and vitamins. Weevils feeding on the endosperm remove much of the carbohydrates in the grain. In all these cases weight loss will give a distorted view of the nutritional loss. Loss of seed viability occurs in storage (Howe, 1973) and can be determined only by germination tests. Commercial losses may occur from farmer to country level. They include reduction in value of a sub-standard product, loss of goodwill, costs of legal action and the cost of pest prevention. (Wright, 1995). Although physical weight loss may be the simplest parameter to measure, it is not necessarily the most realistic. Any measure of loss must encompass the economic and social factors relevant to the loss sufferer.

Losses tend to be an amalgam of many, individual small, losses at different stages of the postharvest system. The postharvest sector is often considered in isolation although it is part of a continuous process from planting to consumption. For example, many pests begin their infestation in the field and poor storage of seed grain will result in reduced germination in the following season.

Even it is not really a postharvest loss, soybean yield reduction due to diseases and pests is considered an important loss since the reduction of the potential productivity does not allow to obtain such amount of soybeans as that obtained from a disease-and pest-free field.

Soybean yield losses

Agricultural pests are present in most soybean fields. Table 23 shows the most common diseases and their corresponding causal organism. Depending on the extent of the infestation, soybean yield is affected. Several reports on soybean disease and pest losses exist in the literature. Table 24 shows a summary of these reports.

One of the countries with the highest losses in soybean yield due to insect pests is India. The national average soybean yield is about 0.8 tonne/ha (Kundu and Srivastava, 1992) and a productivity enhancement to 1.25 tonne/ha by 2000 and 1.5 tonne/ha by 2010 is expected (Paroda, 1999). The average world soybean yield is over 2 tonne/ha.

The magnitude of losses caused by soybean diseases has been estimated to be at least US$ 250 million per year in the United States alone (Liu, 1997). Brown leaf spot, frogeye leaf spot, brown stem rot, stem canker, purple seed stain and pod and stem blight are major soybean fungal diseases. Bacterial blight, pustule, wildfire and wilt are major soybean diseases caused by bacterial. Major viral diseases include soybean mosaic, yellow mosaic, bud blight and bean pod mottle. Soybean cyst nematode and root knot nematode are the main species of nematodes that attack soybeans. The estimated soybean yield losses due to diseases were 10.9 million tonnes in 1996, 11.9 million tonnes in 1997 and 14.0 million tonnes in 1998 (Wrather and Stienstra, 2000).

In 1994, soybean total yield losses caused by *Heterodera glycines* were greater than any other disease in the top 10 soybean producing countries (Wrather *et al.*, 1997). Next in order of importance were stem canker, brown spot and charcoal rot. The total yield loss due to disease in these countries was 14.99 million metric tonnes, valued at US$ 3.31 billion. Methods used to estimate soybean disease loss included field surveys, plant disease diagnostic clinic samples, variety trial data, information from field workers and university extension staff, research plots, grower demonstrations and private crop consultant reports.

It has been estimated that soybean yield losses in the world due to diseases fluctuate between 10 percent and 15 percent (Ploper, 1997). In 1987, disease losses were estimated at 10.3 million tonnes, which amounted to 10.4 percent (Sinclair and Backman, 1989).

In Argentina, estimates by INTA (federal agency for agricultural research and extension) indicated that the most prevalent diseases reduce soybean yields annually by 400 000 tonnes, causing losses over US$ 90 million (INTA, 1993). However, considering other diseases, including those caused by nematodes, it is likely that losses in the country are much higher than those figures (Ploper, 1997). Among the most important soybean diseases in Argentina are Sclerotinia stem rot (*Sclerotinia sclerotorium*), root and stem rot (*Phytophtora megasperma f.* sp. *glycinea*) and charcoal rot (*Macrophomina phaseolina*) (Ivancovich *et al.*, 1993). At present, *Fusarium solani* is considered one of the most important soybean diseases (Ivancovich *et al.*, 1997).

In Bolivia, soybean is affected by at least 17 diseases. The average soybean yield loss is estimated at 8 to 10 percent, with annual losses valued at US$9 million (Wrather *et al.*, 1997).

In Brazil, annual yield losses due to diseases are estimated at US$1 000 million (Wrather *et al.*, 1997). The decrease in damage by *A. gemmatalis*, has been imputed to a greater effectiveness of natural enemies with the implementation of IPM systems, which resulted in drastic reduction in insecticide and use of more selective products (Panizzi, 1997).

In Paraguay, stem canker was the most devastating disease recorded. During 1991 to 1992 and 1992 to 1993, several fields had yield losses ranging from 50 percent to almost total loss (Wrather *et al.*, 1997).

In Mexico, whitefly (*Bemisia Argentifolii)* was established in the Sonoran agricultural areas by 1993 (Yepiz-Plascencia *et al.*, 1998); however, its economic impact was not evident until 1994. Average soybean reduction yields about 50 percent were reported in Sonora State; however, some soybean fields at the Yaqui Valley had almost total loss (Castillo, 2000). Since 1994, soybean has not been commercially produced in this region. Besides the whitefly problem, the lack of water availability for soybean cultivation during the summer has contributed to the disappearance of this important crop in the Northwest of Mexico.

Eight species of agromyzids, commonly called bean flies, infest soybean in tropical Asia, Africa and Oceania, but not in North or South America. Three of the species, *Ophiomyia phaseoli* (Tryon), *O. centrosematis* (de Maijere) and *Melanagromyza sojae* (Zehntner) cause significantly yield reduction (Talekar, 1997).

There are also other soybean diseases causes by seed-borne viruses such as peanut stripe, soybean mosaic and tobacco ring spot viruses (Sinclair, 1997).

Harvesting losses

There is a lack of reliable data not only on soybean harvesting losses, but also on each stage of the postharvest system. Losses during mechanical harvesting of soybeans were evaluated by Reis *et al.* (1989) and presented in Section 2.2. (Tables 14 and 15). The harvesting losses estimated by a soybean grower in Culiacan Valley, Sinaloa, Mexico using the equipment described in Figure 8 was 150 kg per hectare, which represents about 7 percent (Godoy, 2000). A similar percentage (≤ 6 percent) was reported by Kowalczuk (1996) when soybeans were harvested with the Z056 "Bizon Super" grain combine harvester equipped with a floating cutting bar. Scott and Aldrich (1970) reported harvest losses between 5.4 and 12.2 percent depending on the height at which the combine cutterbar was operated. The lower loss corresponded to a height of cut of 3.5 inches and the higher to 6.5 inches. Based on these numbers, we could say that harvesting losses using combine harvester are between 4 and 7 percent. The appropriate adjustment to the combine cutterbar (height) is very important to keep losses in this range. Manual harvesting would be the ideal form of harvesting soybeans, since all soybeans are gathered and seed damage is null. Unfortunately, the huge soybean fields have to be harvested in a period of about 15 days. It is impossible to harvest by hand such amount of soybeans in only 2 weeks, so that the losses caused by the equipment (damage, broken, spills, etc) have to be undergone.

Table 23. The causal organisms of yield-reducing soybean diseases in the top 10 soybean producing countries in 1994.

Common name	**Causal organism**
Anthracnose	Colletotrichum truncatum
Bacterial diseases	Pseudomonas syringae pv. glycinea, P. syringae pv. Tabbaci, Xanthomonas campestris pv. glycines.
Brown spot	Septoria glycines
Brown stem rot	Phialophora gregata
Charcoal rot	Macrophomina phaseolina
Diaporthe-Phomopsis complex	Diaporthe and phomopsis spp.
Downy mildew	Peronospora manshurica
Frogeye leaf spot	Cercospora sojina
Fusarium root rot	Fusarium spp.
Phytophthora root and stem rot	Phytophthora megasperma f. sp. Glycinea
Pod and stem blight	Diaporthe phaseolorum var. sojae
Purple stain	Cercospora kikuchii
Rhizoctonia aerial blight	Rhizoctonia solani
Rhizoctonia-Pythium root rot	Rhizoctonia solani and Pythium spp.
Root-knot and other nematodes	Meloidogyne, Hoplolaimus, Pratylenchus, Rotylenchulus reniformis
Rust	Phakopsora pachyrhizi
Sclerotinia stem rot	Sclerotiniasclerotiorum
Southern blight	Sclerotiumrolfsii
Seed disease	Alternaria, Cercospora, Corynespora, Cladosporium and Fusarium spp.
Seedling diseases	Rhizoctonia, Pythium and Fusarium spp.
Soybean cyst nematode	Heterodera glycines
Stem canker	Diaporthe phaseolorum var. caulivora
Sudden death syndrome	Fusarium solani form A
Thielaviopsis root rot	Thielaviopsis basicola

Source: Wrather *et al.* (1997).

Table 24. Soybean yield losses due to diseases and pests in different regions.

Coverage	Period	Estimate Loss	Caused by	Reference
World	1970's 1987 Annually Annually	20-30 % 10.4 % 10-15 % 10-30 %	All pests Diseases Diseases Diseases	Athow, 1981. Sinclair & Backman, 1989. Ploper, 1997. Sinclair, 1997.
Argentina	1993 Annually Annually[a]	400 000 tonnes (US$ 90 Million) 3-5 % 5 %	Diseases Sclerotinia sclerotiorum Viruses	INTA, 1993. Martinez & Botta, 1989. Ploper, 1997.
United States	1991[b] 1996 1997 1998 Annually	12.6 % 10.9 Million tonnes 11.9 Million tonnes 14.0 Million tonnes US$ 250 Million	Diseases Diseases Diseases Diseases Diseases	Sciumbato, 1993. Wrather & Stienstra, 2000. Liu, 1997.
Bolivia	1994	8-10 % (US$ 9 Million)	Diseases	Wrather *et al.*, 1997.
Brazil	Annually	US$ 1 000 Million	Diseases	Wrather *et al.*, 1997.
Paraguay	1991-1992 1992-1993	50-100 %	Stem canker	Wrather *et al.*, 1997.
Mexico	1994	50 %	Whitefly, Bemisia Argentifolii	Yepiz-Plascencia *et al.*, 1998; Castillo-Torres *et al.*, 1998.
Indonesia	Annually	Up to 80 %[c]	Limabean pod borer, *Etiella zinckenella*	Talekar, 1997.
Taiwan	Annually	10-15 %[c]	Limabean pod borer, *Etiella zinckenella*	Talekar, 1997.

[a]Only in Santa Fe and Cordoba Province.
[b]Only in 16 US Southern States.
[c]These percentages correspond to the extent of pod damage.

Storage losses

Data on soybean storage losses is scarce. Examples of heavy losses in soybean quality in land-based bins located in different United States regions have been reported (Christensen, 1986). A concrete silo was loaded in the fall with 40 000 bushels of soybeans. The bin had temperature cables, but no one read and recorded the temperatures. When, months later, someone thought to do this, one thermocouple registered 82 ° C (180 ° F) and another 93 ° C (200 ° F), both in the spout line. About 10 000 bushels (25 percent) of soybeans were severely damaged in quality. A cylindrical steel tank was loaded with 90 000 bushels of soybeans in October. The bin had four thermocouples, but not of them was in the centre where the fines accumulate. The bin had aeration equipment, but the fans could not force air through the densely packed fines in the spout line. Temperature at all thermocouple locations was read and recorded weekly and at no time was there any indication of heating. When the tank was emptied, 14 months later, between 10 000 and 20 000 bushels of soybeans in and adjacent to the spout line were heavily damaged, 10 feet away from the nearest temperature cable. Discolouration of 10 000 bushels of soybeans of the 90 000 bushels stored in a bin for 3 months due to severe heating was also reported.

According to a 1990 survey of extension specialists throughout the United States, stored grain losses exceeded US$ 500 million for the year. Most of these losses resulted from infestation by several species of insects and damage by numerous moulds and mycotoxins (Harein, 1995).

In China, considerable losses during soybean storage are incurred annually due to inadequate drying (Ren *et al.*, 1996).

Storage losses cannot be generalized. The design and type of the storage facility, the continuous inspection of the condition of the beans, temperature and moisture monitoring and records, as well as the corrective practices undertaken to minimize the risk of damage the beans and the appropriate operation of the handling equipment, will determine the total losses (quantitative and qualitative) during storage.

Critical loss operations in post-production

The critical loss operations in the postharvest systems are those in which losses are high. Table 25 summarizes all the operations of the postharvest system and associated losses to each stage, the type of operation and labour involved and the critical activities in each stage that may play an important role in the reduction of postharvest losses of soybeans.

Table 25. Summary of losses through the soybean postharvest system.

Operation	Type of operation	Role played on losses[a]		Estimated total loss (%)
		Quantitative	Qualitative	
Pre-harvest: Soil ploughing and levelling Weeding	Mechaniz. Manual Both	X X XX	X X XX	10 - 15%
Disease and pest control	Both	XXX	X	
Harvest (+ Threshing)	Mechaniz. Manual	XX -	X -	4 - 7% Negligible
Pre-drying	Natural Artificial	XX X	XX XX	
Transport (+ Handling): Road (truck) Rail Ship		XX X X	X XX XX	< 1% 1 - 3 % 1 - 3 %
Storage	In bags Bulk	X X	XX XX	
Processing	Small (home) Industrial	- X	X X	

[a] Contribution to total losses, X = Low; XX = Medium; XXX = High.

The most critical activities in each stage of the postharvest system are:

Pre-harvest

Diseases and pests control

Weeding

Harvest

Mechanical: Combine cutter bar adjustment and appropriate seed moisture content for harvesting.

Manual: Appropriate seed moisture content for harvesting.

Pre-drying or drying

Natural: In the field, monitor seed moisture content.

In storage facilities (silos, storehouses), monitor seed moisture content and temperature of the exhaust air.

Artificial: use appropriate drying temperatures and drying rates, monitor seed moisture content to avoid damage.

Transport & Handling

In bags: check if the bags have holes before loading to avoid leakage during transport and use clean and preferentially fumigated bags to avoid reinfestation.

In bulk (rail or ship): Clean and fumigate railcars or ship compartment where soybeans are going to be transported before loading. For long distance, make sure that soybeans moisture content is low enough for safe storage without compromising the integrity of the grain (damage it) during loading and unloading.

Storage

Monitor grain moisture and temperature.

Check condition of the grain. Simply, take some beans on your hand, smell and touch them. Unusual odours may be an indication of something is going on. Warm grains may also indicate an infestation by insects or a hotspot due to the lack of ventilation. Depending on grain temperature and moisture and the presence of insects or other storage pests, the grain must be aerated or fumigated.

Processing

Generally, the soybean processing industries or any processor in small- or large-scale must store soybeans to ensure an immediate supply. They have to take the same kind of precautions mentioned previously for safe storage. In addition, they have to be aware of the appropriate operation of the handling equipment to avoid seed damage and appropriate conditioning of the grain before processing. In fact, when the grain is not well conditioned, it may cause higher processing losses and reduce the efficiency of the whole process.

4. Storage Pests

Soybeans, as plants in the field or seeds at any stage of the postharvest system, are the target of many diseases and pests worldwide. In this section, the pest species more frequently found in soybean fields in some regions of the world are listed and reviewed as well as those that may be present during storage if the conditions (temperature and moisture, etc.) favour their development.

Preharvest pests

Soybeans are susceptible to attacks by various diseases and pests throughout their growing season. All pests have the ability of decrease soybean yield. Brown leaf spot, frogeye leaf spot, brown stem rot, stem canker, purple seed stain and pod and stem blight are major soybean fungal diseases. Bacterial blight, pustule, wildfire and wilt are major soybean diseases caused by bacterial. Major viral diseases include soybean mosaic, yellow mosaic, bud blight and bean pod mottle. Soybean cyst nematode and root knot nematode are the main species of nematodes that attack soybeans (Liu, 1997). The causal organisms of soybean diseases in the top 10 soybean producing countries during 1994 are shown in Table 23.

Insects are serious pests, particularly in tropical and subtropical areas, because they feed on all parts of the soybean plant. Larvae of lepidoptera (moths) and coleoptera (beetles) are two major groups that attack soybean foliage. Within the lepidopterous larvae group, green cloverworm (*Plathypena scabra,* Fabricius), soybean looper (*Pseudoplusia includens,* Walker), velvetbean caterpillar (*Anticarsia gemmatalis,* Hubner) and corn earworm (*Heliothis zea,* Boddie) are four major species that often cause problems to soybean farmers. Stink bugs (*Acrosternum hilare,* Say), alfalfa hopper (*Spissistilus festinus,* Say) and lesser cornstalk borer (*Elasmopalpus lignosellus,* Zeller) are the major pod- and stem-feeding insects. Other pests attacking soybeans include birds and rodents. Birds and rodents attack soybean most often immediately after planting.

Preharvest pest control

Rotating crops, spraying chemicals and choosing resistant cultivars brought about by plant breeding and have been the major tools used by farmers to control diseases and pests. Among all practical methods of insect pest control, planting cultivars resistant to insect pests is the most economical, sustainable and environmentally acceptable (Talekar, 1997).

Rotation

Among the recommended disease management practices are the use of resistant varieties (Ivancovich *et al.*, 1993) and crop management such as crop rotation, tillage and planting date (Ivancovich *et al.*, 1997). Diseases than can be reduced by crop rotation are those caused by bacteria; fungal foliage diseases- Alternaria leaf spot, anthracnose, Septoria brown spot, Cercospora leaf spots, Choanephora leaf blight, Phyllostictia leaf spot, red leaf blotch; fungal diseases of roots and lower stems- brown stem rot, charcoal rot, pod and stem blight, Sclerotinia and Sclerotium blight and stem canker; and nematode diseases- root knot and cyst (Sinclair and Backman, 1989).

Chemical control

The use of chemical compounds is another alternative to control weeds, diseases and pests. In general, they are known as pesticides. A complete list of pesticides tolerance levels for soybeans is given in the Annex. The chemical compounds (pesticides) used to control weeds are called "herbicides", those used to control insects are called "insecticides" and those used to control fungal diseases are called "fungicides".

The groups of pesticides are chlorinated hydrocarbon, organo-phosphorus, carbamates and pyrethroids. Pesticides are used in the form of spray, dust, granules and seed dressing. Fungicide seed treatment is an alternative to control soybean diseases in several countries. In Brazil, the use of fungicides for seed treatment has increased since 1991. In the 1991/92 soybean crop, about 5 percent of the cultivated land used seed treated with fungicides, whereas in the 1999/2000 crop more than 85 percent of the cultivated area used treated seed (**Http://www.cnpso.embrapa.br**). About 30 fungicide formulations used to treat soybean seed (1999/00 crop), among commercially available and others, were reported. In Argentina, fungicide seed treatment is a recommended practice since efficiently controls most of soybean seed diseases (Larreche and Firpo Brenta, 1999).

Insect resistant cultivars

The use resistant cultivars to the attacks of different insects have been developed. Recently, a soybean cultivar with resistance to white fly, the devastating insect that caused severe yield losses in the Northwestern part of Mexico, was developed (Castillo *et al.*, 1998). Some other resistant cultivars were presented in Section 2.1. The cultivar "Hartwig" is probably the best source of resistance to the cyst nematode, *Heterodera glycines* (de Toledo *et al.*, 1997). Duyn *et al.* (1971) reported genes for insect resistance in PI 229358, PI 227687 and PI 141451.

Disease resistant cultivars

Cultivars with resistance to some diseases have been developed and used in most of the soybean producing countries. Brazil has several cultivars with resistance to stem canker disease (*Diaporthe phaseolorium* f. sp. *meridionalis)*. Brazilian cultivars with resistance to this important soybean disease are BR-1, Doko, CAC-1, Dourados, EMGOPA 302, FT-Estrella, IAC-13, IAC-17, MTBR-45 and UFV-9 (de Toledo *et al.*, 1997). Another resistant cultivar to stem canker is Tracy M (Kilen and Hartwig, 1987).

Biological control

Biocontrol of plant diseases is accomplished through the use of resistant cultivars, crop rotation, clean tillage practices or organic manures (Schippers *et al.*, 1987). The use of successful biocontrol agents for soybean is still being investigated. A potential biocontrol agent for a soybean disease (caused by *Rhizoctonia* solani) is seed or soil treatment with *Bacillus megaterium* strain B153-2-2 (Liu and Sinclair, 1990, 1991). Another example is the use of Bacillus *cereus* Frankland & Frankland, strain UW85, as a seed treatment to reduce soybean seedling damping-off caused by *Phytophtora* spp. (Handelsman *et al.*, 1988). In

Brazil, the widespread use of the virus *Baculovirus anticarsis* has shown some success to control *A. gemmatalis* (Panizzi, 1997). Also, the liberation of one species of parasitoid, *T. basalis* in the field (5 000 adults/ha) has proved to be efficient to maintain stinkbug populations below the economic injury level (Correa-Ferreira, 1993).

Cultural practices

Maintaining adequate availability of plant nutrients and proper soil pH, supplying adequate water, weed control, avoiding excessive plant density and planting high-quality seeds are effective in reducing damage from many diseases.

Integrated pest management

Most research on integrated pest management (IPM) for soybean has been taking placed in the temperate zones of North America, South America and the Orient (Kogan *et al.*, 1988). The components and a generalized scheme of an IPM program were reported by Kogan (1997). IPM programs have been successfully implemented in countries such as the United States, Brazil and Argentina. However, widespread adoption of comprehensive IPM strategies is yet to occur anywhere in the major soybean growing regions of the world. In Brazil, the implementation of IPM systems leaded to a drastic reduction (over 75 percent) in the amount of insecticide used, use of low dosage (half recommended dosage of commercial insecticides with the addition of sodium chloride to the solution) to control stink bugs.

Storage pests

Moulds and insects are the primary causes of quality deterioration in stored soybeans. Both are favoured by high moisture and warm temperatures, as well as the presence of damaged grain and excessive foreign material in the soybeans. The insect pests which are known to cause damage and loss to soybeans are almonds moth, (*Ephestia cautella* (Walker), tobacco borer beetle (*Lasioderma serricorne* (Fab.), red grain beetle (*Tribolium castenum* (Herbst), *T. confusum* Kackuelinduval, khapra beetle, *Trogoderma granarium* Everts and pulse beetle, *Callosobruchus analis* Fab. and C. *chinensis* (L.). The beetle pests fail to develop on whole seeds but can multiply slowly on broken seeds. Fungi can also damage soybeans and soybean meal during storage if the moisture content of these materials is in equilibrium with relative humidities from 65 to 70 to 85 to 90 percent. Table 26 shows the equilibrium moisture contents of soybeans and soybean meal at 65 to 90 percent relative humidity (25 ° C) and fungi likely to be encountered.

Table 26. Equilibrium moisture content of soybeans and soybean meal at 65 to 90 % relative humidity (25 ° C) and fungi likely to be encountered.

Relative humidity (%)	Equilibrium moisture contents (%)		Fungi
	Soybeans	Defatted soybean meal	
65-70	11-12	12-14	*Aspergillus halophilicus*
70-75	12-14	13-15	*A.restrictus, A. glaucus, Wallemia sebi*
75-80	14-16	14-16	*A. candidus, A. ochraceus*, plus the above
80-85	16-19	15-18	*A. flavus, Penicillium* spp., plus the above
85-90	19-23	17-20	Any of the above

Source: Sauer *et al*. (1992).

Storage pests control

Pesticides most commonly used to control pests in stored soybeans and soybean products are shown in Table 27. In grain storage, the primary pesticides utilized are insecticides, including grain protectants, residual sprays and fumigants. One of the most important sources of insect infestation is residual grain in the storage bin or storehouse. It is very important to remove all trash from the bin or storehouse and the surroundings before insecticide treatments are applied. A common practice in a crushing industry in Mexico, which utilizes a similar storage facility to that shown in Figure 19 (left), is to sweep the floor and walls of the building with diesel to remove dust and to drive away insects. Once the bin is clean, it can be treated with chlorpyrifos-methyl, synergised pyrethrins, cyfluthrin, or methoxychlor before the grain is loaded. Phosphine-producing materials and methyl bromide are the two fumigants permitted for treating stored products. Fumigation is needed when no other pesticide or control method can reach the insect infestation. Fumigation is the most hazardous type of pesticide treatment, it is expensive, provides no long-term residual protection and may cause resistance problems if conducted repeatedly. Some industries do not have trained personnel to fumigate the storage facility; therefore, they have to contract the service of fumigation companies to get the job done. In large bulk storage facilities where methyl bromide is used, some type of recirculation system is usually employed to achieve an even distribution of the fumigant after application. Fans can be used to distribute methyl bromide in smaller facilities. Respiratory and detection equipment is mandatory when using methyl bromide. Cans of methyl bromide can be used to fumigate a small space, but they require a special "can opener" often called a "Jiffy" or "Star" opener. These openers puncture the can and allow the methyl bromide to escape through polyethylene tubing. Before the can is opened, the tubing can be inserted into a rail car, truck trailer, bin plenum, or fan housing (Leesch *et al.*, 1995). Steel cylinders can be fitted with special metering devices to fumigate small places, such as rail cars, or the gas applied can be measured by loss of weight from a cylinder. It is necessary to seal the bin or the storehouse containing the soybeans before start fumigation. Once that the fumigation has been accomplished, the sealed bin is left undisturbed for 24 hours and then opened to air out. Turning on the bin fan will help remove the fumigant quickly from the bin. Detection equipment must be on hand to determine when the concentration falls below 5 ppm (0.02 g/m^3) for re-entry into the facility. One advantage of methyl bromide over phosphine is that methyl bromide requires less time to kill insects than phosphine. While phosphine requires from 3 to 10 days, depending on the temperature, methyl bromide exposure time usually ranged from a few hours to one day.

Keeping the grain at low moisture and temperature can prevent moulds growth in stored soybeans. Removing caked and obviously moulded grain from storage bins or storehouses and disinfecting the storage facility is another way of preventing soybean spoilage during storage.

Rodents can also deteriorate soybeans during storage. Effective control of rodents in the storage facilities requires an integrated approach that involves sanitation, rodent-proof construction and population reduction (Hygnstrom, 1995). Sanitation can be as simple as cleaning spilled grain or products in rodent-proof buildings, rooms, or containers whenever possible. Stack sacks of grain or products on pallets with adequate space left around and under stored articles to allow for inspection for sign of rodents. The most successful and permanent form of rodent control is not allowing them to have access to the building. It is recommended to use a 1/2 x 1/2 –inch galvanized hardware cloth to screen ventilation openings. Rodenticides are used to control mice and rats when population exceeds tolerable levels. Rodents can also be killed with methyl bromide; only one-fourth pound per 1 000 cubic feet is required for 12 to 24 hours. Phosphine and chloropicrin also kill rodents.

Table 27. Pesticides tolerance in soybean and soybean products.

Commodity	Chemical name	CFR Cite	ppm
Soybeans (Postharvest)	Aluminium phosphide (residues calculated as phosphide)	180.225	0.1
	Methyl bromide	180.123	200.0
Soybeans, Aspirated grain fractions	Glyphosate, isopropylamine salt	180.364	50.0
	Sulfonium, trimethyl-salt with N. (phosphonomethyl) glycine (1:1)	180.489	210.00
Soybeans dry	Captan	180.103	2.0
	Linuron	180.184	1.0
	Malathion	180.111	8.0
Soybean meal	Acephate	186.100	4.0
	Fluazifop-butyl	186.3250	2.0
	Metaloxyl	186.4000	2.0
	Quizalofop-ethyl	186.5250	0.5
Soybean oil	Azinphos-Methyl	185.2225	1.0
	Fluazifop-butyl	185.3250	2.0
Soybean flour	Inorganic bromides resulting from fumigation with methyl bromide, ethylene dibromide and/or 1,2-dibromo-3-chloropropane (185.3700, 186.3700)	185.3700	125.0
	Quizalofop-ethyl	185.5250	0.5
Soybean seed	Halosulfuron	180.4798	0.5
	Sulfonitrazone	180.496	0.05
	Sulfonium, trimethyl-salt with N (phosphonomethyl) glycine (1:1)	180.489	3.0

Source: Code of Federal Regulations (1997).

5. Economic and Social Considerations

The production practices followed by farmers to produce soybeans varied from region to region. The cost of producing a hectare of soybeans also varied according to prices of inputs and methods of producing the crop. Economic and social considerations related to this important crop are discussed in this section.

5.1 Overview of costs and losses

The cost and return of producing soybeans in three different countries are shown in Table 28. Even the production costs and returns do not correspond to the same period, they are valid for comparison purposes, obviously with that reservation. The only direct valid comparison is that of South Vietnam, in the Mekong Delta.

The importance of an improved technology or better cultural practices is evident if the costs and returns obtained by farmers during 1993 are compared with those of producing soybeans testing (experimental) better cultural practices. In this case, a dual benefit was obtained since 60 more workdays were used per hectare and a higher net return was reached. The main differences between these two production methods in Mekong Delta were the use of less seed (60 compared to 100 kg), the use of less of one of the fertilizers (50 kg compared to 70 kg) and an additional ($CaCO_3$, 500 kg), the use of 10 more bottles of chemicals and the additional costs of gasoline (25 litres) and other. In spite of the higher operating costs (US$ 498.3 compared to 336.8) the improved production scheme had a higher net return. This was mainly due to the increase (78 percent) in soybean productivity, which doubled the net return.

The costs and returns of producing soybeans in the US and Mexico can be compared even they are from 2 different years (subsequent). In both countries soybean farming is mechanized. In the case of Mexico, the data correspond to the costs of producing soybeans with own machinery. Data were classified in specific categories whenever the available information allowed. It is clear, that some activities include costs of required materials and labour. One of the main differences in soybean production practices in Mexico and the United States are the intense use of water (100 percent compared to 5 percent), which increase the production costs. The purchase of irrigation water represented almost 15 percent of the operating costs. In addition, the costs of chemicals, fertilizers and seed for planting are higher in Mexico than in the United States. In Mexico, the operating cost per hectare of soybeans during 1999 was US$ 442.00 (corresponding 29 percent to the cost of inputs), whereas that in the United States was US$ 196.00 during 1998. For the same periods, the net returns per hectare for Mexican and American farmers were US$58.00 and US$355.45, respectively. These numbers explain why Mexican farmers do not want to grow soybeans.

In South Vietnam, soybean farming is not mechanized. Thuy *et al.* (1998) reported that it often takes 2 workdays to sow a hectare of land. Weeding is done by hand. A total of 40 men are needed for weeding a hectare and this activity has to be done from 2 to 3 times during the cropping season.

In Argentina, the cost of soybean harvesting under no tillage represented 10 percent over gross profit (price x yield) (Larreche and Firpo Brenta, 1999). In Mexico, the cost of harvest the 1999 soybean crop under no tillage represented 9.4 percent of the gross profit.

There is a tendency to use less insecticide in soybean production. Argentina and Brazil are using less insecticide and lower number of applications. Larreche *et al.* (1999) reported insecticide costs up to US$ 5.00 per hectare for the successful control of insects. The implementation of integrated pest management has allowed these two countries the reduction in the use of insecticides.

In Mexico, soybean crop required 23.7 workdays per hectare in the 80's (Marquez-Berber, 1989). In 1995, labour utilization was 12.7 workdays per hectare for farmers not owing machinery. In 1999, labour utilization was 10 workdays per hectare; 2 people hired and 8 people eventually hired (Banco de Mexico and FIRA, 1995; 1999). Table 29 shows the labour employed in the different operations of soybean cropping during 1995. Irrigation was the most labour demanding operation; almost 60 percent of the total labour hired performed irrigation work.

Diseases, pests and weeds are the main concern of soybean farmers worldwide. Annually, soybean yield losses are about 15 percent. In some places, yield losses are higher, especially when a new pest or disease invades the soybean fields. In Mexico, almost 16 percent of the total operating costs per hectare of soybean are spent on disease, pests and weeds control. In the United States, the expenditure for disease, pests and weeds control is about 33 percent of the total operating cost. It is worthwhile to remember that the operating cost of producing a soybean hectare in Mexico is 2.25 times higher than that in the United States. It seems that the use of resistant cultivars (to insects, diseases and herbicides), better cultural practices and integrated pest management are the most effective forms of counteracting the effects of these important biotic factors. The other losses in the post-production chain can be more easily controlled. Cares on soybean handling throughout the postharvest system will have an effect on the reduction of postharvest losses. To diminish soybean postharvest losses the following precautions should be taken:

Harvest soybeans at maturity, ideally at the safe storage moisture. If soybeans are harvested at higher moisture, dry the beans as soon as possible. Never use drying temperatures higher than 76 ° C since higher temperatures cause discoloration and soybean protein denaturation.

Clean the beans. Remove as much as possible of the foreign material splits and damage seeds. It is recommended to clean the beans before artificially drying is done. In this way, all heat will be used to dry the beans.

Clean and if it is possible, fumigate the handling equipment (including trucks or railcars) and the storage facility where the soybeans will be stored.

Check that thermocouples in the storage facility measure temperature properly.

Check the initial moisture content and condition of the beans.

Monitor soybean temperature and moisture periodically.

Check the condition of the beans periodically and make some inspections in the storage facility looking for insects and other storage pests.

If increases in temperature and/or moisture of the beans are detected, aerate the beans to decrease temperature or dry the beans to eliminate some moisture. If these two abiotic factors are well controlled the risk of soybean postharvest losses is minimum.

Table 28. Net return of soybean production by farmers in three different countries.

Gross value of production	US$/ha			
	United States (1998)	Mexico (1999)	S. Vietnam (1993)	
			Farmers in the Mekong Delta	Experimental Results in the Mekong Delta
Total gross value of production	551.45	500.00	660.38	1 179.2
Operation costs: Seed	50.56	79.6 (Planting)	47.17	28.3
Fertilizer	19.77	41.4	78.30	121.70
Soil conditioners	0.25	26.8 (Land prep.)	47.17 (Land prep.)	47.17 (Land prep.)
Manures	1.98			
Chemicals	65.85	70.6 (Disease, weeds and pests control)	22.64	41.5
Custom operations	14.43	30.8 (Cultural practices)	141.50 (Labour)	226.40 (Labour)
Fuel, lube, electricity	14.75	47.0 (Harvesting)		5.9
Repairs	23.70	-		
Irrigation water	0.12	65.1		
Interest on operating capital	4.60	80.7 (Other)		27.3 (Other)
Total operating costs	196.00	442.00	336.80	498.3
Allocated overhead: Hired labour	4.89			
Opportunity costs of unpaid labour	44.75			
Capital recovery of machinery and equipment	125.18			

Opportunity cost of land (rental rate)	191.90			
Taxes and insurance	17.02			
General farm overhead	31.97			
Total allocated overhead	415.72			
Value of production less total costs listed	(60.27)			
Value of production less operating costs	355.45	58.00	323.78	680.9
Supporting information: Yield (metric tonne/ha) Price (US$ per metric tonne)	2.89 191	2.0 250.00	1.4 471.69	2.5 471.69

Table 29. Labour (workday) employed per soybean hectare in Mexico, during 1995.

Operation	Labour (work-day)/ha
Land preparation	0.32
Fertilization	0.18
Planting	0.32
Cultural practices	2.20
Irrigation	7.54
Diseases, pests and weeds control	0.10
Harvesting	0.03
Other	2.00
TOTAL:	12.69

Source: Banco de Mexico and FIRA (1995).

5.2 Major problems

The major problems that soybean small-holders face are the lack of drying facilities, inadequate storage facilities and inadequate drying and lack of cleaning equipment. These problems are present mainly in rural areas of tropical and subtropical regions. On the other hand, the major problems that medium-scale soybean farmers face are pests, diseases and weeds, labour shortage, especially in Asia where most of the operations of soybean cropping are manually done, lack of high quality seed, lack of cultivars resistant to diseases or insects, lack of economical resources to buy the required inputs (fertilizer, herbicides, chemicals), poor control of pests and diseases and drought.

5.3 Proposed improvements

Integrated pest management, the use of fungicide treated seed as well as soybeans resistant to the main pests and diseases in the different soybean producing areas, improved cultural practices, the use of glyphosate-resistant soybeans, soybean cultivars resistant to adverse handling and storage conditions are the most profitable improvements that may contribute to a decrease in soybean postharvest losses.

5.4 Small-scale technology

In the last decade, technologies for small-scale refineries and for small-scale soymilk production have been developed. Adoption of these technologies has contributed to higher soybean consumption in several countries, especially those unable to invest in big processing plants or where the product's demand is small. An alternative to solvent-extraction is the dry extruder called "Insta-Pro", which is a complete ExPress system. Sixty plants have been established in the United States and Canada with a capacity between 10 to 100 tonnes/day. In India, this technology is being used mainly in rural areas. Inexpensive machines (ASSOY) capable of producing 20 litres of soymilk/batch are available. To date, 300 machines have been sold in Russia. Soymilk produced by the ASSOY machine is used by the Feed the Children Program.

5.5 Fortification of staple foods with soybeans

Many staple foods have been fortified with soybean or soybean products throughout the world. In Mexico, corn tortillas are being fortified with 4 to 5 percent soyflour plus minerals. In Guatemala, fortification of flours, gruels, cookies and other foods are fortified with soy proteins. In Costa Rica, annually 100 metric tonnes of soyflour are incorporated into the wheat flour, which is used to make baked products and other. In India, several foods are being fortified with soybean or soybean products and being used in Welfare Programs.

5.6 Modifications to soybean cultivars

Soybean composition has been modified in the last two decades. In early 1990's, soybeans that lack lipoxygenase enzyme were developed. These soybeans have the functional properties of traditional soybeans with less bean-like flavour. Later, soybeans with higher protein content, higher sucrose level and lower oligosaccharides, altered fatty acid compositions of the oil, higher fermentable sugars and higher yield were developed. More recently, the use of "organic" farming techniques has gained followers. On the other hand, genetically modified (GMO) soybeans have generated controversy. There are some who are willing to pay premiums in the market place for certified GMO free soybeans. The specific composition and functional properties of the modified soybeans make necessary to preserve the identity of soybeans throughout the food system, which necessarily will change the actual marketing system. A bushel of soybeans (commodity) is paid at US$ 5, whereas a bushel of identity preserved soybeans is paid by some processors at US$ 18. The economic implications that this may bring about are enormous.

There is a concern about assessing the safety of foods and food ingredients derived from genetically modified plants. Expert consultations convened by Food and Agriculture Organization of the United Nations (FAO), World Health Organization (WHO) and Organization for Economic Cooperation and Development (OECD) have recommended that the concept "substantial equivalence" be an important component in the safety assessment of foods and food ingredients derived from genetically modified plants intended for human consumption (OECD, 1993; FAO, 1996). The approach is not intended to establish absolute safety but to consider whether the genetically modified food is as safe as its traditional counterpart, where such a counterpart exists. Data for comparison should be obtained using validated methods and analysed using appropriate statistical techniques. In the case of GMO soybeans, the agronomic advantage (higher yield) is evident, at least so far, but the risks to human health and environment need to be evaluated according to guidelines of FAO/WHO. Factors that must be taken into account in the assessment of safety include: identity, source, composition, effects of processing/cooking, transformation process, recombinant DNA involved, protein expression product of the novel DNA (effects on function, potential toxicity, potential allergenicity), possible secondary effects on gene expression or the disruption of the host DNA or metabolic pathways and potential intake and dietary impact of the introduction of the GMO food (FAO/WHO, 2000).

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7. Annexes

Annex 7.1 Table A1. Pesticide tolerances in soybean and soybean products.

Commodity	Chemical name	CFR Cite	ppm
Soybeans	Acephate	180.108	1.0
	Acetamide	180.464	0.01
	Acetochlor	180.470	0.1
	Alachlor	180.249	0.2
	Aldicarb	180.269	0.02
	Alidochlor	180.282	0.05
	Alternaria cassiae	180.1001	exempt
	Azinphos-Methyl	180.154	0.2
	Barban	180.268	0.1
	Beauvaria bassiana	180.1146	exempt
	Benomyl	180.294	0.2
	Bentazon	180.355	0.05
	Butralin	180.358	0.1
	Carbaryl	180.169	5.0
	Carbofuran	180.254	1.0
	Carboxin	180.301	0.2
	Chitosan	180.1072	exempt
	Chloramben	180.266	0.1
	Chlorimuron ethyl	180.429	0.05
	Chloroneb	180.257	0.1
	Chlorothalonil	180.275	0.2

	Chloroxuron	180.216	0.15
	Chlorprophem	180.181	0.2
	Chlorpyrifos	180.342	0.3
	Chlorthal-dimethyl	180.185	2.0
	Clethodim	180.458	10.0
	Clofencet	180.497	30.0
	Clomazone	180.425	0.05
	Colletotrichum gloeosporioides spores	180.1075	exempt
	Dalapon	180.150	1.0
	Di-allate	180.277	0.05
	Diazinon	180.153	0.1
	Dicamba	180.227	0.05
	4-(2,4-Dichlorophenoxy)butyric acid	180.331	0.2
	2,4-Dichlorophenoxy-acetic acid	180.142K	0.1
	Diclolop-methyl	180.385	0.1
	Diflubenzuron	180.377	0.05
	Dimethoate	180.204	0.05
	Iphenamid	180.230	0.1
	Disulfoton	180.183	0.1
	Ethalfuralin	180.416	0.05
	Ethoprop	180.262	0.02
	Ethylene	180.1016	exempt
	Fenamiphos	180.349	0.05

	Fenoxaprop-ethyl	180.430	0.05
	Fenvalerate	180.379	0.05
	Fluazifop-butyl	180.411	1.0
	Fluchloralin	180.363	0.05
	Flumetsulam	180.468	0.05
	Fomesafen	180.433	0.05
	Gibberellic acid	180.1098	exempt
	Glufosinate-ammonium	180.473	2.0
	Glyphosate, isopropylamine salt	180.364	20.0
	Imazamox	180.506	0.1
	Imazaquin	180.426	0.05
	Imazethapyr, ammonium salt	180.447	0.1
	Indole-3-butyric acid	180.1099	exempt
	Kaolin	180.1180	exempt
	Lactofen	180.432	0.05
	Lagenidium giganteum mycelium	180.1113	0
	Lambda-cyhalothrin	180.436	0.01
	Magnesium phosphide (residues calculated as phospine)	180.375	0.1
	Mefluidide	180.386	0.01
	Metalaxyl	180.408	1.0
	Methomyl	180.253	0.2
	Metolachlor	180.368	0.2
	Metribuzin	180.332	0.1

	N-1-Naphthylphthalamic acid	180.297	0.1
	Norflurazon	180.356	0.1
	Oxadixyl	180.456	0.1
	Oxamyl	180.303	0.2
	Oxyfluorfen	180.381	0.05
	Paraquat dichloride	180.205	0.05
	Parasitoid insects	180.1101	exempt
	Parathion	180.121	0.1
	Pendimethalin	180.361	0.1
	Permethrin	180.378	0.05
	Phorate	180.206	0.1
	Propionic acid	180.1023	exempt
	Quizalofop-ethyl	180.441	0.05
	Sesame plant, ground	180.1087	exempt
	Sethoxidin	180.412	10.0
	Sdium 5-nitroguiacolate	180.1139	exempt
	Sodium acilluorfen	180.383	0.1
	Sodium chlorate	180.1020	exempt
	Sodium o-nitrophenolate	180.1140	exempt
	Sodium p-nitrophenolate	180.1141	exempt
	Sulprofos	180.374	0.5
	Thiabendazole	180.242	0.1
	Thifensulfuron methyl	180.439	0.1
	Thidicarb	180.407	0.2

	Thiophenide-methyl	180.371	0.2
	Trefomethrin	180.422	0.05
	Thrichoderma viride serious Bimby	180.1102	Exempt
	2,3,5-Triiodobenzoic acid	180.219	0.15
	Vernolate	180.240	0.1
Soybeans (Postharvest)	Aluminium phosphide (residues calculated as phosphide)	180.225	0.1
	Methyl bromide	180.123	200.0
Soybeans, Aspirated Grain Fractions	Glyphosate, isopropylamine salt	180.364	50.0
	Sulfonium, trimethyl-salt with N. (phosphonomethyl) glycine (1:1)	180.489	210.00
Soybeans Dry	Captan	180.103	2.0
	Linuron	180.184	1.0
	Malathion	180.111	8.0
Soybean Meal	Acephate	186.100	4.0
	Fluazifop-butyl	186.3250	2.0
	Metaloxyl	186.4000	2.0
	Quizalofop-ethyl	186.5250	0.5
Soybean Oil	Azinphos-Methyl	185.2225	1.0
	Fluazifop-butyl	185.3250	2.0
Soybean Flour	Inorganic bromides resulting from fumigation with methyl bromide, ethylene dibromide and/or 1,2-dibromo-3-chloropropane (185.3700, 186.3700)	185.3700	125.0

	Quizalofop-ethyl	185.5250	0.5
Soybean Seed	Halosulfuron	180.4798	0.5
	Sulfonitrazone	180.496	0.05
	Sulfonium, trimethyl-salt with N (phosphonomethyl) glycine (1:1)	180.489	3.0

Annex 7.2 Soyfood recipes

CHINESE BARBECUED TOFU WITH SESAME NOODLES (1)
ALL-AMERICAN SOY BURGER (2)
DAIRY-FREE CHOCOLATE-ALMOND CAKE WITH CHOCOLATE (3)
FRANCINE'S BEST SOY COOKIES (4)
TOFU AND MUSHROOM DELIGHT (5)
LAYERED TOFU SALAD (6)
MISO MARINADE (7)
LEMON GINGER MISO DRESSING (8)
CORN AND SOY MUFFINS (9)
OVEN ROASTED TOFU AND VEGETABLES (10)
SAMURAI SALAD (11)
STRAWBERRY SMOOTHIE (12)
RASOGOLLA ANALOG (Indian Food) (13)
SOYDHAL (Indian Recipe) (14)
SOYFLOUR (Indian recipe) (15)
MURUKKU AND OMAPODI (Indian recipe) (16)
PALMENI (Russian food) (17)
SPONGE CAKE (18)
DONUTS (19)
FORTIFIED COOKIES WITH 12 percent SOYBEAN FLOUR (20)
COOKIES WITH PIECES OF CHOCOLATE (21)
OATS COOKIES (22)
EXTRATO DE SOJA "LEITE DE SOJA" (Brazilian recipe) (23)
FARINHA DE SOJA (Brazilian recipe) (24)
"CARNE" DE SOJA (HYDRATED TVP) (25)
GRÃOS COZIDOS (Brazilian recipe) (26)
MASSA BÁSICA (Brazilian recipe) (27)

CHINESE BARBECUED TOFU WITH SESAME NOODLES (1)

INGREDIENTS	AMOUNTS
Marinade: Soy sauce, regular or light	¾ cup
Hoisin sauce	¾ cup
Oyster sauce	6 tablespoons
Sherry wine or beer	6 tablespoons
Brown sugar, firmly packed	3 tablespoons
Garlic, crushed	9 cloves
Five spice seasoning	1 - ½ teaspoon
Tofu, firm or extra firm	11 pounds
Soy oil	As needed
Sesame noodles: Chinese egg noodles	2 pounds
Water	As needed
Soy sauce, regular or light	1 cup + 2 tablespoons
Sesame oil	6 tablespoons
Granulated sugar	2 tablespoons
Carrots, bias cut	1-1/2 pounds
Green onion tops, chopped	18
Cucumbers, peeled and seeded	8
Garnishes: green onion brushes, carrot curls	As needed
Cucumber fans	As needed

METHOD

1. Combine soy sauce, hoisin sauce, oyster sauce, sherry or beer, brown sugar, garlic and five spices for marinade. Set aside.
2. Slice each 10-ounce brick of tofu into eight ½ -inch portions. Dry thoroughly between several layers of paper towels.
3. Heat a non-stick skillet and brown tofu on both sides using a small amount of oil. Remove from skillet. Cool slightly.
4. Cover with Chinese Barbecue Sauce and marinate 30 minutes to 2 hours.
5. Charbroil tofu over hot coals until browned on both sides. Baste tofu several times.
6. Cook egg noodles in simmering water 2 to 4 minutes or to al dente state. Drain and cold shock to stop cooking.
7. Drain well. Season with soy sauce, sugar and sesame oil.
8. Toss with assorted vegetables.

9. Serve noodles at room temperature with barbecued tofu.
10.Garnish with onion brushes, carrot curls and cucumber fans, if desired.

ALL-AMERICAN SOY BURGER (2)
YIELD: 10 servings

INGREDIENTS	AMOUNTS
Soybeans, cooked and drained	2-1/2 quarts
Fresh whole wheat bread crumbs	10 oz. (1-1/4 qt.)
Onions, finely chopped	13 oz. (2-1/2 qt.)
Garlic, minced	1 oz. (1/4 cup)
Carrots, grated	7 oz. (1/4 cup)
Soy protein isolates	5 oz. (1-1/4 cups)
Fresh parsley, chopped	2/3 cup
Dried thyme, crushed	2-1/2 teaspoons
Salt	2-1/2 teaspoons
Ground pepper	1-1/4 teaspoons
Eggs, beaten	5
Soybean oil	As needed

METHOD
1. Coarsely mash cooked soybeans until lumpy
2. Combine all ingredients in large bowl. Form No. 8 scoops into patties.
3. Cook on a lightly oiled griddle over medium heat until thoroughly heated and browned on both sides.
4. Serve on a bun.
5. Add 1-pound dry soybeans to 1-1/2 to 2 quarts boiling water; boil 5 minutes.
6. Cover pot, remove from heat and let stand 1 hour.
7. Drain; add 1-1/2 quarts water. Do not add salt at this point or it will delay the softening of the beans.
8. Bring beans and water to boil; reduce heat and simmer, with lid tilted on pot, about 3 hours or until beans are tender.
Yield: 1 to 1-1/2 quarts cooked beans.

DAIRY-FREE CHOCOLATE-ALMOND CAKE WITH CHOCOLATE GLAZE (3)
YIELD: One 12-cup Bundt cake

INGREDIENTS	AMOUNTS
Unbleached white flour Baking powder4 teaspoons	2-1/4 cups 4 teaspoons
Salt1/4 teaspoon	¼ teaspoon
Unsweetened cocoa	1 cup
Soybean margarine, softened to room temperature Tofu, crumbled and drained	½ cup (1 stick) 2/3 cup
Soy milk	1 ¼ cup
Pure almond extract	1 teaspoon
Silvered almonds	1 cup

METHOD
1. Preheat the oven to 350 degrees.
2. Measure the flour, baking powder, salt, sugar and cocoa into a bowl. Sift them together into a large mixing bowl.
3. Measure the soy margarine, tofu, soymilk and almond extract into a blender. Cover and blend on low speed for 5 seconds.
Stop to scrape the sides using a rubber spatula.
4. Pour the blended ingredients over the dry ingredients all at once. Beat lightly with a wooden spoon for about 30 seconds to
Mix. Stir in almonds.
5. Spray a 10-inch Bundt pan with non-stick cooking spray. Turn the batter into the prepared pan, using a rubber spatula to
Scrape the bowl. Spread the batter smooth.
6. Bake for about 50 minutes until a tester inserted into the centre comes out clean. Remove the pan from the oven and let set
For 2 minutes before turning onto a cake dish.

FRANCINE'S BEST SOY COOKIES (4)
YIELD: 8 dozen

INGREDIENTS	AMOUNTS
Soy margarine Packed brown sugar	2 cups 2-1/4 cups
Granulated sugar	2-1/4 cups
Eggs	4
Vanilla All-purpose flour	1 tablespoon 3-1/2 cups
Soy flour	¾ cup

Salt	1 teaspoon
Baking powder	2 teaspoons
Baking soda	2 teaspoons
Quick-cooking rolled oats	1-1/2 cups
Shredded coconut	2 cups
Semi-sweet chocolate chips	2 cups
Whole toasted soybeans	2 cups

METHOD
1. Cream margarine, sugars, eggs and vanilla on medium speed of mixer until blended.
2. Combine flour, soy flour, salt, baking soda and baking powder; mix well.
3. Add flour mixture to creamed mixture. Mix until ingredients are combined; do not overmix.
4. Add remaining ingredients, one at a time; mix well after each addition.
5. Lightly spray-baking sheets with soy pan spray.
6. Drop dough onto sheets 2-inches apart, using a No. 40 scoop.
7. Bake at 325°F about 15 minutes or until lightly browned.

TOFU AND MUSHROOM DELIGHT (5)
YIELD: 8 portions

INGREDIENTS	AMOUNTS
Tofu, firm Soybean oil	16 oz. 2 teaspoons
Garlic clove, minced	1
Onion, yellow, sliced	1 cup
Button mushrooms, sliced Shiitake mushrooms, sliced	8 oz. ½ cup
Water	3 tablespoons
Cornstarch	2 tablespoons
Oyster sauce	2 tablespoons
Soy sauce	2 teaspoons
Sugar	½ teaspoon
Salt White pepper	¼ teaspoon 1/8 teaspoon
Green onion, thinly sliced garnish	
Sweet red pepper, thinly sliced garnish	
Yellow peppers, sliced garnish	

METHOD
1. Rinse tofu, set on several layers of paper towels and allows draining to remove excess water.
2. Cut tofu into 1-inch cubes. Heat wok or heavy skillet until hot over high heat.
3. Add 2 tablespoons soybean oil and brown the garlic about 10 seconds.
4. Add sliced onions mushrooms, bamboo shoots and stir with a ladle until aromatic, about 1 minute.
5. Add broth and tofu. Bring to a boil and cover with pan lid. Steam cook 1 minute and remove cover.
6. Add oyster sauce, soy sauce, sugar, salt and white pepper.
7. Mix water and cornstarch.
8. Add cornstarch solution to stir-fry, stir until thickened.
9. Serve family-style with freshly cooked rice or on noodles as a balanced meal. Suggested garnish: thin slices of green onion,
Red and yellow peppers. *When using dried shiitake mushrooms, hydrate in water and slice.

LAYERED TOFU SALAD (6)
YIELD: 12 servings

INGREDIENTS	AMOUNTS
Shredded iceberg lettuce Red onions, thinly sliced	1-1/2 gallons (2 large heads) 1 lb. 8 oz. (3 medium)
Bean sprouts	3 qt. (48 oz.)
Tomatoes, ½ inch cubes	2 lbs. 14 oz. (9 medium)
Silken tofu, ½ inch cubes Canned red salmon or light tuna	3 lbs. 1 lb. 8 oz.
Watercress, cut in 1-inch piece optional	3 cups (3 oz.)
Warm soy sauce dressing: Soy sauce	1 cup
Soybean oil	¾ cup
Green onions, minced	1-1/2 cups
Garlic, mashed	9 cloves
Sugar	1-1/2 teaspoons
Bottled hot pepper sauce	¾ teaspoon

METHOD
For buffet service:
1. Layer salad ingredients in order of listing in a large shallow bowl or serving platter.
2. Just before serving, heat ingredients for Warm Soy Sauce Dressing. Toss salad and serve.
For table service:
1. Toss salad and serve about 2 cups per serving.
2. Garnish with choice of cherry tomatoes, sliced red onions, sweet red or yellow peppers, sugar pea pods or sliced cucumbers.

MISO MARINADE (7)
YIELD: 1 quart.

INGREDIENTS	AMOUNTS
Miso (fermented soybean paste) Soy sauce	1-1/2 cups 1 cup
Brown sugar, packed	1-1/2 cups
Dry vermouth	1 cup
Fresh ginger root, grated Garlic, crushed	1 tablespoon 2 large cloves

METHOD
1. Mix all ingredients until well blended.
2. Marinade is sufficient for 5 pounds of chicken, pork or fish.
Preparation Tips:
Marinate chicken or pork in Miso Marinade up to 12 hours or brush on fish 2 to 4 hours before grilling.
To serve meat with sauce, 2 parts of marinade may be diluted with 1 part of water, stock or vermouth, cooked to a boil rained.

LEMON GINGER MISO DRESSING (8)
YIELD: 1 quart.

INGREDIENTS	AMOUNTS
Miso (fermented soybean paste) Water	1-1/2 cups 1 cup
Fresh ginger, grated	2 tablespoons
Lemon juice	1 cup
Sugar Vegetable oil	1 cup 1/2 cup
Lemon peel, grated	1 teaspoon

METHOD
1. Mix miso, water and ginger in blender. Strain mixture and return liquid to blender.
2. Add remaining ingredients and mix well.
Serving suggestion: Serve two ounces over mixed greens or sliced cucumbers.

CORN AND SOY MUFFINS (9)
YIELD: 12 muffins

INGREDIENTS	AMOUNTS
All purpose flour Yellow cornmeal	1-1/2 cups ½ cup
Soy flour	1/4 cup
Sugar	¼ cup
Vanilla	1 tablespoon

All-purpose flour	3-1/2 cups
Soy flour	¾ cup
Baking power	2 teaspoons
Salt	½ teaspoon
Light soymilk	1 cup
Eggs, beaten	2
Soybean oil	¼ cup

METHOD
1. Mix flour, cornmeal, soy flour, sugar, baking powder and salt.
2. Combine soy milk, eggs and oil; add to dry ingredients and mix only enough to moisten.
3. Fill oiled muffins tins. Bake at 400°F 20 minutes.

OVEN ROASTED TOFU AND VEGETABLES (10)

INGREDIENTS	AMOUNTS
Extra firm tofu, drained Balsamic vinegar	16 ounces 3 tablespoons
Vegetable oil	2 teaspoons
Sugar	2 tablespoons
Garlic, minced Dried oregano, crushed	1 clove ½ teaspoon
Salt	½ teaspoon
Sweet red pepper, quartered	1
Medium onion, quartered	1
Medium mushrooms, quartered	3
Chopped parsley for garnish	As desired

METHOD
1. Cut tofu in half vertically then horizontally. Drain on several layers of paper towels to remove as much liquid as possible.
If desired, score surfaces to allow more marinade to penetrate tofu.
2. Combine vinegar, oil, sugar, garlic, oregano and salt; mix well.
3. Place tofu and vegetables in a shallow baking pan leaving enough space between the pieces for even roasting; brush with
Vinegar mixture.
4. Let stand 30 minutes, brush again and let stand 30 minutes longer.
5. Bake tofu, pepper and onion at 500 F 30 to 35 minutes. Turn once halfway through baking time.
6. Add mushrooms during last half of roasting time.
7. Transfer to platter and sprinkle with parsley. Makes 4 servings.

SAMURAI SALAD (11)
YIELD: 24 servings.

INGREDIENTS	AMOUNTS
Firm tofu*, drained, sliced to 2-1/2 oz. 48 slices Soybean oil	7 lb. 8 oz. As needed
Ginger Dressing:	
Soy sauce	3 cups
White wine vinegar Fresh ginger root, grated	3 cups 1/2 cup
Bottled hot pepper seasoning	2 tablespoons
Garlic salt	As needed
Salad greens	6 gal. (12 lb)
Green onions, diagonally sliced	3 cups (9 oz.)
Tomato slices, small	48
Sesame seeds, toasted, optional	¼ cup

METHOD
1. Lightly brush tofu with oil and Ginger Dressing; sprinkle with garlic salt.
2. On a well oiled grill*, cook tofu until golden brown on both sides.
3. Toss greens with Ginger Dressing; portion onto individual serving plates.
4. Place tofu slices on bed of lettuce; sprinkle with green onions and garnish with tomato slices.
5. Sprinkle with sesame seeds, if desired.
* Tofu may be cooked in a lightly oiled non-stick skillet over medium heat until golden brown on both sides. \

STRAWBERRY SMOOTHIE (12)
YIELD: 24 servings

INGREDIENTS	AMOUNTS
Frozen strawberries, thawed, including juice Water	3 qt. 3 cups
Soy protein isolate	3 cups
Crushed ice	3 qt.

METHOD
1. For each serving, thoroughly mix 1/2 cup thawed strawberries and 2 tablespoons each water and soy protein isolate in a blender.
2. Add 1/2 cup-crushed ice and blend until smooth.
3. Serve in a 12-ounce glass.
Nutritional Analysis Per Serving: 62 Cal., 9 g pro., 0.4 g fat (6 percent Cal from fat), 7 g carb., 0 mg chol., 1.2 g fibre and 113 sodium.

RASOGOLLA ANALOGUE (Indian Food) (13)

INGREDIENTS	AMOUNTS
Soybeans Sodium hydroxide (1%)	100 % 400 %
Calcium lactate	2 %
Sugar syrup	50-55%
Water	As needed

METHOD
1. Soak soybeans, in water containing 1 percent sodium hydroxide, overnight at room temperature in the ratio 1:4 (w/v).
2. After soaking, remove the husks by rubbing with hand.
3. Grind the clean soybeans (200g) in mixer with lukewarm water (1000 ml).
4. Filter the resulting suspension through a double layer muslin cloth.
(Up to here, soymilk is prepared).
5. Heat the soymilk to coagulation temperature (85 ° C) in a beaker and add 2 percent calcium lactate solution with gentle and
Continuous stirring until coagulation completed.
6. Stand (undisturbed) the contents at room temperature for 20 min.
7. Remove the whey by filtering through muslin cloth and hang it for 30 min or until dripping of free whey completely cease.
(Up to here, soy-chhana is prepared)
8. Knead manually the soy-chhana into smooth dough.
9. Prepare by hand round balls of uniform size (8 g) and cook them for 15 min in boiling clarified 50 to 55 percent sugar syrup.
10. Concentration of sugar in the syrup is maintained by adding hot water at frequent intervals.
The cooked soy-rasogolla is placed in hot 40 percent sugar syrup and allowed to cool to room temperature.

SOYDHAL (Indian Recipe) (14)

INGREDIENTS	AMOUNTS
Soybeans Chick pea flour	50 % 50 %
Water	As needed
Oil	As needed

METHOD
1. Soak clean soybeans in water for one second and roast them with sand at 160 ° F.

2. Sift the roasted soybeans to remove the sand
3. Mill the beans in a dhal mill to remove the hulls and split the beans.
Soy dhal can be used to prepare soy flour and a variety of foods such as sundal, vadai, idly, dosai, payasam and sambar.

SOYFLOUR (Indian recipe) (15)

INGREDIENTS	AMOUNTS
Soy dhal	100 %

METHOD
1. Soy dhal is sun dried to moisture content of 8 percent.
2. Mill the sun dried soy dhal in a flourmill.
Soy flour can be used to prepare a variety of foods such as mysore pack, boondhi, omapodi, pakoda, bajji, ribbon pakoda, and murukku.

MURUKKU AND OMAPODI (Indian recipes) (16)

INGREDIENTS	AMOUNTS
Soy flour Chick pea flour	50 % 50 %
Water	As needed
Oil	As needed

METHOD
1. Add the murukku mix (50 percent soy flour and 50 percent chick pea or rice flour) to a container
2. Add enough water to make into a tick paste.
3. Fill in to the murukku or omapodi mould and press into the hot oil at smoking temperature in the deep fat frying pan.
4. Remove from the oil when the product turns golden brown in colour without release of any bubble in the pan.
Place the product in a tray.

INDIAN FOODS DERIVED FROM SOYDHAL (6):

NAME	DESCRIPTION
Vadai	A deep fat fried snack, 50% substitution of soy dhal in the place of chick pea
Idly	A deep fat fried snack, 50% substitution of soy dhal in the place of black gram dhal
Dosai	A shallow fried breakfast dish, 50% substitution in the place of

NAME	DESCRIPTION
	black gram dhal
Sundal	A seasoned dhal, 100% substitution of soy dhal for red gram dhal
Fried dhal	100 % substitution of soy dhal for chick pea
Sambar	A curry, 100% substitution of soy dhal for red gram dhal

INDIAN FOOD DERIVED FROM SOYFLOUR (7):

NAME	DESCRIPTION
Mysore pack	A sweet, 100% substitution of soy flour in the place of chick pea flour
Boondhi	A deep fat fried snack, 50% substitution of soy flour in the place of chick pea flour
Omapodi	A deep fat fried snack, 50% substitution of soy flour in the place of chick pea flour
Pakoda	A deep fat fried snack, 50% substitution of soy flour in the place of chick pea flour
Bajii	A deep fat fried snack, 50% substitution of soy flour in the place of chick pea flour
Ribbon pakoda	A deep fat fried snack, 50% substitution of soy flour in the place of chick pea flour
Murukku	A deep fat fried snack, 50% substitution of soy flour in the place of chick pea flour

PALMENI (Russian food) (17):
A ravioli-like food, which includes a (65/35) meat/soy blend.

SPONGE CAKE (18):

INGREDIENTS	AMOUNTS (%)
Wheat flour High-fat soy flour	100.00 2.50
Non-fat dry milk	8.00
Salt	2.50
Dry whole eggs	10.25
Yellow colouring	1.25
Granulated sugar	116.00
Water	99.00
Baking power	5.00

METHOD

1. Add all ingredients except baking power and 46.00 percent of water in a mixer container and mix for 1 min. at low speed.
2. Then mix for 3.5 min at second speed and 0.5 min at third speed.
3. Add the baking power and the remaining water to the previous mix. Then, mix 1 min at low speed, 2 min at second speed, and 0.5 min at third speed.
4. Put in moulds and bake for 12 min at 200 to 205 ° C.

DOUGHNUTS (19)

INGREDIENTS	AMOUNTS (%)
Sugar Salt	0.681 0.028
Shortening	0.114
Milk powder	0.114
Cake flour	1.136
Bread flour	0.454
Egg yolk powder	0.142
Sodium bicarbonate	0.025
Sodium acid pyrophosphate	0.034
Water	1.240

FORTIFIED COOKIES WITH 12 percent SOYBEAN FLOUR (20)

INGREDIENTS	(%) TOTAL BASIS
Wheat flour Soy flour	34.00 11.70
Sugar, sifted	9.30
Sugar, granulated	14.00
Invert syrup	2.00
Fat, liquid	11.00
Salt, refined	0.80
Sodium bicarbonate	0.30
Mono-calcium phosphate	0.06
Ammonia bicarbonate	0.90
Lecithin	0.20
Mono- and di-glycerides	0.25
Coconut, ground	2.40
Flavourings	0.05
colourings	0.02
Water	13.00
	100.00

Flavourings: coconut and essential lemon oil.

COOKIES WITH PIECES OF CHOCOLATE (21)

INGREDIENTS	(%)
Phase 1: Cookie flour Defatted soy flour	94.00 6.00
Sodium stearoyl-2-lactylate (SSL)	0.28
Salt	2.60
Phase 2:	
Shortening	32.00
Margarine or butter	28.00

Sugar, unrefined	29.00
Vanilla	1.60
Water	0.80
Phase 3:	
Whole eggs, liquid	39.00
Phase 4:	
Chocolate, pieces	55-100

METHOD
1. Combine the in gradients of Phase 1.
2. Mix the ingredients of Phase 2 and form a cream.
3. Add gradually Phases 3 and 1 to the creamy mix and mix well.
4. Add the Phase 4.
5. Put on greased trays for cookies.
6. Bake at 190 ° C for 10 to 12 min.

OATS COOKIES (22)

INGREDIENTS	(%)
Phase 1: Cookie flour Defatted soy flour	94.00 6.00
Sodium stearoyl-2-lactylate (SSL)	0.28
Sodium bicarbonate	3.70
Salt	5.20
Phase 2:	
Shortening	107.00
Sugar, unrefined	85.00
Sugar, granulated	74.00
Whole eggs, liquid	44.00
Water	44.00
Vanilla	1.50
Phase 3:	
Oats, crumbled	167.00
Phase 4:	
Chocolate, pieces	55-100

METHOD
1. Combine the in gradients of Phase 1.
2. Mix the ingredients of Phase 2 and form a cream.
3. Add the Phase 1 to the cream formed with the ingredients of Phase 2. Mix for 2 min.
4. Add the Phase 3 to the mixture. Mix during 30 sec.
5. Put on greased trays for cookies.
6. Bake at 177 ° C for 12 to 15 min.
If desired pieces of nuts, chocolate, coconut, or raisin can be added.

EXTRATO DE SOJA "LEITE DE SOJA" (Brazilian recipe) (23)

INGREDIENTS	AMOUNTS
Soybeans	3 cups
Water	4.5 litres
Salt	1 teaspoon
Sugar	6 tablespoons
Sodium bicarbonate	1 teaspoon

METHOD:
1. Boil 1.5 litres of water in a container, add half of the bicarbonate and mix.
2. Add the soybeans. Once boiling starts, keep boiling for 5 min.
3. Drain water and wash the beans with top water. Rub the beans between hands to remove the hulls.
4. Add the remaining water and boil. Add the other half of bicarbonate and cook the beans for 5 min.
5. Stand until the beans are warm. Put the beans and water in a mixer and mix for 3 min.
6. Cook in an uncovered pan for 10 min, reducing the flame after boiling and stirring all the time.
7. Stand until it is warm. Strain using a clean cloth and squeeze through the cloth. The drained liquid is the soybean extract (milk) and the remaining massa is the residue.
8. Boil the extract for 2 min
9. Add the sugar and salt to the extract.
To obtain different flavours just add chocolate, cinnamon, vanilla or any desirable flavour.

FARINHA DE SOJA (Brazilian recipe) (24)

INGREDIENTS	AMOUNTS
Soybeans, selected and unwashed	As desired

METHOD
1. Add the soybeans to a pan with boiling water, according to the procedure described for soybean extract (Recipe 19) and cook for 5 min.
2. Drain the beans and put them on a clean and dry cloth for 1 hour.

3. Roast the beans in the oven using low flame for about 1 hour stirring all the time, similar to roasting peanuts.
4. Grind the roasted beans in a mixer or in a meat mill.
5. Sift the flour obtained, using a fine sifter and keep it in a dry container with lid.

"CARNE" DE SOJA (HYDRATED TVP) (25)

INGREDIENTS	AMOUNTS
Textured vegetable protein, (TVP)	1 cup
Water, boiling	2 cups

METHOD
1. Put the TVP in a pan and cover it with boiling water.
2. Stand for 10 min to allow water to be absorbed by the TVP.
3. Drain the hydrated TVP with a sifter, removing the excess of water using a spoon pressing against the sifter.
4. Use in stews, sauces, stuffed and fillings.
TVP is also known as TSP (textured soybean protein).

GRÃOS COZIDOS (Brazilian recipe) (26)
COOKED SOYBEANS

INGREDIENTS	AMOUNTS
Soybeans, selected and unwashed	2 cups
Sodium bicarbonate	¼ teaspoon
Water	8 cups
Soybean oil	1 tablespoon

METHOD
1. Boil 3 cups of water, add half of the bicarbonate and cook for 5 min, after the second boiling.
2. Drain the water and provoke a heat shock by washing the beans with cold water, as described for soybean extract (Recipe 19).
3. Drain the water and put the beans with 3 cups of cold water for about 8 hours.
4. Drain the beans and separate the hulls.
5. Add 1 tablespoon of soybean oil and cook in an uncover pan for 1 hour or in a steam cooker for 20 min

MASSA BÁSICA (Brazilian recipe) (27)

INGREDIENTS	AMOUNTS
Soybeans, selected and unwashed	2 cups
Sodium bicarbonate	¼ teaspoon
Water	8 cups
Soybean oil	1 tablespoon

METHOD

1. Boil 3 cups of water, add half of the bicarbonate and cook for 5 min, after the second boiling.
2. Drain the water and provoke a heat shock by washing the beans with cold water, as described for soybean extract (Recipe 19).
3. Drain the water and put the beans with 3 cups of cold water for about 8 hours.
4. Drain the beans and separate the hulls.
5. Add 1 tablespoon of soybean oil and cook in an uncover pan for 1 hour or in a steam cooker for 20 min
6. Mill the cooked soybeans in a meat mill or in a mixer until obtaining a homogeneous massa.

This massa can be stored in the freezer to be used in the preparation of different dishes.

Annex 7.3 Quotations and Technical Specifications of Thresher Machines

Quantity	Almaco#	Description	Total (US$)
1 1	5100 50714	ALMACO Small Bundle Thresher, Model SBT-RCB-G Rubber coated steel raspbar cylinder, overshot style Rubber coated steel raspbar concave - 3 h.p. air-cooled gasoline engine - Feeding hopper - Grain rebounding baffle - Auxiliary beater and strawpuller - Bladed type winnowing blower with adjustable air intake - Removable recleaning pan - Interchangeable screens for recleaning pan; one each 1/8", ¼", 3/8" and 1/2" mesh size - V-Pulleys and V-Belts - Safety cover guard screens - 10" x 1.75 Ball bearing - Hand truck-type handles - Grain catch pan Export crate	4 902.00 243.00
TOTAL			US$ 5 145.00

Quantity	Almaco#	Description	Total (US$)
1 1	51163 50738	ALMACO Single Plant Belt Thresher, Model BT-14 G Adjustable clearance between belts to regulate threshing aggressiveness Air column cleaning system for clean, pure seed samples - SAE standard size drive components and parts - 3 h.p. air cooled gas engine - Feeding chute - Side delivery seed collection chute - Spring loaded door on seed chute to allow bagging small individual samples or lock in open position for continuous threshing - Designed for use by single operator - Four pneumatic 4.8 x 8 wheels with towing handle and hand brake - 14" wide threshing belts for increase separation and threshing capacity - Trash containment curtain - Hinged safety cover guards Export crate	7 227.00 518.00
TOTAL			US$ 7 745.00