Taxonomy of the Genus *Glycine*, Domestication and Uses of Soybeans[1]

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The genus Glycine *has had a stormy taxonomic history. Recent studies of herbarium specimens and cytological and morphological analyses of living collections, coupled with chemotaxonomic investigations, have made it necessary to revise the genus. In the first part of this paper the current taxonomic status of the genus* Glycine *is reviewed.*

The soybean was domesticated in China. It is unfortunate that the literature concerned with the antiquity and historical development of the soybean is obscured by legends and myths. In the second section of the paper, the archeological, historical, agricultural and botanical literature is summarized in order to present all the known evidence as to when, where and by whom the soybean was domesticated.

The soybean is the world's premier source of dietary vegetable oil and is nutritionally an excellent and inexpensive source of protein for use either as human food or animal feed. In addition, the soybean has numerous industrial uses. In the last section of this paper the traditional uses of fermented and nonfermented soybeans in the East as well as the high-technology-developed uses of soybeans in the West are summarized.

TAXONOMIC HISTORY OF *GLYCINE*

The name *Glycine* was originally introduced by Linnaeus in the first edition of his *Genera Plantarum* (Linnaeus, 1737a). This new genus was based on *Apios* of Boerhaave. *Glycine* is derived from the Greek *glykys*, meaning sweet, and probably alluded to the sweetness of the edible tubers produced by *Apios* (Henderson, 1881). In the *Species Plantarum* of 1753, Linnaeus listed 8 *Glycine* species (Table 1). All these were subsequently moved to other genera, although *G. javanica* remained as the lectotype for the genus (Hitchcock and Green, 1947) until 1966. It is of interest to note that when *Glycine apios* once more became *Apios*, the original justification for the name *Glycine* was also removed from the genus; the Greek *glykys* thus does not refer to any of the current *Glycine* species, despite which floras are still being published with the information that the roots and other plant parts are edible and sweet.

The cultivated soybean was described by Linnaeus in 1753 as both *Phaseolus max*, based on specimens that he saw, and *Dolichos soja*, which he compiled from the descriptions of other writers. This gave rise to a great deal of confusion later concerning the correct nomenclature of the soybean. Linnaeus apparently

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TABLE 1. THE SPECIES OF *Glycine* ACCORDING TO LINNAEUS, 1753, AND THEIR SUBSEQUENT CLASSIFICATION.

1. *G. apios*	=	*Apios*
2. *G. frutescens*	=	*Wisteria*
3. *G. abrus*	=	*Abrus*
4. *G. tomentosa*	=	*Rhynchosia*
5. *G. comosa*	=	*Amphicarpa*
6. *G. javanica*		
7. *G. bracteata*	=	*Amphicarpa*
8. *G. bituminosa*	=	*Fagelia*

had the soybean in mind when he described *Dolichos soja,* but, although *Phaseolus max* was based on actual specimens of the soybean, Linnaeus apparently intended the name to apply to the mung bean of India (Piper, 1914; Piper and Morse, 1923). It was not until several years later that he obtained seed of *Dolichos soja* and grew the plants at Uppsala; he was only then able to see that *Phaseolus max* and *Dolichos soja* were one and the same plant, and that the mung bean was still without a name. Thus in the *Mantissa Plantarum* published in 1767, Linnaeus described the mung bean for the first time under *Phaseolus mungo.*

Until the time of De Candolle's *Prodromus* in 1825 the genera *Glycine* and *Dolichos* became, in Bentham's words, "receptacles for all Phaseoleae which had no very striking character to distinguish them" (Bentham, 1865). This proliferation of species both before and after De Candolle has led to a total of 286 species of *Glycine* as listed in *Index Kewensis,* with additional subspecies and varieties bringing the number to 323.

The first arrangement of *Glycine* that most closely approximates the modern one was that published by Bentham (1864, 1865) (Table 2). At this time 6 wild

TABLE 2. THE GENUS *Glycine* L. ACCORDING TO BENTHAM (1864, 1865).

Section *Leptocyamus*		
1. *G. falcata*		
2. *G. clandestina*		
G. clandestina var. *sericea*		
3. *G. latrobeana*		
4. *G. tabacina*		
G. tabacina var. *latifolia*		
G. tabacina var. *uncinata*		
5. *G. sericea*		
6. *G. tomentosa*		
Section *Johnia*		
7. *G. javanica*		
Section *Soja*		
8. *G. soja* (cultivated)		
9. *G. hedysaroides*	=	*Ophrestia*
10. *G. pentaphylla*	=	*Ophrestia*
11. *G. Lyalli*	=	*Ophrestia*

TABLE 3. THE GENUS *Glycine* L. ACCORDING TO HERMANN (1962).

	Subgenus *Leptocyamus*
1.	*G. clandestina*
	G. clandestina var. *sericea*
2.	*G. falcata*
3.	*G. latrobeana*
4.	*G. canescens* (previously *G. sericea*)
5.	*G. tabacina*
6.	*G. tomentella* (previously *G. tomentosa*)
	Subgenus *Glycine*
7.	*G. petitiana*
8.	*G. javanica*
	Subgenus *Soja*
9.	*G. ussuriensis*
10.	*G. max* (cultivated)

Australian species were recognized in the section *Leptocyamus*; *G. javanica* was the sole remaining Linnaean species; and the cultivated soybean was listed as *G. soja*. Bentham's *G. falcata* was the last true *Glycine* to be described, as since that date all proposed species have been either synonymous or not congeneric with already named species.

In 1962, Hermann of the U.S.D.A. Agricultural Research Service undertook a revision of the genus *Glycine* and its allies (Table 3). In doing so he performed the useful task of bringing together the pertinent literature on *Glycine* nomenclature, and also of listing all those species that had been published as *Glycine* at one time or another but later excluded from the genus. Bentham's arrangement of *Glycine* species into 3 sections remained essentially the same, although Hermann found that name changes had to be made because of earlier homonyms. Thus *G. sericea* became *G. canescens, G. tomentosa* became *G. tomentella,* and variety *latifolia* of *G. tabacina* was no longer considered distinct. The wild counterpart of the soybean was included in the subgenus *Soja,* described as *G. ussuriensis* by Regel and Maack in 1861. After considerable debate the combination *Glycine max* proposed by Merrill in 1917 became accepted as the valid designation for the cultivated soybean.

The next revision came in 1966 when Verdcourt chanced to examine Linnaeus' specimen of *Glycine javanica* during the preparation of the *Flora of Tropical East Africa*. He discovered that the type specimen was not a *Glycine* at all, but in fact a *Pueraria* with an abnormal inflorescence. In order to avoid changes in nomenclature in genera that included several agriculturally important legumes, including the soybean, Verdcourt proposed that the name *Glycine* be conserved from a later author, and that *Glycine clandestina* should become the type species. All those plant populations previously regarded as *G. javanica* were thus without a name, and these Verdcourt called *G. wightii* (Table 4). Subgenus names were revised, and at this point the last Linnaean *Glycine* was removed from the genus. In 1970, Verdcourt also proposed that *G. soja* was the valid designation for the wild soybean, since it was described in 1846 by Siebold and Zuccarini as a new species and not one based on Linnaeus' *Dolichos soja* as previously thought.

TABLE 4. THE GENUS *Glycine* WILLD. AS REVISED BY VERDCOURT (1966, 1970).

Subgenus *Glycine*
1. *G. clandestina*
G. clandestina var. *sericea*
2. *G. falcata*
3. *G. latrobeana*
4. *G. canescens*
5. *G. tabacina*
6. *G. tomentella*
Subgenus *Bracteata*
7. *G. wightii* (previously *G. javanica*) = *Neonotonia*
Subgenus *Soja*
8. *G. soja* (previously *G. ussuriensis*)
9. *G. max*

Glycine soja therefore predates the *G. ussuriensis* of 1861 which had commonly been in use for the wild soybean (Verdcourt, 1970).

Cytological studies by Pritchard and Wutoh in 1964 showed that the *G. wightii* group had chromosome numbers of $2n = 22$ or $2n = 44$, while all remaining members of the genus were $2n = 40$ or $2n = 80$. There was also a difference in chromosome size, *G. wightii* having larger chromosomes. This caused some doubt as to whether *G. wightii* should be included in the genus at all, and the question was taken up by Lackey in his recent revised classification of the tribe Phaseoleae (Lackey, 1977a). Morphological characteristics, geographic distribution, seed protein electrophoretic banding patterns, presence of the free amino acid canavanine in the seeds, and production of isoflavone derivatives after fungal inoculation rather than pterocarpan derivatives all serve to separate *G. wightii* from the other 2 subgenera (Ingham et al., 1977; Lackey, 1977a,b; Mies and Hymowitz, 1973). Lackey has therefore removed *G. wightii* from the genus *Glycine* alto-

TABLE 5. THE GENUS *Glycine* WILLD. AS CURRENTLY DELIMITED.

Species	$2n$	Distribution
Subgenus *Glycine*		
1. *G. clandestina* Wendl.	40	Australia
1a. var. *sericea* Benth.	—	Australia
2. *G. falcata* Benth.	40	Australia
3. *G. latifolia* (Benth.) Newell & Hymowitz	40	Australia
4. *G. latrobeana* (Meissn.) Benth.	40	Australia
5. *G. canescens* F. J. Herm.	40	Australia
6. *G. tabacina* (Labill.) Benth.	40, 80	Australia; south China; Taiwan; Ryukyu Is., South Pacific Islands
7. *G. tomentella* Hayata	38, 40, 78, 80	Australia; south China; Taiwan; Philippines; Papua New Guinea
Subgenus *Soja* (Moench) F. J. Herm.		
8 *G. soja* Sieb. & Zucc.	40	China; Taiwan; Japan; Korea; USSR
9. *G. max* (L.) Merr.	40	Cultigen

gether. Since there was no earlier valid generic name to accept the transfer, he proposed the new designation *Neonotonia wightii* (Lackey, 1977c).

The genus *Glycine* now consists of 2 subgenera, *Glycine* and *Soja* (Table 5). A seventh species has been added to the subgenus *Glycine*, *G. latifolia*. Under Bentham's description of *G. tabacina* in the *Flora Australiensis* of 1864 he listed the variety *latifolia*, originally described by him as a separate species but then relegated to varietal level under *G. tabacina*. Morphological, cytological and seed protein electrophoretic data, as well as limited data from hybridization studies, suggested that this former variety deserved specific rank, as it was quite distinct from both *G. tabacina* and *G. tomentella*, the 2 species with which it was usually confused (Newell and Hymowitz, 1980).

All 5 diploid species in the subgenus *Glycine* are restricted in distribution to Australia; the tetraploid races of *G. tabacina* and *G. tomentella* spread north to south China, Taiwan and the Ryukyu Islands, and east as far as Tonga in the South Pacific (Newell and Hymowitz, 1978). The wild soybean, *G. soja*, continues north from Taiwan into Japan, Korea, China and the U.S.S.R.

DOMESTICATION

According to Chinese tradition, Emperor Shen Nung, having a body of a man and the head of an ox, was Father of Agriculture and Medicine. The legend fosters the belief that before Shen Nung, the Chinese were nomadic food-gathering people. With the arrival of Shen Nung the Chinese became sedentary, food-producing agriculturists. Supposedly Shen Nung taught his subjects how to use the plow and sow grain; he kept his people healthy by prescribing for their ailments native herbs that had medicinal value (Bretschneider, 1881/1882; Chang, 1965; Cheng, 1960; Lee, 1921; Watson, 1966). Numerous publication dates, from 2300–2800 B.C., have been acclaimed for the herbal *Shen nung pen ts'ao* which contains a reference to the medicinal value of the soybean (Chang, 1965; Dyer Ball, 1904; Hirth, 1908; McKie and Anderson, 1967; Old, 1904). Contemporary sinologists believe that the herbal of Emperor Shen Nung is a complete fabrication of Han historians as is the emperor himself (Bretschneider, 1894/1895; Hirth, 1908; Keng, 1974; Triestman, 1968).

The earliest identified Neolithic tradition in China is called the Yang-shao Culture. It was centered about the middle course of the Huangho River in Henan, Shaanxi, and Shanxi. Radiocarbon dates indicate that the culture flourished from 5000–3200 B.C. A second Neolithic culture, the Lung-shan, flourished from 2500–1850 B.C. in east and north China. Between the Yang-shao and Lung-shan periods is a sequence of cultures collectively known as the Lungshanoid cultures (Chang, 1968, 1977). Thus far no soybeans have been found in any Neolithic site in China (Ho, 1969).

Current evidence for the antiquity of the soybean lies in the pictographic analysis of the archaic Chinese word for the soybean, the *Book of Odes*, and bronze inscriptions.

Analysis of the development of the archaic character for soybean (*shu*) reflects the observation and knowledge of the ancient Chinese at a given period. The character shu (Fig. 1) pictographically depicts the following concept: (1) the horizontal line in the middle symbolizes earth; (2) the upper and lower parts represent the stem and root respectively; and (3) around the root the 3 tear-drop-like lines

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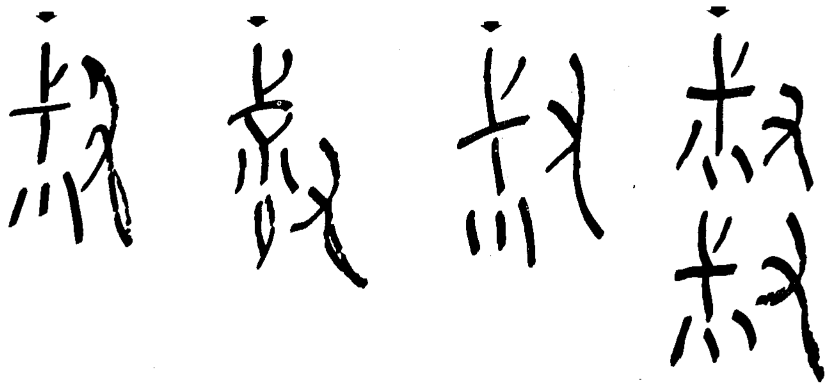

Fig. 1. *Shu*, the archaic Chinese character for soybeans.

illustrate the nodules. Hu (1963) believes that the shu pictograph can be traced back to approximately the 11th century B.C.

The *Book of Odes* spans the period from the 11th century to the 7th century B.C. during the reign of the royal house of Chou. The geographic area covered by the *Book of Odes* is essentially the winter wheat-kaoliang and winter wheat-millet regions of north China with some overlapping into the rice areas of the Yangtze Valley. The 305 odes in the book were divided by Dobson (1966) into 4 time periods: 11th–10th century B.C., 10th–9th century B.C., 9th–8th century B.C. and 8th–7th century B.C. The character shu appears in 6 odes covering all the time periods (Karlgren, 1944, 1945). In addition, the character shu was found in bronze inscriptions dating approximately from the 10th to the 9th century B.C. (Karlgren, 1940). Lastly, the first precise recorded date for soybeans is 644 B.C. when the Shan-Jung tribe paid a soybean tribute to the Royal House of Chou (Ho, 1975).

All of the above lines of evidence point to the emergence of the soybean as a domesticate during the Chou Dynasty. However, domestication is a trial and error process and not an event. This process for soybeans probably took place during the Shang Dynasty (ca. 1700–1100 B.C.) or earlier (Hymowitz, 1970).

The primary soybean germ plasm pool or, in Vavilov's (1951) terminology, the primary gene center is China. Surely the soybean reached northeast, central and south China as well as peninsular Korea (Kwon, 1972; Lo, 1961) by the first century A.D. The movement of the soybean within the primary gene center is associated with the development, consolidation of territories and degeneration of Chinese dynasties.

From the first century A.D. to the Age of Discovery (15th–16th century), soybeans were introduced and land races were established in Japan (Hymowitz and Kaizuma, 1979), southeast Asia and southcentral Asia. These regions comprise the secondary gene center for soybeans. The movement of the soybean during this period of time was based upon the establishment of sea and land trading routes, for example, the silk road (Boulnois, 1966); the emigration of certain tribes from China, for example the Thais (Prince Dhaninavat, 1961); and the rapid acceptance of the soybean as a staple food by certain cultures, for example, the Indonesians.

The soybean reached the West quite late. It must have reached the Netherlands before 1737 as Linnaeus described the soybean in the *Hortus Cliffortianus* which was based on plants cultivated in the garden at Hartecamp (Linnaeus, 1737b). In 1739, soybean seeds sent by missionaries in China were planted in Jardin des Plantes, Paris (Paillieux, 1880), and in 1790, soybeans were planted at the Royal Botanic Gardens at Kew, England (Aiton, 1812). The earliest report seen on the introduction of soybeans into South America was published in 1882 (Da Silva Junior, 1882).

The first mention of the soybean in the United States literature is by Dr. James Mease in 1804 who wrote "The soybean bears the climate of Pennsylvania very well. The bean ought therefore to be cultivated" (Mease, 1804). Dr. Mease served for many years as the secretary and then vice president of the Philadelphia Society for Promoting Agriculture. The agricultural society was established in Philadelphia in 1785 (Anon., 1808). The soybeans referred to by Dr. Mease probably were sent to Philadelphia by the Honorable Benjamin Franklin, the United States Ambassador to France. Franklin's letters clearly point out that he befriended Compte du Buffon, the director of the Jardin des Plantes, and arranged for seed exchanges between the 2 countries (Hays, 1908).

USES

For centuries the soybean has been the cornerstone of east Asian nutrition and cuisine. Although many different foods were developed from the soybean, the 4 most important are *miso, shoyu* (soy sauce), *tempeh* and *tofu*. These traditional foods have little physical or flavor identity with the original bean. Hence it is not too surprising that Marco Polo, who travelled from Venice to Cathay and throughout the Orient between 1271 and 1295, makes no mention of the soybean (Rugoff, 1961).

The earliest accurate European's description seen for the use of soybeans as a food was by Friar Domingo Navarrete (Cummins, 1962). In 1665, he wrote the following in his tractate:

> Before I proceed to the next Chapter, because I forgot it in my first Book, I will here briefly mention the most usual, common and cheap sort of Food all China abounds in, and which all Men in that Empire eat, from the Emperor to the meanest Chinese, . . . It is call'd Teu Fu, that is Paste of Kidney Beans. I did not see how they made it. They drew the Milk out of the Kidney-Beans, and turning it, make great Cakes of it like Cheeses . . . All the Mass is as white as the very Snow . . . It is eaten raw, but generally boil'd and dress'd with Herbs, Fish, and other things. Alone it is insipid, but very good dress'd as I say and excellent fry'd in Butter. They have it also dry'd and smok'd, and mixed with Caraway-seeds, which is best of all. It is incredible what vast quantities of it are consum'd in China, and very hard to conceive there should be such abundance of Kidney-Beans. That Chinese who has Teu Fu, Herbs and Rice, needs no other Sustenance to work . . . Teu Fu is one of the most remarkable things in China, there are many will leave Pullets for it. If I am not deceiv'd, the Chinese of Manila make it, but no European eats it, which is perhaps because they have not tasted it . . . .

However, it was not until 1712, when Engelbert Kaempfer, who lived in Japan from 1690 to 1692 as a medical officer of the Dutch East India Company, published his book *Amoenitatum Exoticum* that the western world fully understood the connection between the cultivation of soybeans and its utilization as a food plant. Kaempfer's drawing of the soybean (Fig. 2) is accurate and his detailed description of how to make soy sauce is correct.

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Fig. 2. Engelbert Kaempfer's drawing of the soybean.

In the West, uses of the soybean for food have followed a different pattern than in east Asia. The 2 main products of soybean are oil and protein-containing defatted meal. Soybean cultivars currently grown in the United States contain 20–23% oil and 39–45% protein (Wilcox, 1970). A large portion of the oil is converted to margarine, shortening, mayonnaise, salad oils and dressings. Most of the soybean meal is used as a source of high protein in animal feeds for the production of pork, beef, poultry, milk, butter and eggs. Recent developments in the utilization of soybean protein in the form of flour, concentrates and isolates offers a Western view to man's protein needs in a world with a rapidly growing population (Wolf and Cowen, 1971). On a protein cost-per-kilogram basis, the soybean is today the cheapest source of dietary protein (Judd, 1970).

It is beyond the scope of this paper to provide detailed descriptions of how each of the dozens of east Asian soybean foods are prepared. Numerous books already have been published on the subject (Chen, 1962; Shurtleff and Aoyagi, 1975, 1976, 1979). Nor is it possible for us to provide detailed flow diagrams of how soybeans are processed into oil and meal and then converted into hundreds of dietary or industrial products. However, we will discuss the principles underlying the development of the various soybean products and wherever possible provide a geographic and historic time frame in the evolution of these products.

EAST ASIAN NONFERMENTED SOY FOODS

Tofu

Tofu is the most important of the nonfermented soybean foods in east Asia. It forms the foundation of the Japanese diet in much the same manner as meat, dairy and egg products are used in the dietary patterns of the West. The traditional tofu is a highly hydrated gelatinous product containing about 88% water and 8% protein, and resembling cottage cheese. With a digestion rate of 95%, tofu is by far the most digestible of all natural soybean foods (Shurtleff and Aoyagi, 1975).

Tofu is made by curdling a heated extract of soy milk with various salts (Smith and Circle, 1972). It is prepared daily and consumed as a fresh product. In 1613, Captain John Saris visited Japan. In his log he wrote the following about the food habits of the Japanese: ". . . of cheese they have plentie. Butter they make none, neither will they eate any milke . . . ." Obviously Captain Saris mistook tofu for cheese (Satow, 1900).

According to popular tradition tofu was discovered by Prince Liu An of Huainan about 164 B.C. According to Shinoda (1971), from the 4th–7th centuries A.D. nomadic tribes from northcentral Asia migrated to central China. Unlike the Chinese, the nomads drank animal milk (Laufer, 1914/1915) and brought with them the technology of how to make cheese. The Chinese adapted the cheese-making technology to the soybean for the production of soy milk and tofu-like products. Thus, by the time of the Sung dynasty (960–1127 A.D.) tofu became a common food of the lower classes and during the Ming dynasty (1368–1662 A.D.) tofu was accepted as a food by upperclass families. Most probably tofu was introduced into Japan around the 12th century by Buddhist monks who proselytized the virtues of a vegetarian diet.

In Japan, tofu traditionally was made in small household shops. However, in recent years mass production and mass distribution has replaced the small family shop. Today in the United States tofu can be found in the vegetable section of many supermarkets. It is usually sold in water-packed polyethylene containers.

There are many different varieties of tofu in the Japanese, Chinese and Korean cuisine. For example, kori-tofu is a dried tofu, aburage is a fried tofu and doufukan is a pressed tofu. Each province or region makes its own varieties and has its own names. Tofu can be made into dressings, sauces, dips and spreads. It can be added to salads and soups. Tofu can be combined with grains and boiled, fried, grilled, baked or sauteed.

Soy milk

The discovery of soy milk, like tofu, has been ascribed to Prince Liu An of Huai-nan. In general east Asians do not drink animal milk despite an abundance of milk-producing animals such as cows, buffaloes and goats (Laufer, 1914/1915). Instead, east Asians use soy milk in the same way that cows' milk is now used in the West.

Soy milk is an aqueous extract of whole soybeans. Nutritionally soy milk compares very favorably with cows' and mothers' milk (Chang and Murray, 1949; Shurtleff and Aoyagi, 1975).

In Hong Kong and Singapore soy milk is being marketed like bottled soft drinks in the United States. In Japan, traditionally, soy milk was sold by the family-owned tofu shops. Today, in Japan as well as in Thailand, Indonesia, and the Philippines, soy milk is made in modern soy milk factories and mass distributed in conventional milk-type cartons.

In the West, soy milk is used primarily in formulas for infants allergic to cows' milk, infants with galactosemia and infants intolerant of lactose. The soy milk-based formulas are fortified with minerals and vitamins and the fat content adjusted to either mothers' or cows' milk (Rackis, 1979; Shih, 1970).

Yuba

Yuba is a protein film that forms on the surface of soybean milk when heated to near boiling in a shallow vat. Yuba contains about 52% of high quality protein. It is commonly sold in single circular sheets in 3 different states: as fresh yuba, half-dried yuba and dried yuba.

The art of making yuba originated in China and was transmitted to Japan about 1,000 yr ago. In Japan, most of the yuba produced is dried yuba and is considered a gourmet food. It is used in salads, soups and sauces or as an hors d'oeuvre. Yuba production is centered about the ancient capital of Kyoto and is sold in yuba shops run by a single family. In China and Taiwan about 90% of all yuba made is sold fresh. It is a popular, cheap, soy food used in imitation meat dishes (Shurtleff and Aoyagi, 1975).

Kinako

This product is made by dry-roasting soybeans, dehulling, and grinding into a flour. *Kinako* has a nutty flavor and fragrance. In Japan, it is used as a cake base, and confections are often dusted with a light coating of sweetened kinako (Shurtleff and Aoyagi, 1975).

Sprouts

Sprouts from soybeans and several other legume species such as mung beans (*Vigna radiata* (L.) Wilczek) are produced by germinating the seed in the dark. The sprouts are high in vitamin C and free amino acids. They usually are consumed as a fresh vegetable (Hofsten, 1979; Morse and Cartter, 1952; Smith and Circle, 1972).

Green soybeans

Green immature soybeans are known as *edamame* in Japan (Shurtleff and Aoyagi, 1975). They are an excellent source of protein, vitamins and minerals especially calcium, phosphorus, magnesium and iron. The green beans simmered in the pod until tender, shelled, salted, and cooled are served as an hors d'oeuvre, excellent in cold salads, and served with meat or fish dishes (Morse and Cartter, 1952; Rasmussen, 1978; Van Duyne, 1950).

EAST ASIAN FERMENTED SOY FOODS

Miso

Miso essentially is an all-purpose, fermented, soybean-protein seasoning that can be used like a bouillon or meat stock in the preparation of soups and stews, in sauces, dips and dressings, or as a gravy base. There are a number of basic types of miso, the most common types being soy-rice, soy-barley and soy alone. The protein content of miso ranges from 13.5–21% depending on the type produced. About 80% of the miso produced today is the soy-rice type (Shurtleff and Aoyagi, 1976).

Miso is made by cooking soybeans, blending with *koji* (steamed rice covered with a growth of *Aspergillus oryzae*), salt, water and inoculating with a yeast. The mixture is then fermented for several months to a smooth peanut-butter consistency (Fukushima, 1979; Hesseltine and Wang, 1972; Shurtleff and Aoyagi, 1976). The Florentine Francesco Carletti, who visited Nagasaki, Japan, in 1597, was a keen observer of Japanese cuisine. He wrote in his memoirs:

> They prepare various sorts of dishes from fish, which they flavor with a certain sauce of their's which they call *misol*. It is made of a sort of bean that abounds in various localities, and which cooked and mashed and mixed with a little of that rice from which they made the wine already mentioned, and then left to stand as packed in a tub—turns sour and all but decays, taking on a very sharp, piquant flavor. Using this a little at a time, they give flavor to their foods . . . (Carletti, 1964).

Most probably miso is derived from the Chinese food called *chiang* (Fukushima, 1979). Chiang originally was developed as a way of preserving protein-rich fish, shellfish, and game. Chiang was completely different from modern miso in that it contained no soybeans, grain or koji. The substitution of soybeans for meat and fish as a basic protein source probably took place between the 2nd century B.C. and the 4th century A.D. (Shurtleff and Aoyagi, 1976) and is first described in the Chinese encyclopedia of agriculture—*Ch'i Min Yao Shu*—which was written from 533–544 A.D. (Shih, 1962).

The earliest mention of the soybean in Japan occurs in the *Ko-Ji-Ki* (712 A.D.). According to the myth, soybeans were born in the body of the slain Princess-of-Great-Food (Chamberlain, 1906). However no mention is made of miso. The earliest Japanese publication mentioning miso was the *Todajii Shosoin Monjo* which was published from 730–748 A.D. (Shurtleff and Aoyagi, 1976).

Soy sauce

In the West, soy sauce is the best known east Asian soy product. It is used primarily as a flavoring agent. Soy sauce is known as *shoyu* in Japanese, *chiang-yu* (liquid pressed from chiang) in Chinese, and *tayo* in the Philippines.

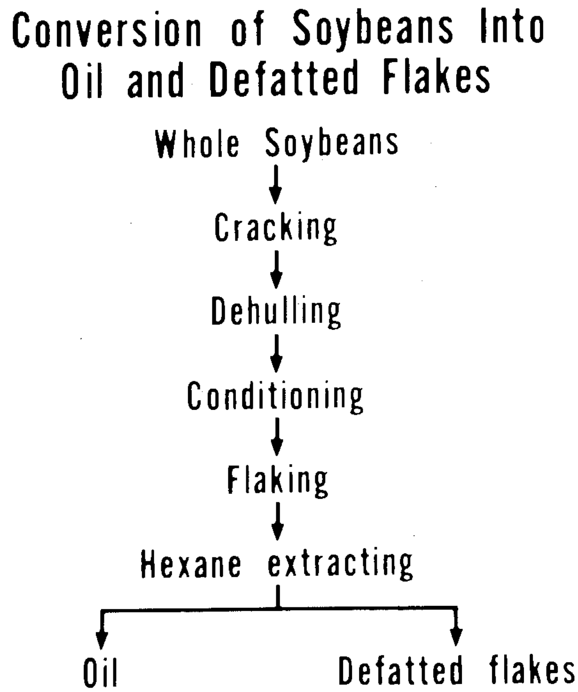

Fig. 3. General outline of the process for producing crude oil and defatted meal from soybeans. (Photo courtesy of W. Wolf, N. Regional Research Center, U.S.D.A., Peoria, IL.)

Cooked, defatted, soybean flakes are mixed with wheat flour and inoculated with *Aspergillus oryzae*. After the mold grows for 2–3 days, salt solution is added and the fermentation process proceeds for 8–12 mo. The liquid portion then is separated from the insoluble residue, and processed for edible uses. In east Asia soy sauce is a fermented soy product whereas in the United States it is mass-produced by acid hydrolysis. The acid-hydrolysis-produced soy sauce does not possess the same flavor or odor as fermented soy sauce. Today, in the United States soy sauce is found on the shelves of most supermarkets in the condiment or Oriental food sections (Fukushima, 1979; Hesseltine and Wang, 1972; Wolf and Cowen, 1971).

Like miso, soy sauce most probably is derived from the Chinese food called chiang. However in Japan soy sauce or shoyu emerged as a separate food product much later than miso. The word shoyu first appeared in a Japanese dictionary *Ekirin Bonetsu Yoshu* published in 1597 but is thought to have been written sometime between 1469 and 1503 (Shurtleff and Aoyagi, 1976).

In the 17th century, soy sauce was a common item of trade from the East to the West (Dampier, 1906; King, 1858; Ovington, 1929). By 1705, European pharmacologists were familiar with the soybean from Japan and the culinary value of soy sauce (Dale, 1705).

Tempeh

Tempeh is a popular Indonesian fermented food consisting of soybeans or other legumes and cereals bound together by a dense cottony mycelium of *Rhizopus* mold. To make soybean tempeh, the soybeans are soaked overnight, dehulled, cooked, and mixed with a previous batch of tempeh. After incubating for 24–48 hr, *Rhizopus oligosporus* organisms grow and bind the soybeans together into a cake-like mass. The raw product is sliced and then fried. Fresh soybean tempeh contains about 20% protein. Soybean tempeh serves as a main dish rather than as a flavoring or seasoning like miso or soy sauce. In addition, tempeh can be used to make dressings or spreads, can be used in salads, soups or added to casseroles. Tempeh also is popular in the Netherlands, Malaysia, Singapore, Surinam, and other areas where Indonesians have emigrated. Tempeh is made fresh daily and sold in family-run shops (Hesseltine and Wang, 1972; Iljas et al., 1973; Shurtleff and Aoyagi, 1979).

It is generally believed that tempeh originated in central and east Java; however no written records have been found providing evidence for the origin or early history of the food. The first written record of soybeans in Indonesia is by Rumphius (1750) who reported that they were being used in Java both for food and as a green manure.

SOY USES IN THE WEST

In the West soybeans are converted into 2 primary products—crude oil and the protein-rich defatted meal. A general outline of the process for producing crude oil and defatted meal is shown in Fig. 3.

Oil

The crude oil is first degummed. This process removes the phosphatide fraction from the oil. The resulting phosphatide fraction is known as soybean lecithin, which is used as an emulsifying agent in bakery and candy products, as a surface active agent in beverage powders and chocolate coatings, as an antispattering agent in margarine, as a stabilizing agent in shortening, and as a pan grease. Lecithin also is used as a dispersing agent in paints, inks and insecticides and as a wetting agent in cosmetics, paints, powdered metals, textiles, and chemicals (Scott and Aldrich, 1970; Wolf and Cowen, 1971). Recently lecithin has been recommended for treatment of a serious disorder known as tardive dyskinesia (Kolata, 1979).

After degumming, the oil is refined, bleached, deodorized, and hydrogenated for use in edible oil products such as margarine, shortening, mayonnaise, salad oils, salad dressings, cooking oils, mellorine, medicinals, and pharmaceuticals. A small percentage of soybean oil is used in the manufacture of putty, soap, printing inks, protective coatings, electrical insulation, insecticides, waterproof cement, plasticizers, and wallboard (Cowen, 1973; Scott and Aldrich, 1970; Wolf and Cowen, 1971).

Protein

The defatted soybean meal, after processing in a toaster to improve its nutritional value, is ground to a desired size in a mill. Two main types of meal are sold: soybean meal (44% protein) and dehulled soybean meal (49% protein). About 95% of the soybean meal is used in livestock and poultry feeds, and pet foods. Except for the sulfur-bearing amino acids methionine and cystine, soybean meal has a high content of essential amino acids. Cereal grains, on the other hand, which generally have high sulfur-amino-acid contents, are low in lysine and tryptophan. Hence soybean meal complements cereal grains in the formulation of nutritionally balanced animal feeds or human foods (Cowen, 1973).

Steadily increasing costs of animal proteins have forced the food industry to look to the soybean as an alternative source of low cost protein. Edible soy protein products for human consumption are manufactured under stricter sanitation practices than are animal feeds. Three general categories of food products are produced from defatted soybeans, based on the protein content: soy flours and grits (minimum 50% protein), soy protein concentrates (minimum 70% protein), and isolated soy proteins (minimum 90% protein). Within each general category there are a number of product types with different physical, chemical, and functional properties such as emulsion formation, emulsion stabilization, fat absorption, water absorption, texture, film formation, color control, and aeration (Kinsella, 1979; Martinez, 1979; Waggle and Kolar, 1979; Wolf and Cowen, 1971).

All soy flours and grits are made from dehulled, defatted soybean meal. Most of the soy flours are ground to 200 mesh. Grits are obtained by coarse grinding and screening to obtain specific particle size. Soy flours and grits are used as a bakery ingredient in breads, cookies, crackers and doughnuts; in noodles; in meat products such as sausages and meat patties; in ready-to-eat breakfast foods; in prepared pancake, waffle and cake mixes; in baby foods; in confections, and in specific diets such as 900-calorie-type drinks (Hoover, 1979; Scott and Aldrich, 1970; Smith and Circle, 1972; Wolf and Cowen, 1971).

A food supplement called CSM, consisting of 63.8% processed corn meal, 24.2% toasted defatted soy flour, 5% dried milk, 5% soybean oil and 2% vitamin-mineral mix was developed in the United States to provide a level of all the essential nutrients sufficient to render adequate the total diet of a preschool child if consumed at a level to supply 25% of the energy needs. The United States government purchases CSM for overseas distribution in certain countries. CSM may be served in the form of a gruel or porridge for school children and infants (Liener, 1972). In addition, soy flours can be textured to produce a wide variety of products with differing sizes, shapes, colors, and flavors for use in imitation meat, fruit, and confection products (Cowen, 1973; Link, 1976; Smith and Circle, 1972).

Soy protein concentrates containing about 70% protein can be produced by removing most of the nonnitrogenous constituents from soybean flour by extraction with ethyl alcohol, dilute acid, or with water, following denaturation with heat. The product has functional properties which make it suitable for use in a variety of food products such as breads, cereals, dietary wafers and comminuted meat products (Cowen, 1973; Smith and Circle, 1972; Wolf and Cowen, 1971).

Isolated soy proteins are processed one step further than the concentrates by removing the water-insoluble polysaccharides, water soluble sugars and other minor constituents. Soy isolates are used extensively as binders in the coating of paper to improve its gloss or strength and as adhesives in paper products. Among the food uses, soy protein isolate is used in certain comminuted meat products. For example, isolate soy protein in frankfurters serves to emulsify the fat and water so that they separate much less readily on storage at low temperatures. Isolate soy proteins also are used in luncheon loaves, soup mixes, whipped toppings, poultry products and in simulated meat products (Cowen, 1973; Smith and Circle, 1972; Wolf and Cowen, 1971).

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