SOYBEANS: Post-harvest Operations

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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.

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).

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).

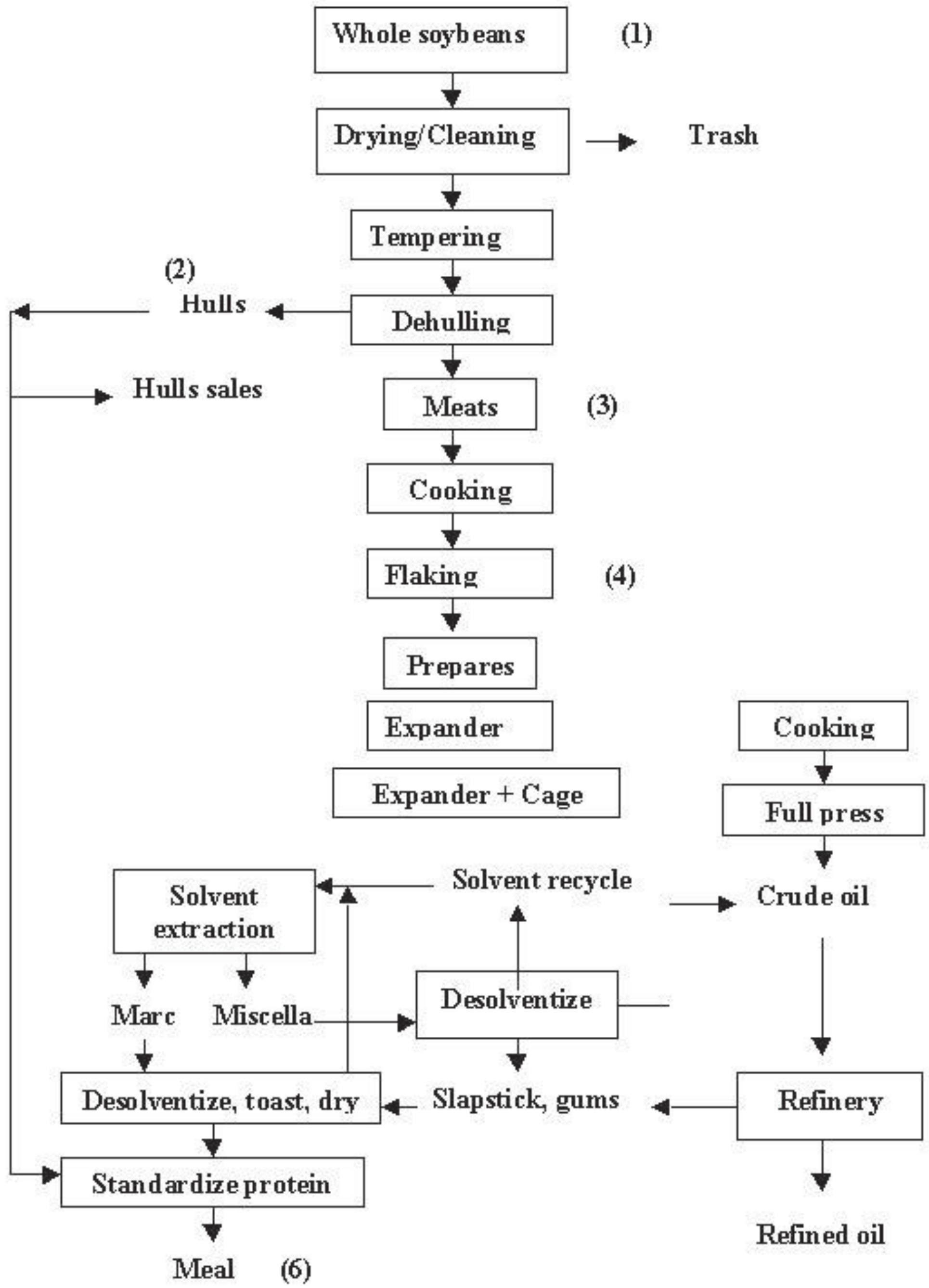

Figure 20. Flowchart of soybean oil extraction process.

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).

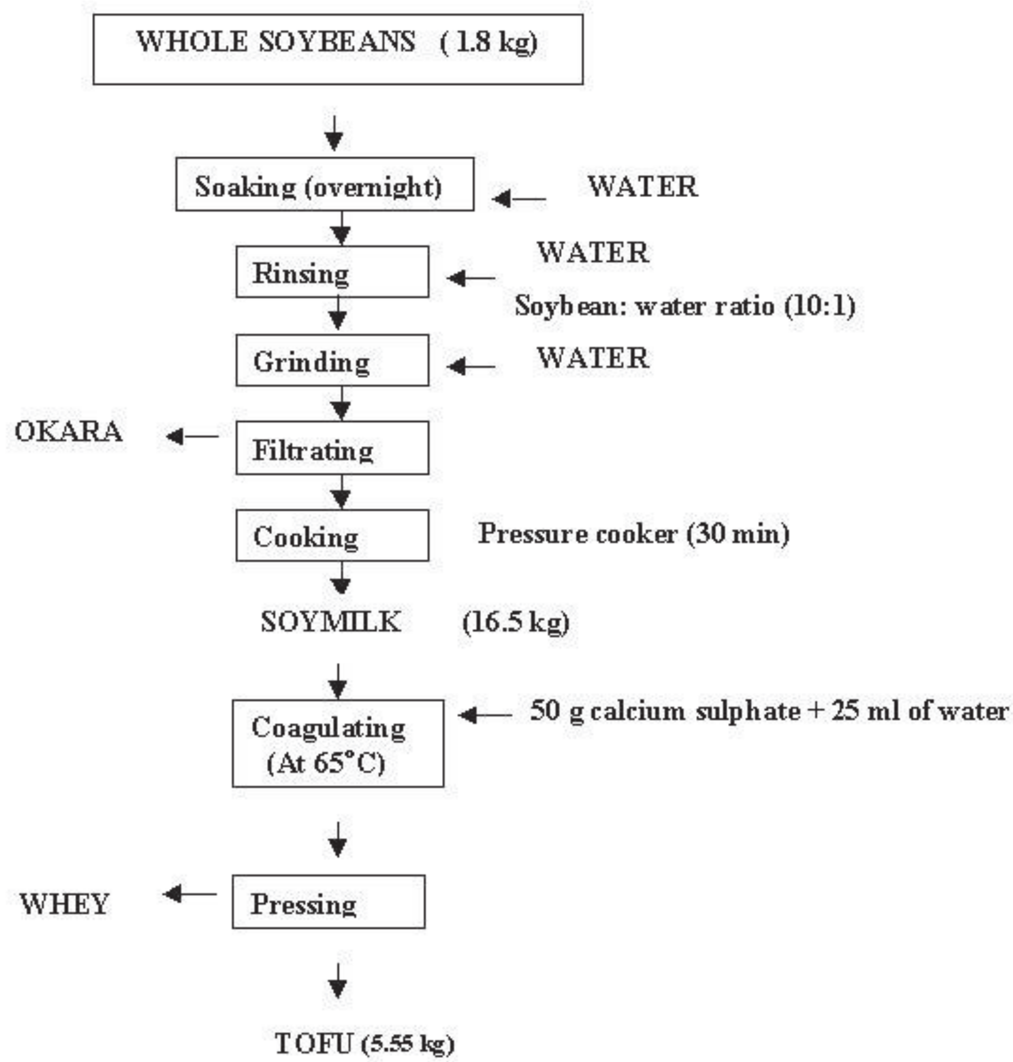

Figure 22. Flowchart for preparation of soymilk and tofu according to the Chinese method.

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