

History of Tempeh

A Special Report on The History of Traditional Fermented Soyfoods

**A Chapter from the Unpublished Manuscript,
*History of Soybeans and Soyfoods: 1100 B.C. to the 1980s***

by

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Tempeh (pronounced TEM-pay) is an Indonesian word referring collectively to a variety of fermented foods (typically tender-cooked legumes) bound together by a dense mycelium of fragrant white *Rhizopus* mold into compact cakes (Ko and Hesseltine 1979). The most popular of these is soy tempeh, and hereafter we will use the term "tempeh" to refer to soy tempeh, unless otherwise noted. In the West tempeh is usually sold in cakes 6 by 8 by 3/4 inch thick (15 x 20 x 2 cm). These are sliced then served fried, baked, or steamed. When fried, tempeh's flavor and texture are meaty, resembling those of southern fried chicken or fish sticks. Before cooking, soy tempeh contains 19.5% protein, compared with 17.9% for hamburger and 21% for chicken, on average.

To make tempeh, cooked and dehulled soybean cotyledons (which may be lightly acidified with a traditional lactic acid prefermentation or, nowadays, with lactic acid or vinegar) are well drained then inoculated with spores of *Rhizopus oligosporus* mold, packed into perforated containers (polyethylene bags or banana leaves, holding about 8 ounces) and incubated at 30-31°C (86-88°F) for about 24 hours, until the beans are bound together tightly by the mycelium. The tempeh is then ready to sell or to cook.

Tempeh is unique among major traditional soyfoods in that it is the only one that did not originate in China or Japan. It originated in today's Indonesia, almost certainly in Central or East Java, almost certainly prior to 1800, and perhaps as long ago as a thousand years or more. Tempeh is also distinctive in that less is known about its origins and early history than about those of any other soyfood.

Etymology . In Indonesia, traditionally and in dictionaries since at least 1875, the name for this food was written *témpé* , with various accents being used, especially to indicate the *ay* pronunciation of the final letter "e." Soy tempeh was called *témpé kedelé* . In August 1972, when Indonesia modernized its language as part of an Indonesian-Malaysian effort to make the two similar languages even more similar, the accents were dropped and the word came to be spelled *tempe* (still pronounced TEM-pay).

In English and other European languages, the word has come to be spelled "tempeh," the final "h" being added to prevent the word from being pronounced "temp." Most Westerners feel that the correct pronunciation is more important than the correct spelling. The first Westerner to use the spelling *tempeh* was the Dutchman H.C Prinsen Geerligs in an 1896 German article about soyfoods. But other early Western authors (especially the Dutch) wrote the word as *témpé* (Gericke and Roorda 1875; Heyne 1913), *tempé* (Boorsma 1900; Stahel 1946), or *tèmpé* (Vorderman 1902). The earliest English language references to this food, both translations of Dutch publications (Ochse 1931, Burkill 1935), referred to it as *témpé* . Van Veen and Schaefer (1950) were the first to spell it *tempeh* in an English language article. The new spelling quickly caught on. Steinkraus et al. (1960) were the first in the US to spell it *tempeh* . Since the early 1960s, the word has consistently been spelled this way in European languages, except in a few Dutch and English language articles written by Indonesians.

In Japanese, Nakazawa (1928) first wrote the word in Roman letters as tempeh. Nakano (1959) wrote *temupe* , in katakana. Ohta et al. in 1964 started writing it as *tenpe* , which thereafter became the standard katakana form, although a few reports have written it as *tenpei* .

World Overview . Tempeh probably originated several centuries ago on the island of Java, in today's Indonesia. The earliest known reference there was in 1875. Much early research and publication was done by Dutch scientists, in Dutch. Tempeh was first produced commercially in Europe sometime between 1946 and 1959 and by 1984 there were 18 tempeh companies in Europe. The earliest known reference to tempeh in the United States was by Stahel in 1946. Extensive research work on tempeh began in the early 1960s at Cornell University (under Dr. Steinkraus) and at the USDA Northern Regional Research Center (under Dr. C.W. Hesseltine and Dr. H.L. Wang). America's first commercial tempeh was produced in 1961 by Indonesian immigrants, and the first commercial production by a Caucasian started in 1975. The number of tempeh companies in America increased from 13 in 1979 to 53 in 1984. The earliest known reference to tempeh in Japan was by Nakazawa in 1928. Starting in 1983, with the soymilk boom in full swing, Japanese food companies started to make tempeh in large quantities. By early 1984 the world's largest tempeh companies were:

Company Name	Country	Year Started	Avg. Weekly Production	
			lb/week	kg/week
1. Marusan-Ai	Japan	1983	15,148	6,885
2. Tempe Production Inc.	Netherlands	1969	13,200	6,000
3. Quong Hop/Pacific Tempeh	USA/CA	1980	7,000	3,182
4. White Wave	USA/CO	1979	5,850	2,659
5. Soyfoods Unlimited	USA/CA	1981	5,800	2,636
6. Torigoe Flour Milling	Japan	1983	5,770	2,623
7. The Tempeh Works	USA/MA	1979	5,500	2,500
8. Marukin Foods	Japan	1983	4,620	2,100

HISTORY OF TEMPEH IN INDONESIA

Early History (pre 1875) . Tempeh probably originated on the island of Java at least several centuries ago. At that time the people of Java, without formal training in microbiology or chemistry, developed a remarkable family of fermented foods called tempeh. Today we might call these products meat analogs, since they have much the same texture, flavor, and high protein content as various flesh foods. The people also learned to make tempeh from oilseed presscakes (the protein-rich cakes left after pressing the oil from oilseeds such as peanuts or coconuts), okara (the soy pulp remaining after making soymilk or tofu), and other agricultural wastes, whose high fiber content and relative indigestibility make them otherwise suited only for livestock feeds (Steinkraus 1983).

Since ancient times the Malay language has been the lingua franca of the archipelago that includes today's Malaysia and Indonesia. The people of Java have had a written language since antiquity, with existing stone inscriptions dating from the seventh century A.D. This early literature concerned primarily religion, philosophy, and culture, with very little information about food.

The world's earliest known reference to tempeh appeared in the *Serat Centini* , which was probably written around A.D. 1815 on the orders of Sunan Sugih, then Crown Prince and later Pakubuwana V of Surakarta, in today's eastern Central Java. The main author was probably Ranga Sutrasna. This classic work of Modern Javanese literature contains a line mentioning "onions and uncooked *témpé* ."

Although the *Serat Centini* was written in about 1815, it is quite possibly based on much older sources; the story is set in the reign of Sultan Agung (1613-45), and the descriptions purport to be of that time. Thus tempeh may well have existed in the early 1600s. However the actual document in which this reference appears (Codex Orientalis 1814 of the Leiden University Library) bears the date 1846, making it conceivable (but highly unlikely) that reference to tempeh was added just prior to publication.

The *Serat Centini* , written in verse, tells of the adventures of "students" wandering in the Javanese countryside in search of truth. In the course of the story, detailed information is given on many subjects including Javanese culture and life. The passage mentioning tempeh occurs in a description of Wanamarta, a prosperous place, in the context of a reception given to Jayengwesti, and involving all sorts of foods. These, including "onions and uncooked *témpé* ," are simply listed without further information.

Conservative estimates that tempeh originated at least several centuries ago are also supported by evidence based on the food's present widespread geographical distribution, popularity, and large number of varieties. Tempeh is known in even the most remote rural areas throughout most of Java, is an integral part of the cuisine served in a wide variety of popular dishes (90 named Indonesian recipes are given in our *Book of Tempeh*), and by the mid-1970s it was being made from at least 17 indigenous seeds and presscakes by more than 41,000 shops, using simple, traditional methods.

But where did tempeh come from? The earliest known written record of soybeans in Indonesia was by the Dutch botanist Rumphius (1747), who reported that they were being used in Java for food

and as green manure. Yet soybeans may well have been introduced to Indonesia at the time that regular trade started with south China in about 1000 A.D. One Sundanese (West Javan) name for soybeans is *kachang jepun* (Japanese bean), which may be historically significant. At least one East Asian scholar (Anderson 1983, personal communication) believes that tempeh developed from an application to soybeans of an earlier fermentation used on coconuts, perhaps the now famous coconut presscake tempeh (*tempeh bongkrek*). The well-traveled Indonesian Dr. Sastroamijoyo (1971) feels that tempeh may have originated over 2,000 years ago. He has pointed out that even before that time the Chinese were making a similar product, the soybean koji for their soy sauce, produced by inoculating cooked dehulled soybeans with wild molds such as *Aspergillus oryzae* . This method could have been brought to Java from China by early traders and modified to suit Javanese tastes; the use of *Rhizopus* may have been due to its better adaptation to the Indonesian climate. The rise of tempeh's popularity in West Java (where the culture is Sundanese), and its spread to other Indonesian islands and other countries of the world, probably began in the 20th century. We hope that Indonesian scholars will soon begin a serious search of their literature to help us construct a more reliable picture of tempeh's early history.

Another possible lead may lie in China. In 1931, in Beijing (Peking), William Morse observed a fermented soyfood closely resembling tempeh and called *tou chiah ping* ("soybean fried cake"; Morse 1928-31). Details on this product are given later at China. No other reference to such a product has been found in European-language soyfoods literature. If this is a type of tempeh, it is probable that it was taken to China from Indonesia (the East Indies) by Chinese traders and that it became established on a local scale in China. There is the possibility, however, that the product originated in China and migrated to Indonesia, where it was developed, perhaps because of a similar existing product made from coconut (tempeh bongkrek). It would be very interesting to

know more about *tou chiah ping* : Is it fermented with *Rhizopus* ? What is known of its history?
There are no known references to it after 1931.

There is a great need for more research on the origins and early history of tempeh. Promising areas for additional searching include early Malay-Dutch dictionaries, the classical Malay literature of the 18th and 19th centuries, the writings of foreign travelers to Java (especially European missionaries, botanists and naturalists, or Dutch or Japanese traders or explorers), and perhaps even Chinese historical records. Professors of Malaysian literature have told us that they think they have seen reference to tempeh in the classical Indonesian literature of the 18th and 19th centuries, but we have been unable to find a specific reference. In 1928 the Malay language was declared the official language of the future Indonesia. Despite the long history of written documents in Indonesia, no known records of tempeh's origin or early history have yet been found in the native language. In fact, the earliest records in Indonesian seem to date from the 1950s!

Early European References (1895-1939) . Since Indonesia (formerly the Dutch or Netherlands East Indies) had been a Dutch colony since the late 1600s, it was only natural that the first Westerners to study tempeh came from Holland. The earliest known reference to tempeh (actually *témpé*) in Indonesia by a European appeared in 1875 in a Javanese-Dutch dictionary, the *Javaansch-Nederduitsch Handwoordenboek* by J.F.C. Gericke and T. Roorda. The term was defined as "Fermented soybeans or presscake (*bunkil*) baked or fried in flat pressed cakes. It is well-liked as a side dish with rice." The term does not appear in Marsden's dictionary of 1812, but then he was in Sumatra and tempeh was most widely found in Java. In 1895 the Dutch microbiologist and chemist H.C Prinsen Geerligs made the first attempt to identify the tempeh mold in his classic article titled "Eenige Chineesche voedingsmiddelen uit Sojaboonen bereid" (Some Chinese Foods Made with

Soybeans). After describing Indonesian soy sauce, and miso (*taucho*), he noted: "In a similar way, in Java, other molds are used to make leguminous seeds into more digestible foods. Thus the presscake, which remains after making peanut oil and would be indigestible without further preparation, is subjected to the action of molds. In central and eastern Java *Chlamydomucor Oryzae* [now known as *Amylomyces rouxii*] is used, whereas in western Java an orange mold of the family Oospore (*Neurospora*) is used. In the former case, the food is called 'bongkrek,' and in the latter 'ontjom.' If soybeans are molded with *Chlamydomucor* the spice is called 'tempets.' In the preparation the seeds are boiled, spread, mixed with a little molded cake from a former batch, and left alone for a while, until the mass is bound into a solid cake." A year later, when this article was published in German, he corrected two mistakes he had made in the 1895 Dutch version. He changed the name of the mold from *Chlamydomucor Oryzae* to *Rhizopus Oryzae* and he changed the name of the product from "tempets" to "tempeh." He added in conclusion that "it was finally sliced and enjoyed, mold and all." But he continued, apparently mistakenly, to refer to tempeh as a Chinese soyfood. Prinsen Geerlig's two articles ushered in the era of scientific research on tempeh by European microbiologists and food scientists.

Prinsen Geerligs and his Dutch colleague F.A. Went were particularly interested in the utilization of by-products from Java's expanding new sugar industry (Went and Prinsen Geerligs 1895, 1896). They wrote many articles about sugar, but also studied tapeh, arak, and other Indonesian fermented foods. In 1901 Went, then at Utrecht, the Netherlands, described onchom (formerly spelled "ontjom," a close relative of tempeh) and studied the mold involved, which he called *Monilia sitophila* ; it is now called *Neurospora* . In 1900 and 1901 the German Wehmer studied Javanese ragi (starter culture cakes, also called "Chinese yeast") occasionally used for making

tempeh. In 1917 Prinsen Geerligs discussed tempeh as a food made using natural enzymes in East Asian home industries.

In 1900 the Dutchman Dr. P.A. Boorsma, who lived in Java and did original laboratory tests, published an excellent 13-page article on soybeans. In a detailed 4-page description of the traditional process for making *Tempe kedeleh*, Boorsma reported that the soybeans were parboiled, soaked in water for 2-3 days, drained, steamed in a steamer, spread in a layer several centimeters thick on woven bamboo trays in shelves, and covered completely with banana leaves. They were then inoculated by mixing in "mold-containing residues of a previous preparation" and covered lightly with banana leaves. "In the evening the mass is remolded a little and after two 24-hour periods one will obtain a coherent cake, which is cut into pieces and taken as is to the market." Boorsma then described the rise in temperature to 10-12°C above ambient temperature during the tempeh fermentation, the formation of ammonia in tempeh after 3 days of fermentation, and the likelihood that stories about nonsoy tempehs causing food poisoning were true. After microscopic examination, he concluded that Prinsen Geerligs and others were mistaken in stating that (1) the mold hyphae penetrate and dissolve the hard soybean cell walls and (2) cellulose is decreased during tempeh fermentation. He studied the chemical and compositional changes at four different stages during a 3-day tempeh fermentation, observing that fats and soluble carbohydrates decreased substantially, while nitrogen decreased only slightly. He also discussed the hydrolysis of soybean lipids and why tempeh is easier to digest than whole soybeans.

In 1893 the Dutch microbiologist Vorderman had described ragi, a traditional tempeh inoculum (though he did not mention tempeh), then in 1902 he discussed in detail two processes he observed for wrapping and fermenting soy tempeh. In the first and best-known way the soybeans

were incubated between banana leaves; in the second the soybeans were wrapped in banana leaves to form a packet 20 cm long and 7 cm wide, then wrapped in a jati leaf. The packets were stacked in a bamboo basket for 24 hours covered with bags, then removed to prevent overheating and spread on the floor for 24 hours more. He noted (as Prinsen Geerligs had in 1896) that tempeh was fermented with *Rhizopus oryzae*. Vorderman (1902) was the first to describe other varieties of Indonesian tempeh and their close relatives. *Ontjom beureum* was made in West Java from peanut presscake fermented with the orange mold *Monilia sitophila*. *Tempe bongkrek katjang* and *ontjom bodas*, made in Banyumas in central Java, were each like peanut presscake tempeh but fermented with *Rhizopus* molds. *Tempe bongkrek kelapa*, from south Banyumas, was made from pressed coconut, inoculated with and in leaves already used for making soy tempeh. Low in price, it was eaten mostly by poor people. *Tempe morrie*, from Banyumas, was made from a mixture of soybeans and coconut milk residue, which had been washed and steamed. After inoculation with ground *bibit* leaves, on which were *Rhizopus oryzae* spores, the mixture was packed in the sheaf of the banana tree stem to form small long packages, then incubated. *Tempe enthoe* and *tempe tjenggereng* were made with steamed coconut oil presscake and coconut milk residue. The latter contained steamed corn bran and both were fermented packed in the sheaf of the banana tree stem for 48 hours. He concluded noting that *tempe tjenggereng*, like *tempe bongkrek kelapa*, had led to several cases of fatal food poisoning.

In 1913, K. Heyne published a lengthy review of earlier literature on tempeh. In 1923 the Dutchman Jansen wrote "The Need of the Animal Organism for the Anti-beriberi Vitamin and the Amount of this Vitamin in Various Foodstuffs." He showed that in tempeh the content of anti-beriberi vitamin (first isolated by Jansen and Donath in 1926, and later named vitamin B-1 or thiamine) was reduced during fermentation. Jansen and Donath (1924), in "Metabolic Experiments on Rats and

Digestibility of the Proteins of Some Foodstuffs" showed that tempeh protein is of good quality and makes a good supplement to the protein in rice. The vitamin A content was about the same as that of raw soybeans. The content of vitamins B-1 and B-2 in tempeh was further investigated by A.G. van Veen (1932, 1935); he found it to be a good source of both.

One of Indonesia's most famous (or infamous) types of tempeh is tempeh bongkrek, which is made from coconut presscake or the residue from homemade coconut milk, rather than from the usual soybeans. When contaminated it becomes toxic, and for as long as the local people can remember, it has periodically caused food poisoning and death in Central Java, mainly in the province of Banyumas and surrounding areas. The first outbreak of bongkrek poisoning was recorded by Dutch authorities 1895. Vorderman described several types of tempeh bongkrek in 1902 and noted that they caused fatal food poisoning. During Indonesia's economic depression between 1931 and 1937, when villagers tried to make bongkrek themselves rather than buying it from experienced producers, the poisonings became very numerous, up to 10 or 12 a year. There were few survivors. The local villagers believed that the poisonings were due to evil spirits or to the Goddess of the Indian Ocean in an angry mood! Starting in the early 1930s a group of Dutch scientists, starting with W.K. Mertens and A.G. van Veen from the Eijkman Institute in Jakarta, began to investigate the causes of bongkrek poisoning (van Veen 1967). Between 1933 and 1938 Mertens and van Veen published nine studies in Dutch and German on the bongkrek poisonings in Banyumas and the toxicology of *bongkrek*. In about 1933 they found the cause of the poisonings and discovered that the bacterium *Pseudomonas cocovenenans* was producing the toxins. Soon thereafter they isolated and named the two poisonous substances (toxoflavin and bongkrek acid). Amar?? and Grevenstuk (1935) and Baars and van Veen (1937) also published on bongkrek poisoning. In 1950 van Veen

showed that at least one of the poisons is also a strong antibiotic for tempeh's *Rhizopus* mold. After 1950 many more investigations were conducted on tempeh bongkrek.

The first English-language information about tempeh appeared in 1931 in J.J. Ochse's *Vegetables of the Dutch East Indies* , an excellent 1005-page tome published in Buitenzorg (today's Bogor), Java. Ochse, a Dutchman, described the tempeh-making process in detail, saying that the mold used was *Rhizopus oryzae* , and that it was obtained from a former batch of tempeh. The next English-language reference appeared in 1935 in I.H. Burkill's *A Dictionary of the Economic Products of the Malay Peninsula* , a two-volume, 2,400-page work published in England. It contained six pages of information about tempeh and other soyfoods, including a description of the tempeh-making process. Burkill was a British authority on the flora of southern and southeastern Asia.

Tempeh During World War II and the Postwar Era (1940-1959) . During World War II almost the entire Malay archipelago was brought under Japanese control. Tempeh served as an important food in Indonesia and surrounding countries during the war, both for the native population and for foreigners in Japanese prisoner of war (POW) camps there.

The first English-language article specifically about tempeh was written in 1946 by Gerold Stahel, director of the Agricultural Experiment Station in Paramaribo, Surinam (a Dutch colony). Stahel described how, during World War II, the United States shipped soybeans to New Guinea in order to feed the Europeans and Indonesians living there. The shippers did not realize that residents of Indonesia, accustomed to eating fermented soyfoods, considered plain boiled soybeans to be unpalatable. Moreover, during the Japanese occupation of New Guinea, tempeh production had stopped and the local New Guinea starter cultures had, therefore, all been lost. Stahel, asked to

furnish new cultures from Surinam, sent both fresh tempeh cakes and pure-culture starters to the Netherlands Indies Civil Administration (NICA) in New Guinea. Soon NICA kitchens all over the territory started using the US soybeans to make tempeh for the people.

As a result of his involvement in this project, Stahel's interest in tempeh grew, and in 1946 he wrote a detailed description of the way Javanese women in Surinam made and sold tempeh. He was the first to report on the bacterial acid fermentation of the soybeans during soaking that preceded the basic mold fermentation. Roelofsen, a Dutchman, was a prisoner of war (POW) in Japanese camps in Indonesia, where many Europeans were starving. Their basic foods were corn, sweet potatoes, chilies, and soybeans. Roelofsen made the soybeans into tempeh there and in 1946 reported the great shortage of protein in the camps and the important role played by tempeh in reducing deaths. He was the first to describe the use of pulverized dried tempeh as an inoculum. Roelofsen (1964) also did important nutritional studies of the food after his release. By a strange twist of fate, van Veen was made a POW during World War II and held in Indonesian camps where tempeh was widely served. In 1946 he reported that even POWs suffering from dysentery and oedema, who could not digest cooked whole soybeans, were able to assimilate tempeh. Fuel was sometimes so short in the camps that the soybeans, served as whole beans or for tempeh, were not adequately cooked. Yet the tempeh process helped to make these undercooked soybeans much more digestible. Van Veen concluded that many POWs owed their very survival to tempeh. De Bruyn, van Dulst, and van Veen (1947) came to the same conclusion. In 1951 Smith and Woodruff and in 1952 Grant wrote articles on "Deficiency Diseases in Japanese Prison Camps." They reported that the POWs, apparently in Hong Kong and Singapore, had made soybeans (often inadequately cooked) into tempeh to make them more palatable and digestible.

The first study in English on the chemical and microbiological changes occurring during tempeh fermentation, was published in 1950 by the Dutch microbiologists van Veen and Schaefer. This classic paper, based partly on van Veen's experiences in a POW camp, was more extensive than that published by Boorsma in Dutch in 1900. It described the tempeh-making process then attempted to show why tempeh was so much more digestible than soybeans. Also in 1950 Tammes published a detailed description of how tempeh was made in Java, including a description of how tempeh starter (ragi) was made.

Other than the Serat Centini (1815, 1846), the earliest known reference to tempeh in Indonesian or by an Indonesian appeared in 1956 (any earlier??) when Soetan mentioned it briefly in a booklet entitled *Kedelai* (Soybeans).

It is curious to note that, despite the fact that tempeh has long been a very important and widely used Indonesian food, all of the scientific studies on tempeh from 1895 to 1960 (and virtually all of the references to it in any language) were done by Europeans living in Indonesia. There are several reasons for this: First, while Indonesia was a Dutch colony, very few Indonesians were able to attend a university or to do scientific research of any type. There were very few Indonesian food scientists or microbiologists, and these were not encouraged to study indigenous foods. Second, during Dutch colonial rule, public opinion was strongly influenced by the Dutch emphasis on Western values and lifestyles, and the devaluation of indigenous values and lifestyles. Consequently a food such as tempeh, which was unknown in the West, and which was a low-priced food of the common people, acquired the image of an inferior, lower-class, or even poor-people's food, even though it was consumed by people of all classes. No Indonesian scientists felt it was worthy of their attention or research. Unfortunately, this attitude persisted even after

independence. Sukarno, President of the Indonesian Republic from 1945-1967, admonished his fellow citizens on numerous occasions, saying "Don't be a tempeh nation," or "Don't be a tempeh scientist," implying that tempeh was somehow second class or inferior. Only by the mid-1960s did that image begin to change. And third, there was little interest in tempeh outside of Indonesia to stimulate interest inside.

New Interest in Tempeh (1960-82) . A new wave of worldwide interest in tempeh began in the early 1960s, sparked largely by the initiation of tempeh research on the part of two groups of American microbiologists and food scientists: one at Cornell University's New York State Agricultural Experiment Station in Geneva, New York, and the other at the USDA Northern Regional Research Center at Peoria, Illinois. Each group had an Indonesian as a catalyst and co-worker for its tempeh research. The Cornell group, under the leadership of Dr. Keith H. Steinkraus, worked with Ms. YAP Bwee Hwa, starting in 1958. This group did extensive, original research on tempeh and from 1960 published a series of pioneering scientific papers on all aspects of the new-found fermented soyfood. The USDA group, under the leadership of Dr. Clifford W. Hesseltine, got interested in tempeh as soon as the Indonesian microbiologist KO Swan Djien arrived in Peoria in 1960 to study industrial fermentations. There Hesseltine encouraged him to start by studying the tempeh fermentation.

The first Indonesian to do scientific research on tempeh, and to write a post-graduate thesis on the subject was Ms. Yap Bwee Hwa - a Chinese Indonesian whose name comes from the Hokkian dialect of Fujian (Fukien) province. After graduating from the Fakultas Ilmu Pasti dan Alam (Faculty of Natural Sciences and Mathematics) in Bandung with a major in biochemistry (degree equivalent of MSc), she went to work in Jakarta at the Nutrition Institute under Dr. Poorwo Sudarmo, a

progressive physician interested in nutritious, low-cost foods for infants. She then won a Fulbright scholarship to the United States and Sudarmo encouraged her to study tempeh. After reading an article by van Veen on the value of tempeh in prisoner of war camps, she made up her mind. The Fulbright committee suggested that she study at Cornell University, so she wrote Dr. Hand, head of the Department of Food Science and Technology at Cornell's New York State Agricultural Experiment Station. She visited plants tempeh plants in Indonesia to study the process, collected tempeh from the Jakarta market, then dried it and put it in a little brown bottle for later use as tempeh starter. She left Indonesia for the USA in August 1957. In the summer of 1958 she started to work in Dr. Steinkraus' laboratory at Geneva, New York, where, for the first time, she prepared tempeh. This was probably the first tempeh ever made in America. A graduate student in nutrition and food science, Ms. Yap pursued her interest in tempeh as a nutritious food for infants and children, in part because of the high rate of infant mortality in Indonesia caused by undernutrition (Yap 1984, personal communication). In 1960 she wrote her MS thesis titled *Nutritional and Chemical Studies on Tempeh, an Indonesian Soybean Product* . That same year she co-authored the Cornell group's first tempeh publication "Studies on Tempeh--An Indonesian Fermented Food" (Steinkraus et al. 1960). It is also interesting to note that it was from the pulverized sample of tempeh that Yap brought with her from Indonesia that the group isolated the culture of *Rhizopus oligosporus* , which Dr. Hesseltine later identified and gave the number NRRL 2710. This is still the most widely used tempeh culture strain in the USA.

Other early but brief descriptions of the tempeh process were given by Prawiranegara (1960) and Hardjo (1964, in Indonesian).

In 1961 Ko Swan Djien became the second Indonesian to publish scientific research on tempeh. Like Yap Bwee Hwa, he was a Chinese Indonesian whose name comes from the Hokkian dialect of Fujian (Fukien) province. By authoring or co-authoring at least six important articles about tempeh, Ko played a key role in introducing this food to the West, and in giving it a better image in Indonesia. Ko studied at the University of Wisconsin at Madison from August 1959, then did research at the NRRC from February to August 1960. Thereafter, he returned to the Bandung Institute of Technology, where his Laboratory for Microbiology began doing cooperative research on tempeh with the Cornell and USDA groups. Ko's first article, co-authored with Hesseltine in 1961, was about "Indonesian Fermented Foods;" it contained detailed information about tempeh making and recipes in Indonesia. Ko noted that there were thousands of tempeh shops in Indonesia and estimated that half or more of the country's 1959 soybean production of 17 million bushels (463,000 metric tons) was used to make tempeh.

Ko's most important and original article, presented in May 1964 at the International Symposium on Oilseed Proteins in Tokyo (and unfortunately never published) was "Tempe, A Fermented Food Made from Soybeans." The best report to date on tempeh in Indonesia, it discussed tempeh's history, traditional production methods, inoculum, packaging, chemistry and microbiology, contamination, shelf life, recipes, and price, plus a review of other research (including the best English-language bibliography of Dutch research to date) and a description of a tempeh pilot plant being developed in Bandung (complete with a mechanical roller-mill dehuller, water flotation hull removal, heated incubator and trays, and improved inocula). It was the first English-language publication to refer to the use of okara (soy pulp) in tempeh. In this article Ko signaled what he hoped would be the beginning of a new image for tempeh in Indonesia: "But there is no doubt that the time will come when Indonesians will be proud of their tempe, in the same way as the Japanese

are proud of their sake, the French people of their wine, Italians of their macaroni, Indians of their curry, Russians of their caviar, the Dutch of their cheese, etc."

During the 1960s at the microbiology laboratory in Bandung, Ko worked to stimulate new research on and interest in tempeh. When Indonesian newspaper reporters finally discovered that he had studied tempeh at a University and in the United States, they were simply astonished. Articles with bold headlines such as "Tempeh Steps to a Higher Throne" appeared in several widely read Indonesian newspapers in September 1965. This marked the beginning of a change in attitude toward tempeh in Indonesia. In 1965 a summary of Ko's work on tempeh was published in Indonesian; it included details of an extensive survey proving that *Rhizopus oligosporus* was the main tempeh microorganism. In 1968 Ko joined the Department of Food Science at the Agricultural University, Wageningen, in the Netherlands. There he began to stimulate new interest in tempeh in Europe. In 1974 Rusmin and Ko wrote an article on rice-grown tempeh inoculum and Ko (1974) showed that the tempeh mold prevented aflatoxin production by *Aspergillus flavus*. In 1979 Ko and Hesselstine wrote "Tempeh and Related Foods," an excellent expanded and updated version of Ko's unpublished 1964 paper, with more details on previous Dutch tempeh research. There Ko reported that, following the change in attitude towards tempeh in Indonesia from the mid-1960s, studies by universities and by government agencies during the 1970s had paid more attention to tempeh. Ko insisted on using the Indonesian spelling for tempeh, even in English-language articles.

Yap and Ko had pioneered the way for Indonesians to do research on tempeh in the United States. Many others followed in their footsteps. The next Indonesian to study tempeh was Nasruddin Ilias, who wrote his MS and PhD theses on tempeh at Ohio State University in 1969 and 1972. His was the first PhD dissertation ever to be written on tempeh. In 1970 and 1973 he published two studies

with Peng and Gould at Ohio State; the first was a short article on ways of preserving tempeh and the second, "Tempeh: An Indonesian Fermented Soybean Food," was one of the best and most extensive works to date, containing a lengthy review of the literature. In 1970 Dwidjoseputra wrote her PhD thesis on the microbiology of ragi (starter) at Vanderbilt University in Tennessee. In 1975 Sudarmadji wrote his PhD thesis on tempeh at Michigan State University, and by 1978 had authored or co-authored five publications on the subject. He found that the phytic acid in soybeans (which can bind dietary minerals) was significantly reduced during the tempeh fermentation. In 1980 Rivai wrote his MS thesis on tempeh at the University of Minnesota.

Interest in and publications about tempeh in Indonesia increased rapidly after the late 1960s. In 1967 the Indonesian Department of Agriculture published *Mustika Rasa* ("Gems of Taste"), a huge (1,123-page) cookbook of the best recipes from throughout the Indonesian archipelago. Referred to as the "Bible" of local cooks, it contained 35 Indonesian tempeh recipes and seven onchom recipes. Also in 1967 several types of tempeh were included in the official *Indonesian Food Composition Tables* (Direktorat GIZI 1967). Dwidjoseputra and Wolf (1970) studied the microorganisms in tempeh inocula. Sastroamijoyo (1971) was the first Indonesian to suggest that tempeh offered an answer to the world food crisis. Hermana was senior author of six important articles between 1970 and 1974, and Indrawati Gandjar wrote the first two of her many publications on tempeh in 1972. In 1972 and 1975 Thio published on tempeh. Winarno was the senior author of three publications written between 1973 and 1976. The most important of these was *The Present Status of Soybean in Indonesia* (1976), compiled as part of the ASEAN Project on Soybeans and Protein-Rich Foods by an interdisciplinary team of Indonesia's top authorities on soybeans. It contained the first detailed analysis of the tempeh industry in Indonesia. This ASEAN Protein Project served as a major stimulus for additional research on tempeh by Indonesians, and

numerous papers were published in its periodical progress reports (Saono et al. 1974, 1976, 1977; Suhadi 1979; Jutono 1979; Hartadi 1980). Tempeh was discussed extensively at workshops on Solid Substrate Fermentation sponsored by the ASEAN Sub-Committee on Protein, held in Bandung, Indonesia, in 1978, and Kuala Lumpur, Malaysia, in 1980. Other studies on soy tempeh were published by Noor (1975), Khumaidi (1976), Loegito (1977), and others.

Starting in the late 1960s and early 1970s a number of changes began to take place in the process for making tempeh in Indonesia. The most noticeable of these was the use of polyethylene bags (and, to a more limited extent, wooden trays lined with plastic sheeting) in place of banana leaves as the container in which the tempeh was incubated and sold. These techniques were developed in 1964 by Martinelli and Hesseltine at the USDA/NRRC in Peoria, Illinois. The oldest method for making tempeh inoculum was the sandwiched hibiscus leaf method, in which inoculated soybeans were sandwiched between hibiscus leaves and incubated until the molds sporulated. The finished inoculum was known as *laru*, *waru*, or *usar*. Finally, the spores on the leaves were rubbed over warm soybeans requiring inoculation. In 1895 Prinsen Geerligs reported that kechap (*katjap*) and taucho (*Tao-Tjiong*) were both inoculated with *Hibiscus tiliaceus* leaves, in Java called "waroe." A sporulated substrate (typically a previous batch of tempeh) was also used. But starting in mid-1960s research began in Indonesia to improve traditional starters. Ko (1964) described an improved soybean-based starter, then in 1967-68 developed and tested a semi-pure culture inoculum based on cooked rice, incubated in aluminum trays, then dried, pulverized, and stored sealed in a cool place. The process required no sophisticated equipment (Rusmin and Ko 1974). Hermana and Roedjito (1971) were the first to publish a method for the use of steamed rice (plus cassava and soy flour) as a tempeh inoculum substrate. By the mid-1970s a pre-prepared rice-based tempeh inoculum started to be used by some larger manufacturers; a key supplier was the Department of

Microbiology at Bandung Institute of Technology (Shurtleff and Aoyagi 1979; Jutono 1979; Hartadi 1980). By 1982 tempeh starter was being sold in Indonesian supermarkets.

Traditionally all of the soybeans used to make tempeh were grown domestically; presumably they had been selected over the years for their suitability to tempeh production. But imports of soybeans, largely from the USA, increased dramatically during the 1970s, reaching 156,000 tonnes in 1976 (about 25% of domestic production) then rising to roughly 365,000 tonnes in 1983 (59% of domestic production). US soybeans were larger, cleaner, and about 15-20% less expensive, but the Indonesian soybeans were found (by whom??) to have a higher content of isoflavones, which retards rancidification of the tempeh when it stands at ambient temperatures. Larger manufacturers began to dehull their soybeans with a motor-driven stone mill, then remove the hulls using a semi-automatic flotation device. However, the abundance of low-cost labor and the high cost of fuel, energy, and imported equipment, prevented widespread mechanization of the process. By 1977 a 75-minute color film had been made on tempeh; it was available from the Jakarta Management Institute (Shurtleff & Aoyagi 1979).

The first detailed and comprehensive survey of the tempeh industry in Indonesia was published by Winarno and co-workers in 1976. It reported that, at that time, tempeh was the nation's most popular soyfood, making use of 64% of the country's total soybean production and imports. There were 41,201 tempeh manufacturers, mostly small, family-run enterprises, which made fresh tempeh daily. They employed a total of 128,000 workers, who produced each year 153,895 metric tons of tempeh having a retail value of US\$85.5 million. Most companies were small, run out of the home. The largest companies used no more than 100 kg of soybeans a day to make 175 kg (385 lb) of tempeh. (This would be 1,050 kg (2,310 lb) of tempeh per 6-day week.) Tempeh was an

important source of high-quality, low-cost protein and vitamins in the diet of all Indonesian socio-economic groups, and especially in the diet of low-income families. Yet its importance should not be exaggerated. Per capita consumption for all Indonesians in 1976 was about 16 gm a day or 5.8 kg (12.8 lb) a year. Tempeh was typically consumed in amounts of 100-200 gm per person per meal. A summary and analysis of Winarno's findings on the Indonesian tempeh industry is given in the professional edition of *The Book of Tempeh* (1979) by Shurtleff and Aoyagi.

The remarkable versatility of the tempeh fermentation process allows the preparation of many different types. Traditionally in Indonesia the great majority of all tempeh was soy tempeh (*témpé kedelé*) and by the mid-1970s it constituted an estimated 90% of all tempeh produced. Well-known varieties of soy tempeh included thick Malang tempeh and one-bean-thick Purwokerto tempeh. Other traditional types of tempeh included: okara tempeh (*tempe gembus* or *onchom hitau* ; Gandjar and Slamet 1972; Gandjar 1977), soybean-hulls tempeh (*tempe mata kedele* ; Gandjar and Hermana 1972), peanut presscake tempeh (*onchom hitam* ; van Veen et al. 1968), the occasionally poisonous coconut presscake tempeh (*tempe bongkrek* ; van Veen 1950-73; Harsono 1970; Gandjar and Hermana 1972; Arbianto 1977), velvet-bean tempeh (*tempe benguk* ; Gandjar 1977), leucaena tempeh (*tempe lamtoro*), mung bean tempeh (*tempe kacang hijau*), mung bean pulp tempeh (Gandjar 1977), plus several other minor varieties (Vorderman 1902; Ko and Hesseltine 1979; Shurtleff and Aoyagi 1979). The okara tempeh, presscake tempehs, and other non-soy tempehs were consumed more by lower-income groups. Starting in the late 1970s, however, the use of new seeds and grains for tempeh-making began to be investigated. Gandjar (1977, 1978) did several studies on winged bean tempeh. Tanuwidjaja (1977) studied the fortification of low-cost presscake tempehs with soy flour to improve the diets of the very poor.

And bulgur wheat was reported to be mixed with soybeans to make tempeh (Hesseltine and Wang 1972).

Poisonings from tempeh bongkrek (made with coconut rather than the usual soybeans) continued to be a problem. From 1951 (when detailed records first began to be kept) until 1976, some 7,216 cases of bongkrek poisoning were reported in Central Java and 86 of these people (1.2%) died. In 1958 Harsono showed that the use of the acidic leaves of an *Oxalis* species (which grows everywhere as a weed in Banyumas) could be used to prevent toxicity in bongkrek. Unfortunately, this simple safety measure has not been adopted (van Veen 1967). In 1960 van Damme et al. elucidated the structure of toxoflavin. Laws have been passed to try to prevent production of tempeh bongkrek by unlicensed amateurs, but these too have not worked. So the periodic poisonings have continued into the 1980s. Fortunately soybeans are not involved.

On 11 March 1979 a key event took place in Indonesia with the organization of KOPTI, the Cooperative of Tempeh and Tofu Producers of Indonesia, with Achmad Rouzni Noor as director in Jakarta. Noor had a deep personal interest in helping tempeh makers to grow, modernize, and thrive. And national laws passed in 1979?? governing import and distribution of soybeans virtually compelled most tempeh makers to join KOPTI. By 1983 KOPTI had over 28,000 members in Java; 72% of these ran home industries. KOPTI's main functions were: (1) to buy basic materials (soybeans, inoculum, oil, etc.) collectively for its members at lower prices, (2) to improve member's production by developing new processing equipment (such as dehulling machines), helping members improve the quantity and quality of their products through better sanitation and preservation practices, and developing new products, (3) to provide marketing services, (4) and to serve as a source of capital for loans and helping members to form cooperatives. In part because of

KOPTI, tempeh production was on the upswing in Indonesia by the early 1980s and the industry was modernizing. In 1984 Ko Swan Djien was able to write: "From my recent visit to Indonesia I get the satisfactory feeling that our efforts to have fermented foods valued in their right proportion are not in vain. Tempe is no longer considered an inferior food. Nowadays Indonesians are as proud of THEIR tempe as Japanese are of their sake, and French of their wine...!" (personal communication).

Shurtleff and Aoyagi (1979) conducted an informal survey in Java to identify which were Indonesia's best known and best liked tempeh recipes. The number preceding each recipe name indicates the order of "best known," with (1) being the best known. The number after the English recipe name indicates the quality ranking with (1) being the best liked. 1. Tempeh Goreng (Deep-Fried Tempeh with Seasonings; 2) 2. Tempeh Bachem (Tempeh Cutlets; 4), 3. Keripik Tempeh (Tempeh Chips; 6), 4. Sayur Lodeh (Tempeh & Vegetables in Coconut Milk Soup; 7), 5. Sambal Goreng Tempeh (Spicy-Fried Tempeh in Coconut Milk; 3), 6. Terik Tempeh (Tempeh in Coconut Milk Sauce; 5), 7. Sambal Goreng Tempeh Kering (Crunchy Chili-Fried Tempeh Topping, 1). Surprisingly the least well known of the "Top Seven" was the best liked.

Java is still the Mecca of the tempeh world, yet over the centuries, wherever Javanese settlers have gone, they have taken tempeh with them. Today it is widely produced and consumed in Surinam (where 30% of the population is Indonesian), and on the west and south coasts of Peninsular Malaysia. To a lesser extent it is consumed in Singapore, New Caledonia, and the other Indonesian Islands (especially Sumatra). Tempeh is also increasingly popular in the Netherlands, where it was introduced by immigrants from Indonesia in the 1940s.

HISTORY OF TEMPEH IN EUROPE AND AUSTRALASIA

History of Tempeh in Europe . As noted previously, all of the references to and articles about tempeh written between 1875 and the early 1950s were written by Europeans, most of them Dutchmen. Senior authors of references prior to 1940 included Gericke and Roorda (1875, 1901), Prinsen Geerligs (1895, 1896), Boorsma (1900), Vorderman (1902), Heyne (1913), Jansen (1923, 1924), Ochse (1931), van Veen (1932, 1933, 1934, 1935, 1936, 1938), Mertens (1933), Amar and Grevenstuk (1935), and Burkill (1935). Yet, perhaps because Dutch was not a widely read or spoken language and tempeh was not known in countries more famous for soyfoods such as Japan and China, tempeh was rarely mentioned in the numerous articles about soyfoods published in French, German, and English prior to the 1950s. Nor are there any records of tempeh being made in Europe during this time. The only two European works in English that mentioned tempeh during this period were those by Ochse (1931) and Burkill (1935), and both were encyclopedic works about the foods and plants of Malaysia and Indonesia; Ochse's work was originally published in Dutch.

Relatively little was published about tempeh in Europe between 1940 and 1959, and most articles focused on its role in prisoner of war camps in Southeast Asia. There were articles by van Veen (1946, in Dutch), Roelofsen (1946, in Dutch), de Bruyn et al. (1947, in Dutch), Tammes (1950, in Dutch), van Veen and Schaefer (1950), Smith and Woodruff (1951), Grant (1951), Dupont (1954), and Autret and van Veen (1955); the latter five articles were all in English. Most of these have been discussed earlier at Indonesia. Boedijn (1958) reported that *Rhizopus oligosporus* can always be isolated from tempeh, implying that it is the primary organism in tempeh.

All of the first tempeh companies in Europe were started in the Netherlands by immigrants from Indonesia. The earliest of these, called ENTI, was founded in April 1946 by a Dutch couple whose last name was Wedding. While living in Indonesia, they had learned to make tempeh. Bringing their starter culture and recipe to the Netherlands, they began to make Europe's earliest known tempeh there on a home scale for friends and relatives. Gradually ENTI grew and became a commercial operation. By the early 1970s they were making 2,000 lb of tempeh a day. In about 1974 they sold the company (located in Zevenhuizen) to Mrs. L.J. Duson, who ran it until January 1984, when she closed it.

Firma E.S. Lembekker, founded in January 1959, was Europe's second tempeh company, and it may have been the first to sell tempeh commercially. In January 1984 it became Europe's oldest existing tempeh company.

Interest in tempeh in Europe began to increase starting in the 1960s. Articles were published by Roelofsen and Thalens (1964; changes in B vitamins), Stanton and Wallbridge (1969; a tempeh-like product made from cassava but with improved nutritional value), Thio (1972, 1975; small scale production and recipes), Jensen and Djurtoft (1976; a large report from Denmark on legume and cereal grain tempehs), Djurtoft and Jensen (1977, tempeh from various African grains and beans), Andersson (1977, volatile components and yellow pea tempeh, from Sweden), and Bahi El-Din et al. (1977; Sudanese researchers at Wageningen, Netherlands). Among these researchers, Thio Goan Loo from Indonesia was especially active in teaching people in Third World countries about tempeh. In 1972 he wrote about tempeh for use in Zambia (Africa) and spent three months in 1979 teaching tempeh production and recipes in Sri Lanka.

Europe's earliest known popular article on tempeh was an excellent 7-page feature story with nine photographs published in 1982 in *Le Compas* in French. In 1982 *Soja Total*, a translation of *The Farm Vegetarian Cookbook* (Hagler 1978), containing 13 pages of information on tempeh, was published in Germany. In 1985 *Das Tempeh Buch*, an updated and expanded translation of *The Book of Tempeh* (Shurtleff and Aoyagi 1979), was also published in Germany. Thus by 1984 there was more information on tempeh available in German than in any other continental European language, including Dutch. However the absence of a center of focused research efforts and a good source of low-cost tempeh cultures, such as the centers at Geneva and Peoria in the US, restricted the development of widespread popular interest in tempeh in Europe. Fortunately in 1984 the Centraalbureau voor Schimmelcultures in Baarn, Netherlands, began to promote their tempeh cultures quite actively.

Europe's largest tempeh company, Tempé Produkten B.V. (Tempe Products Inc., named Handelsonderneming van Dappern until April 1983) was founded in 1969 by Robert van Dappern, with the help of his Dutch father (Herman), his Indonesian mother (Aveline), and his Dutch-Indonesian wife. He paid a Dutch-Indonesian man named Mr. Remmert a substantial sum of money to teach him how to make tempeh. By 1970 they were making tempeh in a small warehouse in Rotterdam. Initially they sold all of their tempeh to a couple of Holland's many Indonesian stores, but then they hired his wife's father, a well-known Indonesian, to deliver to the wider Indonesian community. The company began to grow, but all of the tempeh was being consumed by Indonesians living in the Netherlands. In January 1972 they moved the thriving company to Kerkrade, in southern Holland near the family home in Heerlen, rented a bigger building, and started mass production. Ed van Dappern, the second brother, joined the company as an equal partner. In 1979 Robert sent his wife's brother, Ike van Gessel, to Los Angeles to set up a tempeh

plant there. Ike rented a building but, because of the European recession during the early 1980s and the need for capital to expand the business in the Netherlands, he had to cancel the lease and call off the project, at a substantial financial loss. In June 1980 the company bought a \$1,000,000 modern factory in Kerkrade and expanded again. By mid-1982 Tempé Produkten was producing 6,000 to 8,000 pounds of tempeh a week, making it the largest tempeh company in the world. By early 1984 production had increased to 13,200 pounds (6,000 kg) a week, and an estimated 10% of this was consumed by non-Indonesians. By Dec. 1992 the company was producing 11,000 pounds (5,000 kg) of tempeh a week.

The family developed their own proprietary method for making tempeh starter culture. They developed a leaflet on tempeh, gave demonstrations on making and cooking with tempeh, and got tempeh to be sold at the Central Market, with the result that more and more of the greengrocers, who buy their vegetables there early each morning, started selling tempeh (and tofu). The company exported tempeh and tempeh products to England, Germany, Belgium, and Luxembourg via a major distributor. Robert's Indonesian mother, Aveline, was in charge of preparing these (van Gessel 1982; Welters 1982; van Dappern 1984, each personal communications). By 1984 Tempé Produkten was the world's second largest tempeh manufacturer, after Marusan-Ai in Japan.

In June 1985, Tempé Producten added a new soyfood product to its line - tofu, and by 1991 the company was the largest tofu producer in The Netherlands.

Prior to early 1981 all of Europe's tempeh companies were located in the Netherlands and run by older Dutchmen catering largely to an Indonesian clientele. Europe's first generation of "New Age" tempeh shops was started from 1981 by young people interested in natural foods and/or

macrobiotics. Europe's earliest known New Age tempeh company was Paul's Tofu & Tempeh, which was in operation by January 1981 at 155 Archway Rd., Highgate, in London. JAKSO, the first New Age shop in the Netherlands, started in July 1981. By January 1982 there were 7 tempeh shops operating in Europe; by January 1984 there were 18. Of these, 7 were in the Netherlands, 3 in Austria, 2 each in England and West Germany, and 1 each in Belgium, France, Italy, and Sweden. Total tempeh production in the Netherlands was about 4,500 kg a week (10,000 cakes of 1 pound each) in 1982, rising to 12,000 kg a week in 1984.

By 1980 another center of interest in tempeh had developed at the Department of Botany and Microbiology, University College of Wales, Aberystwyth, Wales, UK. There Dr. J. Hedger and Mr. T. Basuki (from Indonesia) were planning?? to start a tempeh factory, had produced a 4-page leaflet on "Tempe--An Indonesian Fermented Soybean Food," and had written a script for a BBC program "Tomorrow's World," on tempeh, which was broadcast in the summer of 1979. At that time tempeh was also occasionally sold in London, but the name of the manufacturer was not given (O'Neill 1980). In 1982 Hedger wrote a brief article on tempeh production.

History of Tempeh in Australia . Australian interest in tempeh began in about 1977, when McComb published an excellent BS thesis on the use of sweet narrow-leafed lupins to make tempeh. It contained one of the best summaries of the literature to date, plus much original research. A summary of this work was given by Kidby et al. (1977). The earliest known Australian tempeh companies were started in about 1980, and by March 1981 there were three small ones, all run by young "New Age" people, interested in natural foods, meatless diets, and alternative lifestyles. The first two to start were Dharma, part of Earth Foods in Waverley, run by Swami Veetdharma, and a small shop at Bodhi Farm in Channon, New South Wales, run by John Seed. Cyril and Elly Cain

founded Beancoast Soyfoods in Eumundi, Queensland, and started making tempeh in July 1982. In March 1982 *Ziruiz* magazine published a long popular article "Terrific Tempeh" by Shurtleff and Aoyagi. By early 1983 Earth Angel was making okara tempeh. By 1984 there were five tempeh companies in Australia, all quite small.

Because of Australia's proximity to Indonesia, both countries could learn much from each other about traditional and modern tempeh making.

HISTORY OF TEMPEH IN THE UNITED STATES AND CANADA

Early Years in America (1954-1969) . Interest in tempeh in the United States began at a surprisingly late date. As noted previously, early English-language articles on tempeh had been written by Ochse (1931) and Burkill (1935), both published outside the US. The earliest known reference to tempeh in a US publication appeared in 1946, when an article by Gerold Stahel, writing from Surinam in South America about tempeh in Surinam and in New Guinea, was published in the *Journal of the New York Botanical Garden* . A summary appeared in November of that year in *Soybean Digest* . These articles appeared just 50 years after the first reference to tempeh was published in Europe by Prinsen Geerligs. In 1955 Autret and van Veen (both working for the Nutrition Division of the Food and Agriculture Organization of the United Nations, outside the USA) published "Possible Sources of Proteins for Child Feeding in Underdeveloped Countries" in the *American Journal of Clinical Nutrition* . They were the first suggest tempeh as a protein-rich, nutritious, and low-cost food for infants and children in Third World countries. They mentioned tempeh only briefly and noted that soymilk would probably be better suited for feeding children.

Research on tempeh in the US was started in 1954 by Dr. Paul György, a pediatrician and researcher at the Philadelphia General Hospital, and Professor of Pediatrics at the University of Pennsylvania. György had been to Indonesia many times, knew tempeh well, and (like Autret and van Veen) thought that it offered a way of improving the diets of infants and children in Third World countries. György received his first tempeh from Indonesia and Southern Rhodesian in 1954 and 1955. Ms. Kiku Murata of Japan worked with György in the US investigating tempeh during 1959 and 1960. Following largely futile attempts to make tempeh in his own laboratory and lacking adequate facilities for making larger quantities of fermented foods, György worked out a cooperative arrangement in 1959 to have the tempeh made under the supervision of Dr. Hand and Dr. Steinkraus at New York State Agricultural Experiment Station, Cornell University, Geneva, New York. The first publication from this work did not appear until 1961, when György wrote "The Nutritive Value of Tempeh." György gradually moved his research away from a focus on child feeding programs toward the more narrow study of antioxidants in tempeh, which might prevent rancidification of tempeh or other foods.

As noted earlier at Indonesia, a great expansion of interest in tempeh began in the early 1960s, largely because of the pioneering, in-depth research at two centers: Cornell University's New York State Agricultural Experiment Station at Geneva, New York, under the leadership of Dr. Keith H. Steinkraus; and the USDA Northern Regional Research Center at Peoria, Illinois, under the leadership of Dr. Clifford W. Hesseltine. Each center became actively interested in tempeh because of the arrival of an Indonesian researcher. Whereas approximately 15 scientific on tempeh had been published worldwide before 1960, more than 60 were published from 1960 to 1979. Important, original investigations were done on pure culture fermentations, microbiological and biochemical changes during tempeh fermentation, tempeh's nutritional value, and industrial

production of tempeh. This research awakened a new interest in tempeh among microbiologists and food scientists worldwide. Moreover, with this research, the world center of interest in and research on tempeh shifted from Indonesia and the Netherlands to the USA.

In the summer of 1958, when Miss YAP Bwee Hwa from Indonesia started her research on tempeh in New York. Active in nutritional circles in Indonesia, she was the first Indonesian to study tempeh in America; she brought her own little bottle of dried tempeh inoculum with her. She did her course work and rat feeding experiments under the direction of Prof. Louise Daniel and Dr. Richard Barnes in the Graduate School of Nutrition at Cornell University, while pursuing her investigations of tempeh production under Dr. Steinkraus in the allied Department of Food Science and Technology at the New York State Agricultural Experiment Station. Dr. Hand, then head of the latter Department, was very active in nutritional circles and knew of the United Nations' interest in tempeh. In early 1959 Steinkraus, while on a trip to check the UNICEF-supported Saridele soymilk plant in Indonesia, visited a number of tempeh shops, thus becoming the first American ever to study tempeh in its homeland. Also in 1959 Steinkraus' Cornell University group began making tempeh for Dr. György in Pennsylvania.

The first article on tempeh by Americans was written in 1960 when Steinkraus, Yap, van Buren, Provvidenti, and Hand published their now classic "Studies on Tempeh--An Indonesian Fermented Food." This paper (submitted for publication in September 1959) incorporated Miss Yap's tempeh research, plus additional investigations by Steinkraus' group on essential microorganisms, mycelial penetration of the soybeans, etc. In 1961 this paper appeared in a publication by the National Research Council of the National Academy of Sciences. In June 1960 Miss Yap, as part of her graduate degree in nutrition, submitted her MS thesis titled "Nutritional and Chemical Studies on

Tempeh, an Indonesian Soybean Product." Innovations in tempeh production described in these papers included use of lactic acid instead of a prefermentation to acidify the soybean soak water, incubation of the tempeh in stainless steel trays, dehulling the soybeans mechanically (with an electric vegetable peeler), growing the starter spores on bran, and dehydration of the tempeh in a circulating hot air oven. Yap found the PER of tempeh to be 2.5, midway between soybeans (2.3) and casein (2.7). Rats ate 1.5 times as much tempeh as cooked soybeans, and grew almost as fast as those fed casein. Changes in temperature, soluble solids, and soluble nitrogen, and pH during tempeh fermentation were measured and plotted. Yap left the US in April 1962 for Germany, where she worked as a researcher, first for a wine institute, then after 1970 for a chemical-pharmaceutical company.

During the 1960s the Cornell University Group, consisting of interdisciplinary scientists from both the Agricultural Experiment Station and Cornell University, worked together to publish at least 13 original scientific articles on all aspects of tempeh. The group included Steinkraus, Yap, van Buren, Wagenknecht, Provvidenti, Hand, Hackler, Stillings, van Veen, and Shallenberger. Steinkraus was the senior author of 6 papers during this period. Particularly important for the coming new generation of US tempeh manufacturers were his "Pilot Plant Studies on Tempeh" (1962), "Research on Tempeh Technology in the United States" (1964), and "A Pilot Plant Process for the Production of Dehydrated Tempeh" (1965), in which all of the necessary equipment and its manufacturers was described. These represented the first attempts to develop a process for making tempeh in an industrialized country with a temperate climate. Changes during the tempeh fermentation were studied in detail, including changes in lipids (Wagenknecht et al. 1961), in amino acids (Stillings and Hackler 1965), and in carbohydrates (Shallenberger 1967). Hackler et al. (1964) studied utilization of tempeh protein by rats. Van Veen, who had done pioneering research on

tempeh in Indonesia as early as 1932 and had arrived at Cornell in 1962 as a professor of International Nutrition, was senior author of seven papers related to tempeh between 1962 and 1970, including an original 1968 study on peanut tempeh.

In 1960 a second US tempeh research program was started under the direction of Dr. Clifford W. Hesseltine at the USDA Northern Regional Research Center (NRRC) at Peoria, Illinois. As early as May 1948 the NRRC had been sent a tempeh culture (*Rhizopus nigricans*) from Central Sugar Society (N.V. Centrale Suiker Maatschappij) in Amsterdam, together with instructions for making tempeh, but apparently nothing was done with it. Hesseltine first learned of tempeh from papers by Stahel (1946) and van Veen and Schaefer (1950). Much of the interest in tempeh starting in 1960 developed because KO Swan Djien of the Bandung Institute of Technology's Laboratory of Microbiology arrived at the NRRC that year to study industrial fermentations. Hesseltine suggested that he study tempeh; Ko showed Hesseltine and his group how to prepare it. The first publications appeared in 1961 with Ko and Hesseltine's "Indonesian Fermented Foods" and 1962 with Hesseltine's "Research at Northern Regional Research Laboratory on Fermented Foods." From the early 1960s on an interdisciplinary team of researchers at Peoria began to study many facets of tempeh and to develop new types of tempeh and processing techniques. Key figures in this team, in addition to Hesseltine and Ko were H.L. Wang, A.K. Smith, A.F. Martinelli, Mable Smith, W.G. Sorenson, and E.W. Swain. During the 1960s they published 17 original scientific papers (including two public service patents) about tempeh, plus four derivative articles; Hesseltine was senior author of 12 of these, Wang of four, Ko and A.K. Smith of two each, and Martinelli and Sorenson of one each.

In 1963 Hesseltine and co-workers published their first major tempeh study "Investigations of Tempeh, an Indonesian Food." That same year they discovered a mold inhibitor in soybeans. In 1963 and 1964 A.K. Smith and co-workers published pioneering studies on the nutritive value of tempeh in relation to various processing techniques. In 1964 Dr. Martinelli (a Brazilian scientist studying tempeh at the NRRC) and Hesseltine developed a new method for incubating tempeh in perforated plastic bags. It soon became widely used by commercial tempeh producers in both Indonesia and North America, a nice example of cultural cross-fertilization. In the same paper they described fermentation of tempeh in metal and wooden trays, the dry dehulling of soybeans, and the preparation of tempeh from full-fat soy grits. In 1965 Hesseltine wrote a review and history of research on tempeh microbiology and biochemistry. In 1966 and 1967 Hesseltine and Wang published the world's first studies showing that delicious tempeh containing higher quality protein could be prepared using soy-and-grain mixtures (including wheat and rice) or cereal grains alone. In 1969 Wang and co-workers discovered that *Rhizopus oligosporus* in tempeh produces an antibacterial compound or antibiotic, which is very active against a number of Gram-positive bacteria, including *Staphylococcus aureus* and *Bacillus subtilis*, and which retains its activity even after cooking. This supports the view of natives and of some scientists that those who eat tempeh daily have fewer intestinal infections. Hesseltine and Wang sent samples of their tempeh to Dr. Doris Calloway at the University of California, Berkeley. She found in 1971 that tempeh, unlike most foods made from beans, does not cause flatulence. David and Verma (1981) suggested that the antibacterial substance in tempeh may be the cause of this lack of flatulence; it might inhibit the growth of gram-positive *Clostridium* bacteria, which are known to produce gas in the intestines. News of the NRRC discoveries on tempeh was disseminated by *Soybean Digest* (1965, 1967) and the USDA's *Agricultural Research* (1966, 1969).

A key component of the tempeh research at the NRRC concerned identification of the main microorganisms in the fermentation. It has never been clear what the original source of these molds in Indonesia was. Smith and Woodruff (1951) reported that prisoners in Japanese camps in Indonesia during World War II obtained their original tempeh mold culture from the withered petals of the hibiscus plant. Others have said that they came from banana leaves. The genus *Rhizopus* was discovered and named in 1820 by Ehrenberg. In 1895 Went and Prinsen Geerligs first described the species *Rhizopus oryzae*, which was investigated in detail by Wehmer in 1900 and 1901. Until the mid-1960s many microbiologists worldwide (Vorderman 1902; Stahel 1946; van Veen and Schaefer 1950; Dupont 1954; Steinkraus et al. 1960) thought *R. oryzae* was the primary microorganism responsible for the tempeh fermentation. In 1936 Lockwood and co-workers had studied the physiology of *R. oryzae* at the NRRC. In 1905 the Japanese mycologist Kendo Saito first described *Rhizopus oligosporus* on rice meal cakes which came from Shantung province in China, where they were used in making a rice-based fermented alcoholic beverage. Saito did not mention tempeh. In 1958 Boedijn reported that *R. oligosporus* could always be isolated from tempeh, implying that it was the primary fermentation organism. In 1962, after observing 50 tempeh strains from various tempeh sources, Hesseltine identified *R. oligosporus* as the chief tempeh mold. Ko (1965) reported collecting 81 samples of tempeh from various places in Java and Sumatra. Isolation of 116 pure cultures revealed that *R. oligosporus* was always present in good quality tempeh, thereby establishing without a doubt that it was the typical dominant species used. Indonesian researchers, however, maintain that the best quality tempeh contains a mixed culture. By the late 1970s the most widely used tempeh culture in the Western world was *R. oligosporus* strain NRRL 2710. This strain, brought to the US from Indonesia by MS. Yap in 1957, isolated by Steinkraus'

group, and first identified in Hesseltine's lab, continued to be widely distributed from the NRRC culture collection.

It is not known for sure when the first commercial tempeh was made in the US. After the long and bloody war that drove the Dutch out of Indonesia and led to Indonesian independence in 1949, tens of thousands of Dutch and Dutch-Indonesian families were uprooted. Most tried to go to Holland, but the country was too small and the native Indonesians found it too cold. The United States set a quota in 1950 allowing 25,000 of these refugees to immigrate. Only about 10% were culturally native Indonesian; the rest were "Indos," i.e. Dutch-Indonesians or Chinese-Indonesians. Most went to warm areas such as California and Florida. In 1950 an estimated 500 of these settlers arrived in California. The first of these known to have started a tempeh shop was Mary Otten, who in 1961 began making tempeh in her basement on Stannage Avenue in Albany, California. She sold it to her friends and served it at parties that she catered. For starter culture she used *ragi* (an Indonesian starter that comes in small cakes) flown in from Java, until she learned how to make her own in 1973. In 1967 she started Java Restaurant and served many tempeh dishes. Then in 1974 she and her daughter, Irene, started Otten's Indonesian Foods, which by 1981 was making tempeh plus a full line of Indonesian tempeh-based foods under the brand name Joy of Java. These foods included Sweet & Sour Tempeh and Sayur Lodeh Tempeh.

The second earliest known tempeh shop in California (and in the USA) was Runnels Foods, which opened in Los Angeles, California in 1962. Also in Los Angeles, Toko Baru started in 1969 and Bali Foods started in 1975. Thus America's first generation of tempeh shops were all located in California and all run by Indonesian-Americans.

The Americanization of Tempeh (1970 to 1980s) . The 1960s, a decade of creative scientific research on tempeh, laid the foundation for the 1970s, when tempeh began to enter the American diet. The main forces spurring increased production and consumption of tempeh after 1970 were the three closely related movements working to popularize natural foods, meatless and vegetarian diets, and soyfoods. From the late 1970s on there was a rapid growth of interest among many Americans in health, nutrition, and fitness, in low-cost protein sources, meatless diets, and world hunger, in ecology, and simpler, more satisfying lifestyles. Specific factors popularizing tempeh were the various promotional efforts, books, media coverage, and increased availability of good fresh tempeh. By the early 1980s the growing mainstream concern with cholesterol and saturated fats, had also become a significant factor.

During the 1960s the Cornell University group under Dr. Steinkraus and the USDA Peoria group under Dr. Hesseltine and Dr. Wang had completed most of their basic research on tempeh. But a few important discoveries remained to be made during the 1970s. At Cornell, the most important findings concerned the production of significant amounts of vitamin B-12 during tempeh fermentation. In 1977 Liem, Steinkraus and Cronk showed tempeh to be one of the best vegetarian sources of vitamin B-12. Curtis, Cullen and Steinkraus (1977) showed that the B-12 was produced by the bacterium *Klebsiella* . (Nutritional analyses of commercial tempeh done by independent scientific laboratories during the late 1970s and early 1980s showed that typical samples contained an average of 8.8 micrograms of vitamin B-12 per 100 gram portion, or 293% of the US Recommended Daily Allowance of 3 micrograms.)

The most significant research work on tempeh done by the Peoria group during the 1970s concerned the development of improved, larger scale methods for making tempeh starter cultures.

The group showed that rice or a mixture of rice and wheat bran yield the most viable spores, and they developed methods whereby individuals or tempeh manufacturers could make good quality tempeh starter by themselves.

But much more important than the research work of these two groups during the 1970s and early 1980s was their "extension" work. Members of both groups summarized the results of their research on tempeh in at least 35 articles, both scientific and popular. They also gave many speeches. This brought tempeh to the attention of many more scientists and lay readers. Starting with the *Mother Earth News* in May 1976, a number of major magazine articles listed the USDA NRRC at Peoria as America's only source of tempeh starter. Over the next few years the Peoria group sent out some 25,000 tempeh starter cultures and instructions for making tempeh, free of charge to people and organizations requesting them; by 1981 the number had reached 35,000. Partly to stem the flood, in June 1977 Wang, Swain and Hesseltine wrote "Calling All Tempeh Lovers" for *Organic Gardening* magazine (circulation 1,350,000) describing an easy method for making this rice-based tempeh starter at home. Steinkraus organized a Symposium on Indigenous Fermented Foods, held in Bangkok, Thailand, in November 1977 in conjunction with the fifth United Nations-sponsored conference on the Global Impacts of Applied Microbiology (GIAM V), and attended by over 450 scientists from around the world. There 17 papers were presented on tempeh, more than any other single food. In 1983 Steinkraus edited the monumental *Handbook of Indigenous Fermented Foods*, containing 94 pages of information about tempeh, much of it from the 1977 Symposium. Hesseltine, Wang, and Steinkraus also did a great deal to help America's first generation of Caucasian tempeh manufacturers start their businesses and deal with their production problems. They patiently answered hundreds of phone calls and letters from young entrepreneurs trying to educate themselves in the basics of applied microbiology--all in the best

tradition of using tax dollars to serve the people and promote American agriculture and business. For their two decades of pioneering research, more than 65 publications on tempeh, and highly effective extension work, the US tempeh industry owes the Peoria and Cornell groups an immense debt of gratitude.

Also in America during the 1970s, many other researchers published on tempeh. Chen, Packet, and co-workers (1969-72) at the University of Kentucky published three papers on antioxidants in tempeh. In 1970 Noznick and Luksas of Beatrice Foods were granted a patent on a powdered tempeh made by liquid submerged fermentation. Kao (1974) at Kansas State University wrote his PhD dissertation on tempeh made from chick-peas (garbanzos), horsebeans (broad beans), and soybeans. James Liggett of Foundation Foods developed a tempeh meat analog containing sesame seeds (*Soybean Digest* 1975). Jurus and Sundberg (1976) were the first to convincingly demonstrate that the tempeh mold hyphae penetrated deep into the soybeans; this helped explain the rapid physical and chemical changes during tempeh fermentation. Beuchat (1976) in Georgia, studied peanut presscake tempeh. Charles and Gavin (1977) from the Biotechnology Research Center at Lehigh University, Pennsylvania, used a creative engineering approach to investigate the microbiological, biochemical, physical, and nutritional changes occurring during tempeh fermentation. Other studies were done by Souser and Miller (1977, *Rhizopus* lipase), Aramaki (1978, acceptability of tempeh made from bulgur wheat, millet, and azuki beans), Zamora and Veum (1979, fermentation improved the quality of tempeh protein), Gomez and Kothary (1979, tempeh from red kidney beans), Yueh et al. (1979, patent assigned to General Mills Inc. for a process for producing a soy & potato fried tempeh snack food), Rathbun and Shuler (1982, 1983, heat and gas transfer during tempeh fermentation).

During the early and mid-1970s, in addition to the groups at Cornell and Peoria, there were four other main groups that played leading roles in introducing tempeh to America: The Farm in Tennessee, The Soyinfo Center in California, Rodale Press in Pennsylvania, and the food- and counter-culture media.

A great deal of the credit for introducing tempeh to the American public goes to The Farm, a large spiritual and farming community of "long-hairs" living on 1,700 acres in Summertown, Tennessee. People at The Farm pronounced the name of this food as TEM-pi, instead of the standard TEM-pay. In late 1971 Alexander Lyon, a member of The Farm with a PhD in biochemistry, learned about tempeh while doing library research on soy-based weaning foods. In 1972 he helped The Farm to set up a small "soy dairy." While serving as its first manager, and using starter culture and literature supplied by Drs. Hesseltine and Wang at the USDA in Peoria, Illinois, he worked with Dianne Darling to make an occasional small batch of tempeh for the soy dairy crew. In 1972 or 1973 Dianne wrote a ten-step kitchen method for making tempeh using spore suspension for inoculum. Soon Deborah Flowers made two large batches of tempeh, incubated in the boiler room at the Canning and Freezing plant, and many Farm members had their first taste. The group developed a method for growing tempeh starter on chopped, sterilized sweet potatoes with cultures in test tubes. This was America's first Caucasian-run tempeh shop, although it was not a commercial shop. Tempeh was an immediate hit in The Farm's vegan or total vegetarian diet--a diet containing no dairy or other animal foods. In 1974 Stephen, The Farm's spiritual teacher, visited Amsterdam on a European trip and came back with a new realization of the potential of tempeh for The Farm and for a new industry in America.

In 1974 Cynthia Bates joined the Soy Dairy crew and learned the basic lab techniques for making tempeh starter from Alexander. She built a tempeh incubator out of an old refrigerator and by November 1974 was making 20-30 pound batches of okara tempeh, using the soy pulp (okara) left over after making soymilk. By January 1975 The Farm Tempeh Shop was making 80-200 pounds of tempeh a week. The incubator was expanded into a used bean dryer and sporulated okara tempeh (dried and ground) started to be used as a starter. In 1975, in order to share their discovery with people across America and around the world, the community (now having 1,100 members) featured a section on tempeh (written by Cynthia Bates) in their widely read *Farm Vegetarian Cookbook*, including the first tempeh recipes to be published in any European language (Farm 1975).

In 1975, after Wang, Swain and Hesseltine at the NRRC published their paper on mass production of tempeh spores, Bates set up a little laboratory and began making tempeh starter for use on The Farm. The starter was grown on rice, using the syringe inoculation technique and a spore suspension of starter sent periodically and kindly by Dr. Wang. By 1976 powdered pure-culture tempeh starter, made by Bates at the Tempeh Lab, was being sent out or sold to interested people. Publications were now needed to explain how to use the starter to make tempeh, then how to cook the tempeh. In 1975 or early 1976 Alexander Lyon typed up a three-page flyer called "Tempeh Instructions," which contained the first instructions in any European language for making tempeh at home, and listed The Farm as a source of tempeh starter. Bates wrote and The Farm printed a 2-page flyer titled "Tempe," which described how to make five pounds of tempeh and contained four recipes, including the world's first Tempeh Burger recipe. This flyer was distributed with the starter, along with "Fermentation Funnies," cartoons introducing tempeh. In 1976 Bates and co-workers wrote a 20-page article titled "Beatnik Tempeh Making" (later retitled "Utilization of Tempeh in

North America") for the Symposium on Indigenous Fermented Foods in Bangkok. By 1976 The Farm's satellite farms had established commercial tempeh shops in San Rafael, California, and Houma, Louisiana. A number of America's early tempeh shops (such as The Tempeh Works in Massachusetts or Surata Soyfoods in Oregon) were started by people who learned the process on The Farm. America's first soy deli, set up in August 1976 at the Farm Food Company's storefront restaurant in San Rafael, featured tempeh in Tempeh Burgers, Deep-fried Tempeh Cutlets, and Tempeh with Creamy Tofu Topping, the first tempeh dishes sold in an American-style restaurant.

The media blitz for tempeh that began in 1977 created a booming little business on The Farm for tempeh ingredients. A January 1977 article in *Organic Gardening* listed The Farm as the only known source of split, hulled soybeans. Orders began to arrive. Soon Dr. Wang at the USDA in Peoria, flooded by orders for tempeh starter, was forwarding many of them to The Farm. Then articles by The Farm (Cynthia Bates and Deborah Flowers) about tempeh in *Mother Earth News* (Sept. 1977) and *East West Journal* (July 1978) led to a surge of orders for both starter and split soy beans. By 1977 the Tennessee community, with Suzie Jenkins as head tempeh maker, was producing at least 60 pounds of tempeh a day, and they were using a centrifuge to dewater the soybeans after cooking and before inoculation--a technological breakthrough that soon caught on among commercial tempeh makers.

In 1977 Farm Foods was founded; it took over marketing of the tempeh starter, together with hulled soybeans and revised editions of the tempeh instructions (1977, 1978). The three items were sold nationwide as America's first Tempeh Kit by mail order and in some natural food stores. The starter was also sold separately with the leaflet. During 1978 Farm Foods promoted its tempeh starter and tempeh kit by serving grilled tempeh at numerous natural foods trade shows. A large

sidebar in the February 1978 issue of *Organic Gardening* magazine listing Farm Foods as the best source of tempeh starter and split beans, followed by letters of referral from Rodale Press thereafter, stimulated sales. Also in 1978 Hagler edited a revised edition of the *Farm Vegetarian Cookbook* ; it contained 12 pages on tempeh, including many recipes. In 1982 Farm Foods began actively advertising and selling bulk, powdered tempeh starter to America's growing number of tempeh shops, and by 1984 they had captured a majority of the market.

Prior to 1979 tempeh had been available on The Farm only on special occasions. In that year, however, a Tempeh Trailer, developed in Louisiana by John and Charlotte Gabriel, was brought to The Farm. The tempeh incubator was moved out of the Canning and Freezing building and made into a walk-in incubation room in the trailer. John Pielasczyk became head tempeh maker, and thereafter any Farm member could go at almost any time to the Farm store, open the freezer, and take home tempeh. In 1981 Margaret Nofziger, Farm nutritionist, wrote an article on "Tempeh and Soy Yogurt," with five tempeh recipes, for *Vegetarian Times* .

In late 1983 and early 1984 The Farm underwent a major financial restructuring. Farm Foods became financially independent from The Farm and in May 1984 the Tempeh Lab (under the directorship of Cynthia Bates) became independent of Farm Foods. Both became "for-profit" companies. In March 1984 The Farm published *Tempeh Cookery* , America's fourth popular book about tempeh and the first with full-page color photos (Pride 1984). To promote this book (and tempeh), in June 1984 Farm Foods and its sister company, The Book Publishing Company, served samples of deep-fried tempeh and several tofu dishes to 20,000 attendees of the American Booksellers Association Convention in Washington, D.C. Farm Foods was also planning to have one or more large tempeh companies (perhaps one on each coast of the USA) make private labeled

tempeh, which would then be sold nationwide through the company's extensive soymilk ice cream (Ice Bean) distribution channels. Farm Foods could then also use the tempeh, the starter, and the book to promote each other.

William Shurtleff and Akiko Aoyagi of The Soyinfo Center were also active in helping to introduce tempeh to America. They first became interested in tempeh in March 1975 after reading *The Farm Vegetarian Cookbook*. In their *Book of Tofu* (1975), they included a recipe for homemade tempeh and seven Indonesian-style tempeh recipes (learned from an Indonesian tempeh maker in Tokyo), the first such recipes ever published in English. This whole section was published in *Mother Earth News* in May 1976. In late 1976, during a two-week visit to The Farm in Tennessee, they wrote (with Cynthia Bates) a 4-page pamphlet titled "What is Tempeh?" which they enlarged and published in early 1977. In May 1977 they spent a month in Indonesia studying tempeh, and in June their article "Favorite Tempeh Recipes" was published in *Organic Gardening* magazine. In January 1978 William Shurtleff presented a paper and demonstration on how to make tempeh from winged beans at an International Seminar on Winged Beans in the Philippines. In July 1979 Harper & Row published their *Book of Tempeh*, the first book in the world devoted entirely on tempeh. It contained the first sizeable collection of American-style and Indonesian tempeh recipes (130 in all), the first illustrated descriptions of making tempeh, tempeh starter, and oncom on various scales in Indonesian tempeh shops, the first history of tempeh, detailed discussion of tempeh in Indonesian culture and of the many varieties of Indonesian tempeh, and the first recommendations for commercial names for the more than 30 types of tempeh that could easily be made in the West. It also contained chapters and reviews of the literature on tempeh nutrition and the microbiology and biochemistry of tempeh fermentation, plus the largest bibliography on tempeh to date (including many new Indonesian references), an annotated listing of 61 people and organizations

around the world connected with tempeh, and the first list of tempeh companies in the West. By mid-1984 some 20,000 copies of the paperback edition and 960 copies of the enlarged professional hardcover edition had been sold. In early 1985 Harper & Row published a revised second edition of the book. Between 1976 and 1982 Shurtleff and Aoyagi wrote eight articles on tempeh for popular and trade magazines. In March 1980 The Soyinfo Center published *Tempeh Production*, the first book describing how to start and run a commercial tempeh plant in industrialized or Third World countries.

In 1981 Shurtleff and Aoyagi wrote a book on tofu, miso, and tempeh that was published in Mexico in Spanish, and in 1982 they published books containing bulk tempeh recipes and tempeh labels. Starting in 1982 Shurtleff did extensive annual surveys of the tempeh industry and market in the USA, which were published yearly by The Soyinfo Center in *Soyfoods Industry and Market: Directory and Databook*. The Center also developed and sold color slide sets on "Tempeh," "Tempeh Production in the USA," and "Tempeh Production in Indonesia." In 1985 *The Book of Tempeh* was published in German as *Das Tempeh Buch*.

Another early pioneer of tempeh in America was Rodale Press in Emmaus, Pennsylvania, best known as the publisher of *Organic Gardening* and *Prevention* magazines. In the spring of 1975 Rodale's R&D department decided to follow up on the work with tempeh done by Hesseltine and Wang at Peoria. In early 1976 R&D food technologist Mark Schwartz began to work with Dr. Wang in Peoria to develop a simple, inexpensive way to make tempeh at home. They devised a tempeh kit including an incubator made from an inexpensive Styrofoam picnic cooler heated by a light bulb. For a Reader's Research Project, they sent the kit with instructions and a questionnaire to 60 readers across the country, and asked for feedback. The unanimous response was that people

found the new food easy to make and delicious (Podems 1976). This R&D work led to five major articles in 1976 and 1977. In March 1976 Brenda Bortz in "The Joys of Soy" introduced tempeh and Rodale's tempeh research to readers of *Organic Gardening* (OG). In January 1977 OG ran "Tempeh Keeps 'em Coming for More Soybeans." Jack Ruttle, a Rodale staffer, summarized the results of Rodale's research on tempeh to date and gave detailed instructions for making tempeh at home. This was the first major popular article on tempeh published in America. In June *Prevention*, the largest health-food magazine in America, ran a cover story and editorial by Robert Rodale titled "Tempeh, a New Health Food Opportunity." He visited America's first Caucasian-owned tempeh shop (run by Gale Randall), encouraged others to start tempeh shops and to "get in on the ground floor of a new industry," and predicted that tempeh might well become America's most popular way of using soybeans as part of the "coming soy boom." "Tempeh is on its way up," he wrote. "Before long it will be eaten widely and lovingly across this land of ours." Also in June OG published Shurtleff and Aoyagi's "Favorite Tempeh Recipes" and Wang, Swain, and Hesseltine's "Calling all Tempeh Lovers." In addition Rodale Press published books with extensive information on tempeh: *Home Soyfood Equipment* (Wolf 1981) and *Tofu, Tempeh, & Other Soy Delights* (Cusumano 1984). Wolf's book included a new method for making tempeh at home using unsalted soynuts, which took less time and cost only about 28% (10 cents) more per pound than the traditional method. Detailed plans for making a home tempeh incubator were given. *Organic Gardening* (March 1982) summarized Wolf's quick tempeh method.

Starting in 1971, the American media first began to take an interest in tempeh, when *Food Processing* magazine, in its "Foods of Tomorrow" section did an article on "Specialty Fermented Foods," discussing their potential acceptability in the American market. It concluded: "But of all fermented foods, tempeh, with its high ratings in taste, nutritional benefits, and simple, low cost

processing techniques, appears to be the most likely candidate for Americanization . . . Tempeh may be one of the next to appear in the US market place." In May 1976 *Mother Earth News* (Issue #39) ran a long excerpt on tempeh from *The Book of Tofu* by Shurtleff and Aoyagi. Media coverage expanded significantly in 1977. First came the three major Rodale Press articles mentioned above. In September *Mother Earth News* featured "How We Make and Eat Tempeh Down on the Farm," and in November *Vegetarian Times* ran "Tempeh." In July 1978 *East West Journal* ran its first tempeh story, "Make Your Own Soyburger" about the Farm's tempeh. These many articles contained recipes and detailed instructions for home preparation, and some gave the address of the NRRC in Peoria, Illinois as a source of free tempeh starter. In less than 18 months, over 25,000 people requested starter and began making tempeh at home. This early media coverage for tempeh was a veritable blitz for a largely unknown food, and most of the publications had large circulations. In addition descriptions of tempeh began to appear in popular books, such as Beatrice Hunter's *Fermented Foods and Beverages* (1973).

The first commercial Caucasian American tempeh shop was started in the winter of 1975 by Mr. Gale Randall in Unadilla, Nebraska. Randall, a former high school teacher, retired in 1971 and moved his family to the farm in Unadilla where he had grown up. Looking for alternative ways of securing his basic life needs (food, shelter, and clothing), he got interested in single-cell proteins (SCP) and in about 1974 happened to read about tempeh in the proceedings of an international conference on SCP in Kyoto. He read of it again in 1974 in *Today's Living*, a popular health food magazine. He contacted Dr. Wang at the USDA/NRRC in Peoria for starter and instructions. As he later recalled: "She did everything possible to help me get started. She was wonderful." He made tempeh for his family for roughly 6-12 months, then built a tempeh shop in the basement of his home and began selling the product commercially. At night he worked in the post office in Lincoln.

Robert Rodale's article in *Prevention* in mid-1977 brought him and his shop instant national prominence. Randall eventually developed a diverse line of tempeh products but conservative Nebraskans were slow to accept them.

The macrobiotic movement in America took a strong interest in tempeh, starting in the late 1970s. As early as 1974 Michio Kushi had stated (incorrectly) that "Tempe is used by Southeast Asian and Indonesian people like soy sauce." On 21 September 1977 Kushi, by then one of America's best-known teachers of natural foods and healing, speaking in Washington D.C. to the President's committee on food policy, recommended the use of traditional, naturally fermented soyfoods such as soy sauce, miso, and tempeh. Between 1978 and 1984 the *East West Journal* ran three major articles on tempeh (including one cover story) plus many additional recipes. The most important of these was Aveline Kushi's laudatory "My Favorite Tempeh Recipes" (August 1981). Aveline used tempeh extensively in diets for cancer patients. Those practicing a macrobiotic diet increasingly used tempeh as a basic daily protein source, and a number of them started tempeh companies.

Whereas the first generation of American tempeh makers had been Indonesian-Americans, the second generation were mostly long-haired, bearded Hippies or other members of the counter-culture, who were interested in natural foods, meatless diets, alternative lifestyles, and right livelihood as part of a spiritual life. In the midst of the world's largest meat producing country, they began to make tempeh as an alternative source of high-quality, low-cost protein. Many considered tempeh to be the finest "meatless meat" available.

By early 1979 there were 13 tempeh shops in operation in the US, 1 in Canada, and 4 in Europe, all in the Netherlands. Of the 14 North American shops, 3 were run by Indonesians and the rest by

Caucasians; 7 were run out of a home, restaurant, or food retail store, and 7 were run in connection with a tofu shop. Thus, not one was a bona fide commercial plant in its own building, specializing in tempeh.

In July 1979 Michael Cohen (who had formerly lived on The Farm in Tennessee) made his first tempeh at The Tempeh Works in Greenfield, Massachusetts. It was served at the annual Soyfoods Conference at Amherst. The company began regular commercial production in September. This was America's first Caucasian-run tempeh company to make only tempeh in a commercial building. Other early companies making only tempeh in a commercial building were Pacific Tempeh in California (from August 1980), Higher Ground Cultured Foods in Wisconsin (Aug. 1980), Soyfoods Unlimited in California (Feb. 1981), and Appropriate Foods in New York (March 1981).

The Tempeh Works in Massachusetts quickly grew to be the biggest tempeh producer in America at that time, reaching roughly 3,000 pounds a week by the end of its first year (Sept. 1980). The business was started for \$26,000 in a remodeled gas station with 1,200 square feet of floor space. Both the startup cost and the shop size were considered quite large at the time. The company's three main early problems (like many early tempeh shops) were learning how to prevent microbial contamination, undercapitalization, and owner-employee relations, due in part to hard work for long hours at low wages. Cohen chose to sell his tempeh refrigerated rather than frozen, and he developed the first effective steaming system to give such tempeh a long shelf life, 10 days in summer and 14-21 days in winter. By 1980 numerous articles about The Tempeh Works began to be published in regional and national magazines; the company ran ads for its tempeh to accompany many of these articles.

By the fall of 1981 The Tempeh Works was cranking out 6,000 pounds of tempeh a week in a shop that now looked far too small. Then with a capital infusion of \$30,000, it had doubled floor space to 2,400 square feet (including 500 square feet of incubation room floor area), and was employing 12 long-haired workers. Soon the little dynamo was being called "The General Motors of the tempeh industry." Production in September 1981 hit a peak of 6,800 pounds a week, but then the roof fell in. In early 1982 five competitors invaded the Tempeh Works' previously unshared prime market areas of Boston and New York; production dropped 35% and the company almost went under. In January 1982 Tempeh Burgers and Five-Grain Tempeh started to be air-freighted in from California. Slow to introduce variety tempehs and second generation products, the company finally struck back. In May 1982 it launched and promoted heavily a 3 Grain & Soy Tempeh (soy plus equal parts rice, millet, and barley), in July "New England" Tempeh Burgers, and in early 1984 a line of spicy Tempté Spreads. All products were marketed as Kosher/Pareve. In late 1983 the company moved into a new 4,000-square foot plant in Greenfield and by March 1984 they were making 6,000 pounds of tempeh a week, second highest in the industry.

By May 1982 Pacific Tempeh in Emeryville, California, had passed The Tempeh Works in tempeh output to become the industry leader. Founded and run by Travis Burgeson, Pacific Tempeh had started operation in August 1980 with an initial dream of making low-cost okara tempeh, marketed like fish sticks. Startup funds of \$40,000 secured a 1,000 square foot plant with a capacity of 5,500 pounds per week. From the outset, Pacific Tempeh sold the world's first vacuum packed tempeh, refrigerated, not frozen. In January 1981 they introduced America's second tempeh burger. Fried prior to packaging, it was the first to be made and marketed on a large scale. In March they began making all their own starter culture. In January 1982 they began, together with Soyfoods Unlimited, to air-freight their tempeh burgers to the East Coast, where the New England Soy Dairy distributed

them to receptive natural foods stores and supermarkets. In March 1982 Pacific Tempeh developed a handsome full-color poster advertising their tempeh burger, and in April they introduced the first Tempeh Salad/Sandwich Spread called Deli Salad. By the spring of 1982 production of all their tempeh products had reached 5,000 pounds a week. Roughly 80% of this tempeh was sold as tempeh burgers. In February 1983 they introduced Tempeh Lite, America's first commercial okara tempeh; it contained 25% by weight brown rice. After lengthy discussions of a merger with Soyfoods Unlimited, Burgeson finally sold Pacific Tempeh on 1 July 1983 to Quong Hop & Co., a large manufacturer of tofu and soymilk that had not previously made tempeh. Pacific Tempeh was kept as the brand name for Quong Hop's line of tempeh products. By early 1984 production had risen to 7,000 pounds a week. Quong Hop's first new tempeh product was a tofu-and-tempeh burger, made of mixed scraps of each.

Pacific Tempeh's arch rival in the San Francisco Bay area was Soyfoods Unlimited, founded and run by Valerie, John, and Gary Robertson. Incorporated in November 1980, they started making tempeh on 15 February 1981 in their state-of-the-art \$100,000 plant in San Leandro, California. Their efficient, 1,850-square-foot operation had a capacity of 10,000 pounds a week. They were the first commercial company to do dry dehulling and hull removal from their soybeans prior to cooking; for this, they used a simple and ingenious mill and vacuum cleaner system designed by the Department of Food Science at the University of Illinois but modified and enlarged by the Robertsons. They started selling frozen soy tempeh, but after 2-3 months were selling 90% of their tempeh refrigerated, after steaming. In June 1981 they introduced Soy & Rice Tempeh (using brown rice), and in September they introduced America's first nonfried tempeh burger, which they vacuum packed. In January 1982, as mentioned above, they started air-freighting 1,800 pounds a month of their tempeh burgers to the East Coast and picking up other new distributors. Shortly

thereafter they introduced a Tempeh Cutlet (a square tempeh burger with soy & brown rice) and then a Soy & Five Grain Tempeh. By the spring of 1982 production of all their tempeh products had reached 6,000 pounds a week, with tempeh burgers and soy tempeh being the two best sellers. In September they moved into an adjoining building, doubling their floor space to 3,700 square feet. In October they launched a magnificent full-page color ad for their tempeh burgers in several national vegetarian and counter-culture magazines. The catchy slogan ran "All the Sizzle... None of the Steak." Following sales of \$100,000 in 1982 (but only \$108 profit!), the company hit hard times in January 1983, when their master distributor on the East Coast (New England Soy Dairy) stopped carrying their products. But eventually they found new distributors, uncovered a large untapped market in Hawaii, and recovered strongly. In February they spent about \$10,000 setting a lab to produce their own starter culture. In June Lon Stromnes, head of Namaste Marketing, started to work for Soyfoods Unlimited as full-time marketing director, and in October they bought a used \$35,000 Kutter vacuum packager. In January 1984, with tempeh production at 5,800 pounds a week, they introduced a well-conceived media-release program and a tasty vacuum-packed tempeh lasagna, brand-named Leandro's, as part of a new line of Italian-style meatless tempeh products; it was called InterNaturals for the mainstream market. In May they again expanded into an adjoining building, increasing their floor space to 5,550 square feet. In May they debuted tempeh and Indonesian-style tempeh recipes at the International Food and Wine Show, but their Sambal Goreng Tempeh, Sweet & Sour Tempeh, and Bali Tempeh made only a small splash.

The fourth of the "Big Four" tempeh companies in America was White Wave. Founded in 1977 by Steve Demos in Boulder, Colorado, White Wave was initially a tofu shop and soy deli. Tempeh production started in 1979 and that year White Wave introduced Soy & Rice Tempeh, America's first commercial soy & grain tempeh. The company moved into a big new building in late 1980, and

began to make their own starter culture, and to sell all tempeh frozen, after steaming. Tempeh burgers were introduced in 1983 and by 1984 they were the company's best-selling tempeh product, followed by frozen soy tempeh, soy & rice tempeh, then 5-grain tempeh. Accounting for a fourth of White Waves total sales in 1984, tempeh was now the company's most profitable line of products. With a production of 5,850 pounds of tempeh a week, White Wave had become America's second largest tempeh producer (after Quong Hop & Co.), and distribution had reached California.

US tempeh researchers developed a number of important innovations in processing equipment and techniques that helped greatly in adapting tempeh to America, and to temperate climate production in general. While some of these have been mentioned above, we will summarize the key ones here. In 1964 Martinelli and Hesseltine at the USDA/NRRC in Peoria, Illinois, developed the use of perforated polyethylene bags as tempeh incubation containers. This revolutionized the production process. In 1975-76 Hesseltine and Wang at Peoria developed techniques for mass-producing pure-culture tempeh starter on rice using simple equipment and techniques. In 1976 Nelson and Ferrier at the University of Illinois developed and patented a low-tech, build-it-yourself soybean dehuller. It worked well (Shyeh et al, 1980) and homemade variations soon came to be used by many tempeh companies (Fiering 1981). In 1977 The Farm had been the first to use a centrifuge to dewater their cooked soybeans prior to inoculation; in 1979 Island Spring became the first of many commercial shops to use this technique--a major advance. In 1979 The Tempeh Works developed a steam pasteurizing process allowing them to sell refrigerated tempeh with a good shelf life. In August 1980 Pacific Tempeh sold the first vacuum-packed tempeh, and by 1983 much of America's tempeh (especially tempeh burgers) was being vacuum packed. In February 1981 Soyfoods Unlimited did the first commercial dry dehulling and hull removal from soybeans for

tempeh. A number of US tempeh makers (such as Michael Morearty of Hi-Pro Tempeh) began to visit Indonesia to learn more about traditional methods.

New sources and concepts of tempeh starter culture (inoculum) were needed to serve the rapidly growing industry. Prior to July 1980 the main source of starter for American tempeh companies had been Farm Foods in Tennessee, which sold a vacuum-dried powdered starter. That month GEM Cultures in Fort Bragg, California, began to make and sell Living Tempeh Starter, grown on agar in petri dishes. By early 1981 most of the US tempeh shops that did not make their own starter were buying GEM Cultures product. GEM cultures also sold starter for miso and shoyu koji and for viili, plus tofu coagulants. By 1983, however, many larger companies had turned to making their own starter (it was considered much less expensive, and more potent and reliable) and those which did not, generally purchased theirs from Farm Foods. In July 1982 Turtle Island Soy Dairy started selling liquid tempeh starter. To make its own starter, a company typically worked with a trained microbiologist (such as Hananya Kronenberg of Soy Systems, Alexander Lyon of Turtle Island, or a local university student), who showed them how to set up an in-house laboratory, use sterile techniques, and grow the starter on rice. The whole lab and training typically cost \$10,000 or more. In 1984 Farm Foods had about 60% of the US tempeh starter market, Turtle Island 35-40%, and GEM Cultures 0-5%.

New types of tempeh and tempeh products soon began to proliferate. In 1979 White Wave in Boulder, Colorado, developed America's first commercial multi-ingredient soy-and-grain tempeh, Soy & Rice Tempeh. In 1980 The Soy Plant in Ann Arbor, Michigan, developed Tempeh of the Sea (containing sea vegetables such as hijiki, dulse, and arame), which resembled fish sticks. In August 1980 Island Spring near Seattle, Washington introduced America's (and the world's) first

commercial tempeh burgers, made on a small scale in individual petri dishes. In January 1981 Pacific Tempeh began the first large-scale production and marketing of tempeh burgers; later that year Soyfoods Unlimited made the first nonfried burgers; and in mid-1981 Turtle Island initiated Tempehroni and Five Grain Tempeh (the first multi-grain tempeh, made with soybeans, rice, millet, sunflower seeds, and sesame seeds.) In 1981 Surata Soyfoods developed Sprouted Soy Tempeh. Sprouting the soybeans overnight increased the content of B and C vitamins, increased yield by 11%, and facilitated wet dehulling. Hi-Pro Tempeh in Gardena, Massachusetts developed a hickory-smoked tempeh snack, and 21st Century Foods near Boston produced a delicious sausage-shaped Millet & Soy Tempeh, and (in mid-1983) sausage-shaped Soylami. By February 1983 there were three brands of okara tempeh on the market, made by Pacific Tempeh (CA), Swan Gardens (FL), and Southwest Soyfoods (NM). Most contained some rice and/or soybeans too. Other distributed tempeh entrees included Chili Con Tempeh, Sweet & Sour Tempeh, Tempeh Enchiladas, Tempeh Pizza, and Tempeh Lasagna, Tempeh Mock-Chicken Salad, and Tempeh Mock-Tuna Salad.

Of all these second-generation tempeh products, tempeh burgers were by far the most popular. The term "tempeh burger" was coined in about 1975 by The Farm in Tennessee. Early recipes appeared in pamphlets published by The Farm in 1975 and The Soyinfo Center in 1977. The first recipe in a book appeared in *The Book of Tempeh* (Shurtleff and Aoyagi 1979). The first commercial tempeh burgers were launched in late 1980 and early 1981. They came precooked and preseasoned, fried or nonfried, typically weighing 3 ounces and packed two in a vacuum pack. By early 1984 at least eight brands were available nationwide.

In addition, during the late 1970s and early 1980s, many new tempeh dishes began to appear at soyfoods delis, cafes, and restaurants. The most popular ones, in descending order of popularity,

were tempeh burgers, tempeh salads (mock chicken or tuna), tempeh sandwiches (tempeh, lettuce & tomato, etc.), sloppy joe tempeh, tempeh cacciatore, tempeh cutlets, and tempeh stroganoff (Shurtleff and Aoyagi 1983). We wonder if overripe tempeh, whose distinct aroma, soft consistency, and velvety white surface resemble those of a fine Camembert or Brie cheese, will ever be popular in America, as it is in Indonesia.

As the tempeh industry expanded, the national media showed a new wave of interest. Three major media articles on tempeh were published during 1979, five in 1980, four in 1981, seven in 1982 (including a February *Soyfoods* magazine cover story titled "The Coming Tempeh Boom"), and three in 1983 (including feature articles in the *Los Angeles Times*, *Washington Post*, and *Sunset Magazine*). Complete references for each of these are given in *Soyfoods Industry and Market* (Shurtleff and Aoyagi 1984). Moreover, between 1977 and 1980 there were 18 new scientific journal articles on tempeh.

Between 1979 and 1984, seven books on tempeh (or with tempeh mentioned in the title) were published: *The Book of Tempeh* (Shurtleff and Aoyagi 1979), *Tempeh Production* (Shurtleff and Aoyagi 1980), *Using Tofu, Tempeh & Other Soyfoods in Restaurants, Delis & Cafeterias* (Shurtleff & Aoyagi 1982), *Tofu, Tempeh, Miso & Other Soyfoods* (Leviton 1982), *Cooking with Tempeh* (Seguin 1982), *Juel Andersen's Tempeh Primer* (Clute and Andersen 1983), and *Tempeh Cookery* (Pride 1984). In addition, cookbooks that had substantial sections on tempeh included the *Farm Vegetarian Cookbook* (Hagler 1978, rev. ed.), *Tofu Madness* (Olszewski 1978), *The Soy of Cooking* (Norton and Wagner 1980, 1981), *Soy Foodery Cookbook* (Ford 1981), *Home Soyfood Equipment* (Wolf 1981), and *American Wholefoods Cuisine* (Goldbeck and Goldbeck 1983).

During its early years, the US tempeh industry grew rapidly. The period from early 1979 to early 1983 was one of rapid growth in the number of producers. There were 13 commercial tempeh manufacturers in January 1979, 17 in 1980, 31 in 1980, 43 in 1982, 56 in 1983, dropping back to 53 in January 1984. At the latter date there were tempeh companies in 23 states; Hawaii's first tempeh company started in 1982 (Oda 1983). In early 1984 there were also 4 manufacturers in Canada and 25 in other Western countries, for a total of 83 in the West. The largest tempeh makers in North America in January 1984 are shown below.

LARGEST TEMPEH MANUFACTURERS IN THE UNITED STATES

Average Weekly Production

Rank 1984	Rank (lb/week) 1983	Company Name & State	Year Started	1982 May	1985 May	1984 Jan
1	1	Quong Hop/Pacific Tempeh, CA	1980	5,000	4,500	7,000
2	4	White Wave, CO	1979	1,900	4,750	5,850
3	3	Soyfoods Unlimited, CA	1981	3,000	5,000	5,800
4	2	The Tempeh Works, MA	1979	4,250	5,000	5,500
5	7	Appropriate Foods, NY	1981	500	1,200	2,000
6	6	Higher Ground, Inc., WI	1980	700	1,200	1,600
7	16	21st Century Soyfoods, MA	1981	150	250	1,050
8	NL	Panda Foods, NY	1983			1,000

During 1983 the US tempeh industry made an estimated 2 million pounds (900 metric tons) of tempeh, using 514 metric tons of soybeans. It retailed for \$5 million; the average retail price was \$2.50 per pound. There were about 200 employees. Tempeh production grew by 36% during 1982 and by 29% during 1983, making it the fastest growing soyfoods market in the US. The top four manufacturers produced 63% of the industry's tempeh. An estimated 95% of US tempeh was consumed by Caucasian Americans, since there were only 5,000 to 6,000 Indonesian Americans in the entire country and other Asian-Americans consumed almost no tempeh. Although all of America's earliest tempeh companies were run by Indonesian-Americans, all of these remained small, so that by 1984 not one of the 18 largest US companies was run by an Indonesian-American. (By contrast, a majority of the larger tofu companies were run by Japanese- and Chinese-Americans.) Among the top four companies, regular soy tempeh accounted for 33% of sales, tempeh burgers and other second-generation tempeh products for 48%, and soy & grain tempehs for 19%. Second-generation products were seen as the wave of the future.

Tempeh, a new and healthful, low-cost food that gave Americans "all the sizzle without the steak," would appear to have a bright future in the land of the meat-centered diet.

History of Tempeh in Canada . Inspired by Robert Rodale's article on tempeh published in *Prevention* magazine in July 1977, Robert Walker founded Canada's first tempeh company in his home in Port Perry, Ontario. A 58-year-old high-school teacher, Walker started selling tempeh in June of 1978. Each week, while teaching for 40 hours, he made 50 pounds of tempeh and starter, and drove 60 miles into Toronto through heavy traffic each Saturday to deliver it to 5 or 6 health food stores. His "How to Make Tempeh," Canada's first magazine article on tempeh, was published

in 1978. Walker also self-published a sheet of tempeh recipes. But in October 1979 he "burned out" from overwork and had to discontinue his pioneering tempeh activities for health reasons.

Canada's second tempeh company (Thistledown Soyfoods in Duncan, B.C.) was started in 1982 and by early 1983 there were five companies, as there were in 1984. All were quite small, making less than 200 pounds of tempeh a week. In 1984 O'Leary in Canada was writing a vegetarian cookbook titled *Tempeh Mexicana* , using tempeh in popular Mexican-style recipes.

HISTORY OF TEMPEH IN JAPAN

1905 to 1945 . It seems likely that Japanese travelers or traders visiting Indonesia during the 1800s or before saw, tasted, and wrote of tempeh, but as yet no written records have been found. In 1905 Kendo Saito, a professor in the Plant Physiology Laboratory of the Botanical Institute at Tokyo Imperial University, first described and illustrated what is today considered to be the main tempeh microorganism, *Rhizopus oligosporus* . He did not, however, mention tempeh itself, probably because he isolated the mold from rice meal cakes which he obtained from Chinese in Kobe, Japan. These Chinese used the cakes to prepare a rice-based fermented alcoholic beverage and said the cakes originated in Shandong (Shantung) province, China. This mold, never widely used in traditional Japanese fermentations, came to be known as *kumo-no-su kabi* , or "spider's web mold." In 1909 Saito wrote a 200-page book on useful fermentation microorganisms. Again he mentioned *R. oligosporus* , but did not mention tempeh. A great deal of subsequent study of the genus *Rhizopus* , including *Rhizopus oligosporus* , was done by Japanese researchers (Hanzawa 1912, 1914; Inui et al. 1965).

The first Japanese to mention and to study tempeh was the great microbiologist, Dr. Ryoji Nakazawa. Following Japan's victory in the Sino-Japanese War (1894-95), China had been forced to cede Taiwan to Japan. In 1909 Japan built a major research facility in Taiwan, the Taiwan High Commissioner's Office Central Research Laboratory, which soon became a focal point of Japanese microbiological research. Dr. Nakazawa, who had received much of his early microbiological education in Germany, worked at the Taiwan lab from its founding until 1940 and was long the leader of the research group. In his early studies Nakazawa had learned of tempeh through reading the writings of Prinsen Geerligs (1896), Went (1901), and others. In 1912 Nakazawa had asked a person from Southeast Asia to bring him samples of tempeh and onchom (ontjom; made from peanut presscake). He analyzed their microorganisms and repeatedly found *Penicillium*, a grayish brown mold, to be the predominant genus. In 1924 Yoshito Takeda, Nakazawa's co-worker, obtained more samples of these foods from Southeast Asia, and again found *Penicillium* to be predominant. *Monilia* (which in 1901 Went had said was the predominant organism) was not found, and Takeda assumed it had died during transport. In 1926 Nakazawa took a research trip to Java and Sumatra and carefully collected (in sterile containers) 33 samples of soy tempeh and onchom from various markets and small manufacturers. Nakazawa and Takeda analyzed the microorganisms in these fermented foods, and in 1928 published "On the Filamentous Fungi Used to Make Ontjom and Tempeh in the South Pacific" in the Laboratory's Annual Report. This was the earliest known published reference to or study of tempeh by a Japanese. They found the onchom microorganisms to be almost exclusively *Penicillium* and the tempeh microorganisms to be mostly *Penicillium*, but with substantial amounts of *Mucor*, *Rhizopus*, and *Aspergillus* as well. No *Monilia* was found and no species names were reported. Dr. Nakazawa never made tempeh, probably for lack of suitable inoculum. After World War II, Dr. Nakazawa compiled his classic 11-volume

Bibliography of Fermentation and Biological Chemistry (Hakko oyobi Seibutsu Kagaku Bunken-shu , 1950-65); strangely it lists no references to tempeh, even in the more than seven?? pages of references to *Rhizopus* fermentations (he may have listed it under *Penicillium* ??).

During World War II many Japanese stationed in Java and surrounding areas came to know about tempeh. They often called tempeh "Java natto," perhaps because both were fermented soyfoods, incubated in a plant wrapper (leaf or straw), and with some white that formed on their surface during fermentation. Japanese in charge of prisoner-of-war camps in Indonesia, New Guinea, Hong Kong, and Singapore allowed their prisoners to make soybeans into tempeh (Stahel 1946; Roelofsen 1946; Smith and Woodruff 1951; Grant 1952).

One of Dr. Nakazawa's youngest but eventually best known students was Dr. Masahiro Nakano, who worked at the Taiwan laboratory with Dr. Nakazawa from 1934 until the early 1940s and learned from him about tempeh. During World War II, Nakano went to Indonesia for three years as a lieutenant in the Japanese Infantry, as part of the Japanese occupation of Indonesia. There he found time to pursue his interest in fermented foods, although he did no formal microbiological research. He traveled widely, bought tempeh in many local markets, visited roughly five tempeh producers, and frequently enjoyed tempeh cooked Indonesian style, mainly as Tempeh Goreng. In about 1944, on the advice of Japan's great microbiologist, Dr. Shinichiro Sakaguchi, Dr. Nakano (then age 37) went to the National Food Research Institute (NFRI) and created a Department of Applied Microbiology. But little or no work was done on tempeh until World War II was over.

1946 to 1979 . After the war the Department of Applied Microbiology at NFRI, and especially Dr. Nakano and his student Teruo Ohta, introduced tempeh to Japan. They were the first to make and

serve tempeh in Japan. But Nakano's interest in tempeh was the academic interest of a microbiologist in a new fermented food. He was never directly interested in promoting or popularizing it (Nakano 1984, personal communication).

In about 1947-49 Dr. Nakano (or was it Ohta??) wrote the first article on tempeh published in Japan. It appeared in a very popular non-scientific journal, *Nosan Seizo* (Cit??). In those days Nakano and Ohta often made tempeh at NFRI; they served it to co-workers in various ways and everyone said that it was delicious. In the mid-1950s Nakano and Ohta (Ohta's specialty was natto fermentation) suggested to natto makers and the Japan Natto Association that they try to introduce tempeh as a commercial product. In the laboratory and in natto plants, big and small, the researchers showed natto makers how to make tempeh, but the idea did not take root. In 1959 Nakano wrote more about tempeh in a Japanese food journal??, then discussed tempeh in a larger paper on fermented foods at a 1959 FAO conference in India. In 1964 prior to the International Symposium on Oilseed Protein Foods, held at Mt. Fuji, Nakano asked Indonesians to bring fresh tempeh for others to see. In 1964 Ohta, Ebine, and Nakano wrote a journal article titled "Research on Tempeh." Part 1 described the properties of tempeh powder made in Indonesia. In 1965 Ohta (drawing heavily on a 1961 article by Ko), discussed the status of tempeh in Indonesia and the interest of FAO and UNICEF in tempeh since about 1955 as a source of high quality low-cost protein and, in powdered form, for its antioxidant properties. Ohta later wrote detailed chapters on tempeh in several books including *Fermented Foods* (Nakano 1967) and *Soyfoods* (Watanabe, Ebine, and Ohta 1971). In 1979 Nakano wrote *Handmade Healthy Fermented Foods* . This popular book contained a chapter on "Tempeh and Onchom" in which he described the foods and how they were made, but did not give actual recipes. Also in 1979 Ebine wrote an article about tempeh in a food research journal.

In 1960 Mr. Hayashi, director of the new Japanese-American Soybean Institute (*Nichibei Daizu Chosa-kai* ; forerunner of the American Soybean Association) in Tokyo, grew interested in tempeh. That year his institute published (in Japanese) a 4-page pamphlet describing Hesseltine's method for making tempeh and noting that members of the Japan Shoyu Association (*Shoyu Kyokai*) had visited Hesseltine's lab in Peoria, learned about tempeh, and received tempeh starter. He convinced Mr. Haruo Kato of Marukin Shokuhin (Marukin Foods Industry Co. Ltd.), a large natto manufacturer in Kumamoto (Kyushu), to make the first commercial tempeh trials in Japan. Samples were sent to the ASA, where it was served fried and drew nice compliments. The ASA planned to introduce tempeh to tempura restaurants to be served as tempeh tempura, but the project never got started, for Marukin reported that tempeh interfered with the natto fermentation and vice versa.

Another center of tempeh research in Japan developed during the early 1960s at the Food and Nutrition Laboratory, in the Faculty of Science of Living, at Osaka City University, in Osaka. Early research there was done by Dr. Kiku Murata (a woman), Dr. Hideo Ikehata, and co-workers. Dr. Murata, a biochemical nutritionist, studied tempeh with the famed pediatrician Dr. Paul György in the US during 1959 and 1960. In 1964 she and Ikehata co-authored an article with György (senior author) on antioxidants in tempeh. Between 1964 and 1980 Murata was senior author of eight publications on tempeh and co-author of five others; these related primarily to antioxidants in tempeh and to tempeh's nutritional value. Some of this early research was partially funded by a grant from the USDA under the PL 480 program from 1964 to 1969. The most important of Dr. Murata's publications was the four-part "Studies on the Nutritional Value of Tempeh (1967-71). Ikehata was senior author of four papers on tempeh between 1964 and 1968. Other members of the group included Wakaizumi, Sanke, Miyamoto, Ebata, Kokufu, Kasuya, and Sugimoto. During the

1950s and 1960s UNICEF took interest in the work with tempeh antioxidants. György eventually did tests mixing powdered tempeh with powdered milk to make the latter more resistant to oxidative rancidity in tropical countries (Nakano 1979).

There has long been a substantial population of Indonesians in Tokyo and some fine Indonesian restaurants. From time to time an Indonesian would make tempeh as a small side job for use in one or more restaurants?? In 1975 Mr. Muhammad Mustam, a former Indonesian tempeh maker living in Tokyo, was making small amounts of tempeh occasionally and selling it to a small circle of Indonesian friends. In March of that year Shurtleff and Aoyagi were first shown tempeh and how to make and cook with it by Mr. Mustam and his wife. They published this information in their *Book of Tofu* (1975) and expanded it greatly in their *Book of Tempeh* (1979).

The 1980s . In 1980 Fukakura, Asano, and Murata wrote "Survey on Acceptability of Tempeh," based on a survey of 50 members of a taste panel at Teikoku Women's College in Osaka. They found that 76% of the panel members preferred tempeh over natto (this percentage might have been less in northern Japan where natto is most popular), and that deep-fried tempeh, seasoned with salt, was liked best. Tempeh burgers were also well accepted. They concluded: "The possibility of acceptance of tempeh by Japanese is fairly great."

In 1982 Takai, a large Japanese manufacturer of tofu and soymilk equipment, working with KOPTI in Indonesia and with an eye on the US and European soyfoods industries, developed and patented a combination cooker and wet dehuller to aid in mechanizing and modernizing the tempeh making process.

Despite all the research and promotional work from the early 1960s until the early 1980s, tempeh had not yet been produced commercially in Japan. But starting in about 1983 new interest arose for various reasons: (1) the growing popularity of tempeh in the United States and Europe; (2) the activities of KOPTI, the new Indonesian trade association for tempeh and tofu makers; (3) the growing internationalization of the Japanese diet; and (4) the increasingly positive image of soyfoods as a source of high quality nutrition. Thus as Japan's first major postwar soyfoods revolution (soymilk) was getting into high gear, another new one was starting.

Five organizations deserve the lion's share of the credit for commercializing tempeh in Japan, starting in 1983: Torigoe Flour Milling Co., the National Food Research Institute (NFRI), The Japan Natto Assoc., Marukin Foods, and Marusan-Ai. Most of these were large established Japanese food companies, and several had been studying tempeh for more than a decade. They seized the opportunity boldly in launching tempeh.

Torigoe . The first company in Japan to start commercial tempeh production was Torigoe Flour Milling Co. (*Torigoe Seifun*), the nation's fifth largest flour milling company. With wheat quotas fixed by the government and supplies always limited, Torigoe was looking to diversify. In 1975 Mr. Hiroto Nakagawa, head of Torigoe's R&D department received an article on tempeh written by a professor (who??) in Kyushu University's Department of Food Science and Technology. Nakagawa asked for more details and Professor Tadao Watanabe in the department asked one of his students, Kazuhiro Takamine, to study more about tempeh. In 1976 Takamine joined Torigoe's R&D group and Torigoe began to do cooperative research on tempeh and other fermented foods with the department at Kyushu University.

In 1979 the tempeh research began to look very promising, so Prof. Watanabe recommended that Torigoe send Takamine to the USA for further studies. In 1980 Takamine arrived at the University of Minnesota. Working in the Department of Food Science and Nutrition under Dr. William Breene and with Indonesian PhD candidate Abdul Rivai, he began to realize the great potential of tempeh. Takamine returned to Japan in 1981. With solid practical and theoretical knowledge of tempeh, he set out to convince the management of Torigoe that they should invest in a tempeh plant. But the leaders were hesitant, fearing that tempeh might not be suited to Japanese tastes. So first, Takamine developed tempeh with a milder, improved flavor; those who tried it grew to like it a lot. Second, it was learned that the prestigious National Food Research Institute (NFRI) was investigating tempeh. Torigoe's head of R&D went to NFRI in February 1983 and showed them Takamine's product. NFRI researchers, surprised and impressed, told other companies that tempeh looked more promising than ever and even persuaded the Japan Natto Association to look at it carefully. Third, a growing number of articles on tempeh, many from the NFRI, began to appear in Japanese newspapers. And fourth, Prof. Watanabe from Kyushu began giving many lectures to dieticians, nutritionists, and home economists on the high nutritional value of tempeh. By now Torigoe's management had become excited about pioneering commercial tempeh in Japan.

In June 1983 Torigoe started making tempeh at their Fukuoka flour mill in a pilot plant that cost \$50,000 and had a capacity of 15 tonnes (metric tons) or 33,000 pounds of tempeh a month. They made the key decision not to sell plain tempeh, but rather to make two semi-prepared products, both called Gold Tempeh. One was tempeh cut into pieces the shape of small French fried potatoes. These "tempeh fingers" were then dipped into a batter made of vegetable juices, wheat flour, salt, and spices, dusted with bread crumbs, packed in a shallow tray, together with two packets of tartar sauce, and sold frozen. The consumer would then deep-fry them to serve crisp

and crunchy with the sauce. The second product was made by simply by pressing the ground trimmings from the first product into oval patties (no binding was used), then enrobing them in a breaded batter as with the "fingers." The tasty and nutritious morsels, were introduced like fish sticks or cutlets to a school lunch program in Kyushu, where they became very popular. They were also test marketed at several natural food stores, again with good results.

On 30 June 1983 the *Nikkei Sangyo Shimbun* , a large Japanese business newspaper (and many smaller papers), reported on a tempeh press conference held by Torigoe the day before. In mid-July 1983 Torigoe started commercial-scale production. Sales in 600-gm packs to institutions (schools, hospitals, natural food restaurants) began in July, and sales in 140-gm packs to retailers (natural food stores, department stores, and chain supermarkets) in November 1983. Packaged in beautiful full-color boxes with handsome flyers, the tempeh could be used in Western, Japanese, or Chinese style cookery, or as a snack food. Each of the two forms of Gold Tempeh, weighing 140 gm, cost 250 yen (about \$1.05). Nutritional value (17.5% protein, rich in vitamin B-12) was stressed in marketing. By early 1984 Torigoe was producing 10-12 tonnes of tempeh a month, or about 5,770 lb/week, making it suddenly one of the world's largest tempeh manufacturers--yet the product was only in the test market stage! Sales of about \$420,000 were projected for the first year. In early February 1984 Takamine spent five days in the US studying tempeh, including two days at The Soyinfo Center, where he met with leading California tempeh makers. Soon thereafter Torigoe began selling their tempeh at big department stores in Kyushu (such as Iwataya) and at Natural House in Kobe. But most of their tempeh was still sold to schools. Mr. Torigoe, president of Torigoe, thinks that tempeh will become a part of the daily Japanese diet. Dr. Watanabe at Kyushu University has published on tempeh's nutritional value, especially the dramatic increase in its

content of vitamin B-12 during fermentation (*Rinsho Eiyo* , Jan. 1983??; *Yomiuri Shimbun* 23 May 1983; Takamine, personal communication 1984).

Marusan-Ai . Founded in 1952, Okazaki Marusan was primarily a miso maker during its first two decades. In February 1973 Mr. Naoki Kawai, manager of Marusan's development section, discovered tempeh in Indonesia, brought back tempeh starter from Bogor University, and began to study tempeh production and cookery in his laboratory. Since making the koji for Marusan's soybean miso was very similar to making tempeh, the research advanced rapidly. In 1974 the company launched soymilk, then in January 1983 the company changed its name to Marusan-Ai (Ai means "love"). In August 1983, with soymilk sales booming, Marusan-Ai started pilot plant production of tempeh.

Marusan-Ai invested \$129,000 (30 million yen) to remodel part of their main miso plant in Okazaki city, Aichi prefecture, to give them a capacity of 2 tonnes of tempeh a day. They decided to put their full energy into marketing tempeh (just as they did soymilk and miso), focusing their efforts on west and south-central Japan, where natto was not popular. They incubated the tempeh in shallow (2-inch-deep) polypropylene plastic trays. In January 1984 they introduced their tempeh to dietitians and in February 1984 they began to distribute pasteurized, refrigerated bulk tempeh (500 gm and 2.5 kg) for use in local school lunch programs and hospitals, and by caterers. They published a 27-page booklet titled "A New Soy Protein Food for Tomorrow: Marusan's Healthy Tempeh," which included a description with photographs of their tempeh production process and eight Japanese-style recipes. In March they began selling 125-gm and 250-gm cakes retail to consumers, brand-named Sukoyaka Tenpe ("healthy-robust tempeh"). By May 1984 Marusan-Ai was producing 30 tonnes (66,000 pounds) of tempeh a month or 15,148 lb/week, making them the

largest tempeh manufacturer in the world. And in June they started selling tempeh in supermarkets in local Aichi prefecture. Their plant now had a capacity of 2-5 tonnes a day, and their four technical men each had degrees in agricultural chemistry. Most of their tempeh was sold to local schools and hospitals, pasteurized, then refrigerated. Much of the tempeh was used as a meat replacer, as in Sweet-Sour Pork, Tempeh-Hijiki Saute, and the like.

The Japanese food industry and consumers have watched Marusan-Ai's work with tempeh with great interest, for by 1984 the company was one of the country's two largest soymilk makers, and one of the five largest miso makers. More important, Marusan-Ai was widely regarded as one of Japan's most dynamic, innovative, and forward looking food companies. In June 1984 *Toyo Shimpō*, a major Japanese soyfoods newspaper, predicted a significant expansion of Japan's tempeh market after Marusan-Ai's entry. The firm reportedly had big plans to expand production considerably. By June 1984 they were developing second-generation tempeh products such as breaded tempeh, a hamburger in which tempeh was the main ingredient, and *tempeh kamaboko* (a fish and tempeh product). They hoped to introduce these into local school lunch programs and distributed them through their extensive soymilk routes.

National Food Research Institute (NFRI). Work on tempeh at the NFRI picked up during the 1980s. Under the umbrella of various scientific cooperation agreements, Japan had joint research programs with Indonesia and other Southeast Asian countries. The NFRI and Bogor University had a joint research program in microbiology. Ohta and Katoh, both of NFRI, spent various periods of time in Bogor, studying tempeh and other foods. From January to March 1983 Mrs. Ratna Siri Hadioetomo, one of Indonesia's best basic microbiologists, from Bogor University, did research at NFRI, where she taught the Japanese researchers more about tempeh, and also did some research

on tests for vitamin B-12 in tempeh. Mr. Noriyuki Okada of NFRI worked closely with her in studying vitamin B-12 production in tempeh, and he made tempeh regularly at the lab. By mid-1983 the NFRI was assembling a tempeh team of Ohta, Okada, and Katoh. One project was to develop a new tempeh starter containing *R. oligosporus* plus two other microorganisms, one to produce vitamin B-12 and one to produce lactic acid. The latter organism, tentatively named *Lactobacillus soyae*, had been found on Nepalese pickles and was one of the few lactic acid bacteria known to grow well on plant protein foods. Its lactic acid could replace the vinegar or prefermentation now used to keep the pH of tempeh low, to prevent growth of contaminating bacteria, such as natto bacteria. In early 1984 Okada went to Indonesia to get cultures for production of vitamin B-12 in tempeh. The NFRI was having starter made in bulk for itself and the Natto Association by a commercial maker of koji starter cultures?? But perhaps most important the NFRI worked closely with the Japan Natto Association to interest that group in tempeh and to help individual members start production.

Japan Natto Association. The idea of Japanese natto makers making commercial tempeh, having smoldered for over 25 years, suddenly caught fire in about 1983. Natto production had expanded steadily throughout the postwar period. From 1958 to 1982 natto production grew at the admirable compound rate of 6.2% year. Yet per capita consumption in 1982 was still only about 1.4 kg per capita per year, and many Japanese simply did not like this unusual food with its strong ammonia smell and the many long thin stretchy threads that appeared when it was eaten. Thus, by the early 1980s natto makers were looking for a new product, ideally a fermented soyfood, to help expand sales. In May 1981 Ohta of NFRI gave a lecture on tempeh to the Natto Association and showed some samples he had brought from Indonesia. He gave another lecture in September. The head of the Japan Natto Association, Mr. Noboru Ose took an interest in tempeh, as did Mr. Goro

Kanasugi, an officer of the Association. Both men were natto manufacturers. They reasoned that tempeh and natto were made by similar processes and with similar equipment, and could be distributed via natto distribution channels. Both could be used "to help Japanese avoid excess consumption of animal proteins." In May 1983 the Natto Association, at a meeting in Tokyo, decided to go ahead with tempeh research and popularization, including recipe development. Ohta agreed to serve as an advisor. In May 1983 the *Yomiuri* newspaper ran a large article on tempeh entitled "Natto That Doesn't Smell; Even Young People Like It." It described tempeh and its popularity in Indonesia and America, but surprisingly referred to tempeh repeatedly as "tempeh natto," a term that both the Natto Association and NFRI apparently wanted to popularize to aid sales of both tempeh and natto. In April 1984 Ohta wrote an article on tempeh in a popular health magazine, calling it "Java Natto" and lauding its ability to prevent geriatric diseases.

We feel that the use of the term "natto" in conjunction with tempeh is both deceptive and unfortunate, since tempeh and natto bear very little resemblance to one another. They are made in different ways with completely different organisms (tempeh with a mold, natto with bacteria), they look and taste very different (many people who like tempeh do not like natto), and they are served in very different recipes. Moreover, all of the other major tempeh makers in Japan call tempeh by its correct name. Hopefully the Natto Association and the NFRI will soon drop the term "tempeh natto."

In June 1983 the Natto Association sent a team of three men to Indonesia to study tempeh. Mr. Goro Kanasugi, Mr. Hisao Nagayama (a natto historian), and Mr. Kikuo Chiba spent five days in Jakarta, Bogor, and Yogyakarta, looking at tempeh production and visiting KOPTI. The trip was successful, and on their return they presented a report. In July the Natto Association founded a

research laboratory in Omiya city (Saitama prefecture) and at the end of July it started to produce tempeh spores for members of the Association only, and (perhaps) to introduce tempeh as "tempeh natto" in Japanese confections and as a meat extender. They were applying for a patent on tempeh and developing a tempeh cooking pamphlet.

On 2 July 1983 an interesting meeting was held at the Natto Association headquarters in Tokyo. Five leaders of the Association, Ohta and Katoh from NFRI, William Shurtleff from The Soyinfo Center, and Mrs. Yasuko Torii, author of books on natural foods and farming, met for 6 hours to discuss developments with tempeh in the USA and strategies and tactics for introducing tempeh to Japan. The 21 July 1983 issue of *Toyo Shimpo* published extensive information on tempeh in an interview with Shurtleff and Aoyagi.

A colorful leader of the natto-tempeh movement was Goro Kanasugi, vice president of the Natto Association. He started a soyfoods restaurant (when??) named Mame-no-Ko ("child-of-soybean") in Omiya city, Saitama prefecture. By mid-1983 he was serving tempeh there as an alternative to meat in various dishes: tempura, harumaki (spring rolls), karinto (sweet fried dough cake), curry sauce, sauteed vegetables, croquettes, and various others. Many of his recipes contained 10-20% chicken or meat. He was hoping to establish a chain of tempeh restaurants in major cities (Kanasugi 1983). He also developed and sold Tempeh Senbei (traditional rice crackers containing 15% ground tempeh) and Tempeh Okoshi (a crunchy millet-based confection containing 20% ground tempeh). He made his tempeh in one room of his natto plant?? Kanasugi also wrote a number of articles on tempeh.

By December?? 1983 the Natto Association had a big meeting where members brought 100 tempeh dishes, and a cooking teacher prepared 5-6 additional recipes. The food was very well accepted. They decided to call 1984 "The First Year of the Tempeh Era" (*Tenpe Gannen*). A number of natto producers were then organizing to start at least one joint venture tempeh plant, with the aim of starting commercial production. They had finally realized that tempeh cannot easily be made in natto plants, since natto bacteria are the major bacteria causing spoilage in tempeh. In 1983 and 1984 two large natto companies began making tempeh--both prompted by the Japan Natto Association's promotional work for tempeh. They were Marukin Foods and Takashin.

Marukin Foods. The first natto company to start large-scale production of tempeh was Marukin Shokuhin (Marukin Foods Industry Co. Ltd.). Located in Kumamoto, Kyushu (Japan's southernmost main island), they were (in 1984) one of Japan's Big Five natto manufacturers, and they also made several other foods such as roasted soy flour (*kinako*), tofu, and *konnyaku* . In about 1964 Mr. Hayashi of the Japanese-American Soybean Institute suggested that Marukin start to study tempeh. At that time Marukin was looking for a new product, so Mr. Haruo Kato (the brother of Marukin's president and chief of natto production, research, and development) began with great interest to collect material and investigate this little-know fermented soyfood. Kato obtained tempeh culture from an unknown source in 1964 and was soon making small batches of tempeh. However the company eventually came to believe (incorrectly) that tempeh culture could interfere with the natto fermentation, and taste tests of tempeh led Kato to feel that it might be difficult to introduce tempeh into Westernized diets in Japan. So interest in tempeh waned. In July 1982 Marukin and eleven other small- to medium-sized soyfoods manufacturers from throughout Kyushu joined to establish the Kyushu Soyfoods Industry Association (*Kyushu Daizu Shokuhin Kogyo Kumiai*). Marusan's president, Itsuo Kira, became head of the cooperative Association. To help them

compete with larger companies, and supported by Japanese government aid, they built a large and modern factory (6,600 square meters), with a daily capacity of 15 tonnes of natto and 6 tonnes of *kinako* and soy soup base (*gojiru no moto*). In April 1983, this new natto factory, the largest in Japan, started production, employing 85 workers. Marukin decided to use its former natto factory to make tempeh, since there was a growing interest in soyfoods and healthful foods, and since they already had extensive experience in making fermented soyfoods. In November 1983 Marukin Foods launched SunSeed brand tempeh. An article on the product in the 1 December 1983 issue of the *Japan Food News* (*Nihon Shokuryo Shimbun*) was headlined "nonsticky natto" and by May 1984 they were selling 1,500 packs of 200 gm each (300 kg) daily, about 4,620 lb (2,100 kg) a week or 9,150 kg a month. They were also developing secondary tempeh products, including snack foods, paste-type foods, and fried foods. The person in charge of tempeh production and sales was Moto-o Kira, eldest son of the president, Itsuo Kira, and next to top man in the company. Marukin sold its tempeh in department stores and in supermarkets at their own in-store booths. To promote tempeh, the company employed two professional nutritionists to do demonstrations and lectures at cooking classes. Marukin soon hopes to sell tempeh to school lunch programs.

Takashin Foods . Takashin Shokuhin is a new company, a spinoff from a large natto manufacturer called Takato. In 1983 they built a new tempeh plant in Tokyo and began to sell their tempeh as "Tempeh Natto" in small plastic trays. By 1984 their tempeh was being sold at Indonesian restaurants in Tokyo, at Roppongi and Ginza. When start?? How much do they make??

From 1983 on research, publication, and promotion work related to tempeh in Japan increased dramatically. On August 5 the Japan Soyfoods Research and Popularization Association held a meeting in Tokyo at which Prof. Tsujimura, professor of nutrition, lectured on "Will Tempeh Fit into

the Japanese Diet?" and showed slides of tempeh in Indonesia. Many businessmen attended and showed interest in tempeh. Also in August Nihon Kogyo (a big mining company) showed an interest in making tempeh starter and Kyodo Press agreed to distribute articles on tempeh to many local papers.

In July 1984 the Japan Tempeh Research Society (*Tenpe Kenkyu-kai*) was founded in Tokyo to provide a forum for ongoing investigation, discussion, and popularization of tempeh. Dr. Watanabe of Kyushu University was chair, and Dr. Nakano was advisor. In June *Shokuhin Kogyo* (The Food Industry) magazine became the first in Japan to devote a special issue to tempeh. There were articles by Noguchi (recipes), Takamine (production and utilization: technological developments and problems to be solved), Ebine (characteristics and use), and Watanabe (antioxidants). NFRI planned an international symposium in Tsukuba for the fall of 1985 to discuss tempeh and natto.

Yet as of mid-1984 tempeh was not yet widely available at food stores in Japan. The only known retail outlet in Tokyo was Natural House in Aoyama. The only outlet in Kobe was also Natural House, selling Torigoe tempeh.

The future of tempeh in Japan looks promising. As of mid-1984 a number of large Japanese food companies were seriously considering tempeh production. These included: Yuki-jirushi (Snow-brand), Japan's largest dairy products company (with 1982 sales of \$1.8 billion), which was developing a tempeh with an improved flavor; Kibun, a huge food company and Japan's largest soymilk manufacturer; Takasago Koryo, a large flavor and fragrances company, which may work with Nihon Kogyo (the mining company); and a big food company in Hokkaido.

The large amount of okara produced by Japan's huge tofu and soymilk industries could serve as a valuable, low-cost, nutritious raw material for making tempeh. More important, when Japan's sophisticated fermented soyfoods technologies start to be applied to the tempeh making process, exciting new developments are sure to result. Likewise, when fine Japanese chefs set out to create new tempeh recipes--from Teriyaki Tempeh to Tempeh Tempura--the world is sure to take notice. Indeed, Japan could soon lead the world in tempeh research and development--and in large-scale tempeh production.

HISTORY OF TEMPEH IN CHINA, AND SOUTH AND SOUTHEAST ASIA

History of Tempeh in China and Taiwan . As mentioned previously at Indonesian History, a tempeh-like product was observed in Beijing, China in 1931 by William Morse. In the log of the Dorsett-Morse Expedition (Vol. 10, p. 6273) he gave a good photograph and the following description: "Soybean Cake. Peiping, China. A life-sized picture. Chinese name ` *Tou chiah ping* ' ("soybean fried cake"). Small cakes made from boiled soybeans. The beans are pressed into small round cakes which are allowed to develop a mold--taking about seven days. These cakes are broken into small pieces and fried in sesame oil." There are no known subsequent references to this Chinese product in any language.

In 1983 William Shurtleff asked at least 10 people in China connected with soyfoods if they had ever heard of *tou chiah ping* and showed them the characters. None had. Tempeh could be produced easily by Chinese companies making soybean jiang or soy sauce and it would fit nicely into Chinese dietary patterns. But given the proverbial conservatism of most Chinese toward new foods, it might have difficulty in catching on.

In the early 1980s Dr. Steve Chen, Director of the American Soybean Association in Taiwan, wrote two books, *Soy Foods* (1980) and *Handbook of Soy Oil and Soy Foods* (1981), both in Chinese. In each book he discussed tempeh, writing its name with two Chinese characters (meaning heaven + sea shell), which he chose to sound like "tempeh." (In pinyin these are written and pronounced *tian-bei* .) A friend of Chen's, a microbiologist who traveled to Indonesia, developed a tempeh inoculum with a shrimp flavor.

As of mid-1984 there were no known tempeh manufacturers in China or Taiwan. More research is needed on tempeh in China.

History of Tempeh in Southeast Asia . Tempeh migrated with Indonesian travelers to Malaysia and Singapore in early times, although no definite dates of introduction are known. The earliest known journal article about tempeh from Southeast Asia was written in 1968 by Diokno-Palo and Palo in the Philippines. It stated that there was no record of tempeh having ever been made or sold in the Philippines, but the authors recommended its introduction. In 1976 Bhumiratana described a pilot process for making tempeh developed at Kasetsart University in Thailand (Goodman 1976). In 1977 Noparatnaraporn from Kasetsart presented a paper on "Factors Affecting Fermentation and Vitamin B-12 in Tempeh." Also in 1977 Yeoh and Mercian from the Malaysian Agricultural Research and Development Institute (MARDI) presented the first known report on "Malaysian Tempeh." Both have been summarized by Steinkraus (1983). The ASEAN Protein Project stimulated research on tempeh. Noranizam (1979) in Malaysia studied *Rhizopus* isolated from tempeh.

History of Tempeh in India . In about 1936 (according to van Veen 1962) a group of missionaries from Travancore, a poor region from south India, wanted to make and introduced soy tempeh. Van

Veen gave them a 3-week course in production methods. When they returned to Travancore, they made good quality tempeh, but the Indian people there had no interest in this unknown mold-fermented product, and the experiment failed.

In 1959 Dr. Nakano of Japan discussed tempeh at an FAO conference held at the Central Food Technological Research Institute (CFTRI) in Mysore. In 1960 Prawiranegara at the Fourth Pan Indian Ocean Science Congress, described three methods for preparing tempeh starter culture. In the late 1970s researchers at CFTRI in Mysore discussed the process for making a soy & peanut tempeh, and its nutritional value (Bai et al. 1975; Bhavani Shankar et al. 1978). In 1979 Bai and co-workers from CFTRI discussed the nutritional value of tempeh as a supplement to rice-based diets. In 1981 David and Verma at Pantnagar found that soy & fava bean (bakla) tempeh (1:1) had better palatability than pure soy or 3:1 soy:bakla tempeh. In 1982 the Soy Production & Research Association in Bareilly was studying the possibility of producing India's first commercial tempeh. By 1981 M.P. Vaidehi in the Dept. of Rural Home Science, University of Agricultural Sciences, Bangalore, was making her own tempeh, then did a study serving tempeh curry and tempeh chips to 100 villagers and 100 urban consumers. The two products were well accepted. She was working to introduce tempeh to Indian villages (Vaidehi and Vijayakumari 1981; Vaidehi 1981, 1984 personal communication).

History of Tempeh in Sri Lanka . From April to June 1979 Mr. Thio Goan Loo, a Chinese-Indonesian stationed at the Royal Tropical Institute in Amsterdam, was assigned, by the International Technical Assistance Department of the Dutch Ministry of Foreign Affairs in The Hague, to teach low-tech soyfoods in Sri Lanka. He taught many people, especially those associated with the Soyfoods Research Centre at Gannoruwa, how to make and serve tempeh. In January 1981 *Soyanews*

introduced tempeh to its many Sri Lankan readers, with a description of how to make tempeh at home plus several recipes (CR 53). The May 1981 issue of *Soyanews* featured a cover story on tempeh, calling sun-dried tempeh "soya karawala," the latter being a popular type of Indonesian dried fish, which tempeh apparently was found to resemble in texture and flavor. As *Soyanews* continued to praise the virtues of tempeh (June, July 1981; Oct. 1983; April, June 1984) and the Soyfoods Research Center at Gannoruwa, Peradeniya continued to teach people how to make and use it, the new food caught on surprisingly rapidly. Soon?? starter was available locally for people who wanted to make their own on a home or village scale. In 1983 a team from the Research Center was sent to Indonesia for two months to study tempeh. They seemed to prefer fresh tempeh to the dried tempeh typically sold in Sri Lanka. Sri Lanka has a nice balance of both research and extension work with tempeh. This could be the beginning of the first successful introduction of tempeh to a Third World country having no Indonesian influence.

HISTORY OF TEMPEH IN LATIN AMERICA AND AFRICA

History of Tempeh in Latin America . In Latin America, tempeh was first mentioned by Stahel in Surinam in 1946. He wrote: "Here in Surinam, as in the East Indies, most of the soybeans are consumed in this form." In 1964 Martinelli, a Brazilian scientist working in the US with Hesselstine at the USDA/NRRC in Peoria, Illinois, developed the extremely important technique for making tempeh in perforated polyethylene bags. In December 1980 *Natura* magazine in Mexico published a cover story on tempeh by Heltova (largely pirated from *The Book of Tempeh*). In December 1981 *Quadernos de Natura* published an 86-page booklet on tofu, miso and tempeh by Shurtleff and Aoyagi. Yet as of mid-1984 there were no tempeh shops in Latin America (except in Surinam) and no research was underway.

History of Tempeh in Africa . Shortly after World War II, tempeh was introduced in Southern Rhodesia. Van Veen recalled that one of his co-workers had gone there and noticed that a lot of locally grown soybeans were being exported rather than being eaten by the people. Working with the local food technology institute, he and the staff made tempeh for hospitals. The United Nations' FAO gave technical advice and the project looked promising, but it eventually failed since the product was not accepted by the general population, which had no experience with mold-fermented foods (Autret and van Veen 1955; van Veen 1962). György (1962) reported that in 1955 he had received tempeh from the Ministry of Health in Salisbury.

In 1971 Mr. Thio Goan Loo, a Chinese-Indonesian, helped to introduce tempeh (along with other low-tech soyfoods) to Zambia (Thio 1972), but it is not known what became of his efforts. In 1977 Bahi El-Din and co-workers, having done research on the basic tempeh fermentation process at Wageningen, Netherlands, published an article about it in the Sudan. Also in 1977 Djurtoft and Jensen investigated the production of tempeh from beans widely grown in Africa--broad beans and cowpeas, used as is or mixed with wheat or barley. Deep-fried tempeh slices were well accepted by a taste panel of 20 Africans. In 1980 Raintree in Ibadan, Nigeria, published a short article on how to make tempeh from the seeds of the fast-growing leucaena or ipil-ipil tree. The only place this tempeh was made traditionally was in the dry, inhospitable hill country of Gunung Kidul in south central Java. As of mid-1984 we know of no tempeh production or research in Africa.

OUTLOOK AND PROSPECTS FOR TEMPEH

One indication of the widespread and growing interest in tempeh appeared at the United Nations-sponsored international Symposium on Indigenous Fermented Foods (SIFF), held in conjunction

with the fifth international conference on the Global Impacts of Applied Microbiology (GIAM V) convened in Bangkok in November 1977, and attended by over 450 top researchers from around the world. There 17 papers were presented on tempeh, more than any other single food. Those proceedings, edited by Steinkraus, were published in 1983 in *Handbook of Indigenous Fermented Foods* .

In the US only a very small percentage of the population (perhaps 3-5% in 1984) has heard of, much less tasted, tempeh. Thus the main problems are education, publicity, and public acceptance. There is a great need for tempeh to become more widely available and for more American-style second-generation tempeh products (such as tempeh burgers) to be marketed. Solutions to occasional contamination/spoilage problems must be found. Research might help by developing a strain of *Rhizopus* with white spores or developing a mixed inoculum containing a beneficial bacterium that produces both vitamin B-12 and lactic acid (to lower the pH against harmful bacteria).

In Third World countries, where tempeh could make a major contribution, there are numerous problems to its introduction: (1) need for education and promotional work; (2) the difficulty of changing traditional food patterns, especially in areas that have no experience consuming mold-fermented foods (as in most parts of Africa), to which there may be large resistance; (3) teaching uneducated people how to prevent tempeh contamination; (4) developing sources of or methods for making tempeh starter; and (5) finding distribution systems that can deal with tempeh's short storage life when it is not refrigerated. Nevertheless, the experience in Sri Lanka seems to indicate that if tempeh is properly introduced and promoted, it can be a real hit with people in developing countries, even if they have no experience with such fermented foods. Of greatest value would be

a network of soyfoods training centers in developing countries (like the one in Sri Lanka) where local people could learn how to make tempeh and use it in popular local dishes.

Tempeh offers great hope for increasing local supplies of low cost protein, while also providing local employment opportunities.