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Chapter 1

Food Fermentation Research and Development

by

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In the last 20 years, considerable interest has developed in the West in learning the ways employed by non-Western peoples in the use of microorganisms to prepare attractive, nutritious, and highly acceptable foods from legumes and cereals. This has occurred in the West, at least in the United States, for several reasons. One is the interest in the export of agricultural commodities to importing countries which use the commodity in the preparation of traditional foods made by fermentation. Studies on fermented foods at the Northern Regional Research Center were initiated to better understand how U.S. soybeans were used in making the Japanese product, miso (Hesseltine and Shibasaki 1961, Shibasaki and Hesseltine 1961a, 1961b). A second reason is the concern of many people about the nutritional value of foods, and especially the realization that vegetable proteins and oils have great merit as foods. Thirdly, there is an interest in the activities of microorganisms used in food fermentations. The industrial use of fungal enzymes was introduced from the koji process used in making sake and shoyu, in which fungal amylases and proteases play an important role. It is apparent that, besides these enzymes, other secondary products are produced, and some constituents of the substrate are either destroyed or modified. Fourthly, and to a lesser extent, there has been an interest in the bacteria, yeasts, and molds selected through the centuries for making a specific product. Amylomyces, a mucoraceous genus, is not known to occur anywhere in the world except in the starter cultures used in food fermentations in China, Indonesia, and the Far West (Ellis et al. 1976). Fifthly, students from areas where microorganisms are used in preparation of traditional foods have used these processes as research topics during their stay in the West.

Because of these trends, a variety of scientific disciplines have been involved in studies on fermented foods, including food scientists,
biochemists, bacteriologists, mycologists, anthropologists, enzymologists, nutritionists, and chemists. Consequently, publications are scattered in various abstracted journals, including such diverse ones as *Journal of Food Science, Applied and Environmental Microbiology, Agricultural and Biological Chemistry, Mycologia, Journal of Science of Food and Agriculture*, and *Economic Botany*. Moreover, literature often appears in provincial publications, institute reports that are in other than the English language, trade journals such as *Soy Foods*, and proceedings of regional conferences devoted to broader topics than just fermented foods. Likewise, some information appears in nonscientific literature such as newspapers, correspondence, and travel reports.

Since no book is available in English or any other language on this subject at this writing, we believe that a modest book on this subject is justified. Recently four meetings have dealt with research on fermented foods. The first was the Fifth International Conference on Global Impacts of Applied Microbiology at Bangkok, Thailand, in 1977, but the papers were not published. The second was a 1979 International Symposium on Oriental Fermented Foods held in Taipei, Taiwan, for which a Proceedings was published in 1980. The third was the International Symposium on Microbiological Aspects of Food Storage, Processing and Fermentation in Tropical Asia, held at Bogor Agricultural University in 1979; the proceedings was multilithed but not edited. The fourth was the Fermentation Symposium held in 1980 in London, Canada, which devoted several sessions to fermented foods.

It is surprising that so little has been written on the subject in view of the amounts of fermented foods consumed in the non-Western world. For example, data from Dr. H. Ebine (personal communication) of the Food Research Institute in Japan, citing data from The Japanese Food Agency of the Ministry of Agriculture, Forestry and Fisheries, states that 567,776 tons of miso, 1,252,431 kiloliters of shoyu, and 158,000 tons of natto were produced in 1979 in Japan, which has a population of about 114 million (1977 figure). If we consider similar food consumption figures for China, with a population of 866 million, then these numbers are nearly eight times greater. Although we know of no figures on fermented food consumption of India and adjacent countries, where the population in 1977 was 882 million, let us estimate that the figure for fermented foods amounts to 10 kilograms per person, or a total of 8,820 million kilograms. According to Yu and Pyun (1980), 51,237 metric tons of soybean paste, 97,830 kiloliters of soy sauce, and 33,525 metric tons of gochoojang (hot pepper paste) were produced in Korea in 1978. In 1977 in Thailand (Bhumiratana 1980), 120,000,000 liters of nam-pla (fish sauce) was produced and production is rapidly
increasing. From these examples, and there are many others, it is apparent that the production of a number of these products is quite large. Additionally, some of these products are important from the standpoint of health of the people. For example, vegetarian diets need added vitamin B12, and the only source is that produced by bacteria. Nonvegetarians get B12 from meat they eat, which, in turn, originated from bacteria.

Another reason for considering fermented foods is the recent interest in the West for more natural foods prepared in old traditional ways. For example, the Soycrafters Association of North America has estimated that the total retail sales of tofu amount to 49,790,000 pounds, with a retail value of $44,811,000 in the U.S. and Canada, with 147 U.S. production units. Tempeh, produced by 30 units, amounts to 926,640 pounds, with a retail value of $1,667,952. Nine factories in the United States and two in Canada produce miso; the largest reportedly produces about 1,000,000 pounds of miso per year. An interesting aspect of this rapidly growing business in the U.S. is the fact that the traditional Asian processes using soybeans are simple and can be made by persons with little training. Also the equipment, such as cooling water tanks, is already available from the dairy equipment manufacturers at reasonable prices.

We should be interested in some of the fermented food products because the commodities used in the foods are produced in the United States and exported to those countries that make fermented products from them. According to the Washington Farmletter, February 6, 1981 (Anon. 1981), we export 6.16 billion dollars worth of soybeans, 6.55 billion dollars worth of wheat and wheat flour, and 1.17 billion dollars worth of rice. Japan alone buys 5.7 billion dollars worth of agricultural products. Agricultural products purchased by two other countries that make large quantities of fermented foods amount to 1.94 billion dollars for China and 1.6 billion dollars for South Korea. Rice, wheat, and soybeans are singled out above because they are widely used in making miso, and soybeans provide the protein source for natto and shoyu. The shoyu process also uses wheat. It is important to understand how those buying these products use them in fermentation, what problems they have with the products, what characteristics they would like to see in the commodity, and what can be done to improve the process.

Initial work in our Fermentation Laboratory was devoted to a study of the miso fermentation. As soon as the process and the nature of the food was understood, it was obvious that there were problems, such as the pigment about the hilum of some varieties of soybeans, the lack of uniformity in absorption of water, and the lack of uniform cooking to
facilitate mashing of the soybeans. A problem still remains in the export market, in that the miso companies prefer to buy Chinese beans instead of U.S. beans because they claim that Chinese beans make better miso. Some factors, such as the color and the size of the bean, are not important in shoyu making because defatted soy flakes are used for the fermentation. Among our accomplishments in dealing with the Japanese soybean fermentation was the discovery that *Saccharomyces rouxii* (Wickerham and Burton 1960) is heterothallic and, therefore, can be bred to make better strains to be used in high-salt fermentations, to grow faster and produce better flavor. It was apparent that pure cultures of vigorously growing bacteria and yeasts should be used in the miso fermentation to give a reproducible product and a shorter fermentation time rather than using miso paste as a starter. This practice of pure culture inoculum is now widely used in Japan. Another example was the work we did on the tempeh fermentation of Indonesia. We found that the flat soybean cakes could be readily fermented when cakepans were the fermentation vessel. Plastic perforated sheets were used as the covers (Martinelli and Hesseltine 1964), allowing the entry of oxygen into the fermenting soybean mass. The native procedure was to ferment the soybeans wrapped in banana leaves. Much of Indonesia's tempeh now sold is fermented as cakes in plastic bags, and the product is sold by cutting out blocks of tempeh to the size desired by the customer. Thus, with the package open at the sides but the bottom and top still covered with the plastic film in which the tempeh was made, the customer can examine the degree of development of the mold and the odor of the product but still gets the tempeh cake partially protected with cellophane. These are some of the ways in which our research has been transferred to countries where our commodities are used.

The matter of communication between workers in the field of fermented foods has been a problem. No journal is devoted exclusively to the subject. The transfer of technology for making tempeh in plastic containers came about pretty much by chance. Our studies on tempeh were supported by UNICEF and were intended for promotion of this food in South America. As far as we are aware, the use of tempeh never developed there. However, some alert Indonesian scientists, who were sent our publications describing tempeh made in plastic containers, saw possibilities for the process in Indonesia. Through workshops, the process was introduced to the Indonesian tempeh makers. As soon as some of the makers had successfully processed tempeh in plastic containers and were selling the better, cleaner, more attractively packaged product, other makers were forced by competition to accept the method. We have been told that 90% of the tempeh in Indonesia now is prepared in this manner.
An overall look at unusual fermented foods, as contrasted to cheese-making or other well-documented fermented foods, is justified because of the scattered nature of the information in the literature. No single publication specializes in publishing in this growing field. Even though there is worldwide interest in the developing countries, their scientists tend not to publish significant new scientific discoveries. However, recently researchers in these developing countries are becoming more interested in the foods they eat every day and are writing about them. Because of the paucity of information, their papers are essential references even though they appear in obscure reports and journals. Consequently, data on the names of names, on how the food is produced, marketed and consumed, on the microorganisms used, and on nutritional values all become of interest. The literature now is scattered in a wide variety of journals dealing with food technology, chemistry, toxicology, microbiology, biochemistry, nutrition, and mycology. The purpose of this book is to bring some of the essential information together under one cover.

In recent years, natural food stores have increased at a rapid rate and cater especially to those seeking foods normally not sold in the conventional food supermarkets. The clientele of the natural food stores range from those who want more variety in their diet to strict vegetarians who eat only food from plant sources and all degrees in between. Of the 7 million vegetarians in the United States, 0.5% are vegans and 2.6% are nearly so. At these natural food stores many of the new soybean products, such as tofu, are being sold. Some products introduced in specialty shops eventually make the grade into the mainstream grocery shops; this has happened to tofu and fermented shoyu. People interested both in health aspects and in pure vegetarian diets have an interest in traditional fermented foods. Outside of North America, large populations numbering in the hundreds of millions, such as the Hindus of India, are vegetarians because of cultural and religious beliefs.

Another reason for this book on fermented foods is the increase in world population that must have a source of protein other than from meat. This means it must come from legumes and cereals. In the Soybean Digest, March 1970, p. 32, it was pointed out that one acre of land will produce 508 pounds of usable protein, whereas beef will produce 58 pounds per acre. Wheat and corn will produce 180 and 323 pounds, respectively. Plant sources of protein are nutritionally adequate if a source of vitamin B12 is provided. Some microorganisms and certain fermented foods, especially those utilizing bacteria, are an important source of this essential vitamin. Likewise, plant protein by itself often lacks desirable flavors. Flavor and texture are the main
reasons that meat is preferred over plant proteins. To overcome this
deficiency, fermentation can either add desirable flavors or destroy
disagreeable flavors. This is especially true in soybean products made by
fermentation.

Because so much more protein can be produced per acre of land,
vegetable protein is cheaper. For example, soybeans today sells on the
retail market at $0.69 per pound (160 g protein) as compared to $1.53
per pound for hamburger (80g protein) at the retail market level.
Processes for some of the simpler protein products, such as tempeh and
tofu, require little skill, and these foods can be made readily at home.
However, preparation of other products, such as shoyu and miso, is
much more complicated. These processes require more equipment, a
number of careful steps involving multiple types of microorganisms,
and workers with considerable training or a good background in micro­
biology. For example, to make miso koji from rice, a mixture of mold
strains is used to give the proper proportions of proteases, lipases, and
amylases to bring about desirable changes in the soybean. Koji must
then be mixed carefully with the proper bacterial and yeast cultures,
salt, soybeans, and water, followed by varying times of fermentation,
depending on the desired type of miso.

Research on Fermented Foods

Although research and promotion of traditional fermented foods has
accelerated in the last 15 to 20 years, many gaps still exist in our basic
information. Little more is known about some foods than the name of
the product and what it is made from. It is quite apparent that foods
prepared by fermentation, especially those used in the developing
countries, need a great deal more study and research.

1. THE MICROORGANISM. In food fermentation the most important
element of the process in the microorganism(s) used. All the fermenta­
tions discussed in this book originated in antiquity before a written
record of man's technology was made. Because these products have
been used for generations, we know they are safe, just as we do not
question the safety of bread made with yeasts. Therefore, if one desires
to make a new product, it is advisable to use strains of microorganisms
that have been used in other food fermentation rather than trying to use
different species and genera of microorganisms or wild isolates whose
secondary metabolites are unknown. Untested microorganisms may
form toxins or cause other ill effects because of new products produced
from the substrate that taste bad, destroy essential substances, or even
induce infection.
Among all the fermentations discussed in this book, only a relatively few food fermentations have been studied adequately so that we know definitely the microorganism(s) involved. In some instances more than one strain of the same species may be required, or it may be more complex in that 2 or 3 species of yeast and bacteria must be combined. In other instances several organisms are used, but the growth of one is followed by a change in the fermentation conditions requiring a different set of organisms. Thus, koji is produced with a mixture of Aspergillus strains on a solid substrate, wheat and soybeans. Mature koji is then added to water, and salt and inoculated with yeast and bacteria in a liquid mash to produce shoyu.

The food fermentations that have been studied sufficiently to definitely establish the identity of the microorganisms are:

- Miso
- Angkak
- Shoyu
- Kaffir beer
- Natto
- Tamari
- Hamanatto
- Ontjom
- Sufu
- Tempeh

On the other hand, the microorganisms in the majority of fermented foods (there are perhaps 500 of these) are unknown or there is need to confirm the reports in the literature on the isolated organism(s). They have not been tested in pure culture for their ability to produce a product similar in appearance, texture, taste, color, and composition to the food as it is produced traditionally. As we have pointed out elsewhere, a number of steps are required in establishing the actual microorganism(s) used to make the product. The first step is the collection of a number (up to 50) of fresh, good food samples from different producers. Even collecting different batches from the same producer gives useful information as to whether the microorganisms remain constant and in approximately the same number. Often the ideal number of samples cannot be obtained, but certainly more than one sample of the product needs to be examined.

It is important that the samples be examined as soon after collection as possible. If this is not possible, then dried preparations need to be made as soon as possible and sent as quickly as possible to the laboratory. At the time of collection it is necessary to know how the sample has been treated. In some processes, the product may be heated or brined before it is available for consumption, thus effectively destroying the culture used. In making sufu, for example, Actinomucor elegans is allowed to grow on the surface of solid tofu cubes for several days. The molded cubes are then placed in a salt or salt alcohol brine and aged. It would be useless to examine samples of the final product for the mold because it has been killed during the brining step.
Once the sample reaches the laboratory, it needs to be examined microscopically, especially if a fungus is suspected to be the fermentative microorganism. The sample should be placed on a suitable nutrient medium, both under aerobic and anaerobic conditions, at the approximate temperature used in the fermentation. Typically, more than one organism will be found. To ensure that the correct organism(s) is isolated, representative cultures are made from the plates, with special attention to the ones that represent the greatest numbers. Even then the important microorganisms may be missed; sometimes important species will not grow by themselves or will grow only under specific environmental and nutritional conditions. Although the count of spores may be low in the inoculum, the organism may produce a large amount of growth in the fermentation. In the villi fermentation, no more than 26% of the strains of lactics present in this Finnish milk will grow in pure culture. The species found to dominate the population needs to be preserved by lyophilization until it is certain that the important organisms have been isolated. Identifying the culture to genus and species is imperative because one then can go to the literature and determine if this species produces any toxic material or is a pathogen. Usually the literature will indicate some of the enzymes and products this species will produce.

The predominant strains then need to be tested again in the production of the product. At this step, one often discovers whether more than one organism or strain is required. If the product is comparable in appearance, odor, texture, and acceptability, then one undoubtedly has isolated the correct organism. If the same species also appears in all or most of the samples, then it is almost a certainty that the right microorganism has been found. The best strains then may be kept permanently. The designation as the best strain means its growth and activity are uniform and repeatable, it grows vigorously, and it makes an excellent product without any undesirable chemicals.

The Process. In most, if not all, instances in which the microorganism is known, the process of food preparation will also be understood even though it has been demonstrated only on a laboratory scale. In elucidating the nature of the process, it is necessary to check several sources of information to be sure that the usual steps in the traditional method are understood as well as the variations. This information can be obtained from local producers or from technical people in the country of manufacture. For local production, the information usually is best obtained through technicians or scientists who have the confidence of the producer, can converse with the local people in their native language, and are acquainted with their customs.
Information is needed on the nature and amounts of the ingredients and such preparation of the substrate as dehulling, grinding, and soaking. Generally, a cooking step is involved if grain is to be used, and one needs to know the temperature and the length of cooking. The next step is to establish the nature of the starter. Is it a natural inoculation, material from a previous batch, or a crude, nearly pure culture? In the fermentation step, the kind and size of fermentation vessel used, the amount of starter, the temperature and length of fermentation, the expected changes occurring in the substrate as represented by appearance, temperature, and odor all should be known.

One also needs to know the health hazards that may be encountered, as well as the characteristics of an undesirable product and the possible causes of spoilage. One needs to know how to treat the product after fermentation, such as aging, brining, pasteurization, and drying. Finally, one needs to know how the product is sold and the keeping qualities of the final product, and the volume of the product (usually only a guess).

Nutritional Value. Although the process for producing the food is understood, seldom is the nutritional nature of the product known as it is consumed by the natives. A complicating factor may be that the native food may be quite variable in composition; therefore, a report on a single sample may be unreliable in determining the quality of the product most people are consuming. Take, for instance, the controversy regarding the vitamin B12 content of tempeh. Most native tempeh contains B12 in varying amounts; however, this B12 is not produced by *Rhizopus oligosporus* but instead is formed by the bacteria that contaminate the fermentation product. Some bacteria produce little or no B12, whereas others produce relatively large quantities. Surveys for B12-producing organisms have shown that fungi are not B12 producers, and this is true with *R. oligosporus*. When tempeh is made with only the mold, *R. oligosporus*, no B12 is found in the product.

Of significance during the fermentation are the changes in fermentation substrates and the new metabolic products that are made by the microorganism. The kind of information that is needed are the kinds of amino acids, carbohydrates, and fats present, and whether these are available to humans. Perhaps just as important are the trace element contents of the product and the vitamin changes during fermentation. In some of the processes, vitamins are known to increase by fermentation, but in others, the vitamins are utilized by the fermentative microorganism. Because of its harmful effect in circulatory diseases, the amount of salt present in foods also becomes an important consideration.
Synonymy of Names. One of the problems in working with fermented foods is the number of names applied to the same product or to a product made with only slight modification. Different names for the same product may be found in the same region. For example, in Indonesia, ragi is used as a starter in making fermented products from starchy foods. In China, the same starter product is called chiu-yueh or peh-chu. Even in the same country a number of names may be translated for the same product. Because of the numerous dialects used in China and the difficulties of phonetic translation from Chinese to English, sufu, a Chinese food, has appeared in the literature as tosufu, fu-su, fu-ru, toe-fu-ru, tou-fu-ru, teou-fu-ru, fu-ju, fu-yu, and foo-yue.

The microorganism used also may be slightly different. The commercial process for sufu employs *Actinomucor elegans*, but the home or cottage industry may use one or more species of *Mucor*, which evolutionarily is closely related to *Actinomucor*. Products made in the same manner also may be varied by adding various coloring and flavoring agents as in the case of red sufu where *Monascus* pigment is used to color the product. In making different kinds of miso, the proportions of soybeans to cereals will vary, depending on the type being made, even though the inoculum used is the same.

Chemical Changes. During fermentation of the substrate, a multitude of chemical changes occur simultaneously. Some constituents of the substrate are used for energy; other portions are modified to go into the microorganism cell walls, membranes, cytoplasm, and nuclei. At the same time, enzymes are actively modifying substrate constituents and transforming fractions, such as the proteins into amino acids and oils into fatty acids. Furthermore, microorganisms may synthesize entirely new compounds such as the red pigments produced in rice by *Monascus*. Some of the minor constituents are either destroyed or have been replaced by new compounds with the result that undesirable flavors have disappeared and the flavor of the finished product is different. Some vitamins may be synthesized while others are being used up. Of the studies on chemical changes during fermentation, probably the most extensive are those conducted in Japan on the flavor ingredients in shoyu, especially by scientists of the Kikkoman Company, a large manufacturer of shoyu.

Improvement in the Process. Once (1) the natural fermentation process is known, (2) the appearance, taste, and preparation of the food is understood, and (3) the microorganisms involved have been discovered, then the process can be examined from the standpoint of improving the method of production. The object of this research is to make a uniform product, that is, from batch to batch and from year to
year the product will have the same pH, composition, appearance, taste, and keeping time. It will have the same constituents in the same proportions and possess the same nutritional values, and the cultures will be shown to produce no harmful compounds. For example, the industrial strains of *Aspergillus oryzae* are tested to determine that no aflatoxin is produced.

It is essential to establish quality control on the production of the food. At the present time, only a few products, such as shoyu, miso, kaffir beer, and perhaps a few others, have reached this stage of development. For kaffir beer, Novellie and his associates have taken a home or village process and made it a modern industrial process. The product is uniform, even though the process is complicated, involving the use of both a yeast and an acid-producing bacterium, and based on corn and sorghum as the substrate. Equipment has even been modified to put the active fermenting beer in milk cartons for sale.

Studies need to be made on the keeping qualities of the final product and on improving methods to extend the shelf life. Ideally the product should be tested with various food poisoning microorganisms to determine which ones will grow in the product. Also, the commercial product purchased in the market place needs to be studied to determine the types of microorganisms, the numbers present, and which ones bring about spoilage at a given set of environmental conditions.

**Organization of Chapters**

In planning this publication, we decided not to have specific chapters devoted to a single fermentation. Over the years, we have become aware that certain fermented foods often are not restricted to a single country or part of a country but are common in several countries, with several fermentations common to a region. Further investigation shows also that almost identical processes and products from different countries are known by entirely different names, mainly, because of language differences. Soybean paste is common to many Far Eastern countries, but each country has its own name for the product. If we look at the whole future of fermented foods, we recognize distinct geographic regions.

1. In the United States and western countries, bacteria and yeast are used to prepare cheese, fermented milk, bread, vinegar, sauerkraut, beer, and wine.

2. The Far East, including Japan, China, Korea, and, to a certain extent, Indochina, uses yeasts and mold koji to make miso, soy sauce,
and rice wine. Exceptions are the use of bacteria making in natto in Japan and kimchi in Korea.

(3) In the East Indies, we encounter some new products not known in the Far East such as the mold fermentation of peanut press cake and the use of *Rhizopus* to make tempeh. This region also uses products resembling miso and soy sauce that undoubtedly were introduced by Chinese traders who settled in this area.

(4) The midcontinental area of Asia with the center in India, uses products made by fermentation based on milk, cereals, and legumes but not on soybeans. For all practical purposes, the use of molds is not important except in the north of India and Nepal.

(5) The Near East (Iran eastward) and north Africa, represent the Moslem countries. Typically, their fermented food products are based upon bacterial fermentation of milk and cereals combined into yogurt-like products that can be dehydrated and kept for a long time. Alcoholic beverages are not made.

(6) A region adjacent to this is the Eastern European countries and the Soviet Union, where bacteria and yeasts are used. Often these fermentations involve a symbiotic relation of yeasts and bacteria as fermenting agents in such products as kefir, tea fungus, and koummiss.

(7) Africa, south of the Sahara Desert, produces sour cereal products and as a rule, lactic acid bacteria are the fermenting microorganisms. Typical of these products are kaffir beer and kenkey. Often the cereal used is sorghum or maize, but legumes are not used.

(8) The last region is Central and South America. Most of our information comes from Mexico, where fermented products are based on maize and agave. Pozol is a food prepared from maize; this fermentation uses a mixed flora of bacteria, yeasts, and molds; pure cultures are not used.

Because of these regional similarities, we have tried to secure experts who could write authoritatively about each of these areas. Since China has a long history of food fermentation, the first chapter deals with the history of Chinese fermented food with invaluable relevant information provided by Dr. Fang (his contribution has been translated into English). This is contrasted by Dr. Chiao's chapter on modern fermentation in China. For Indonesia, Dr. Gandjar discusses the importance of fermented soybeans products, some of which are quite unique for this region. Mr. Djien, who grew up in Indonesia and taught there for many years, discusses other fermentations not based on soybeans. Next, Dr. Muller, whose students have worked with him on
many aspects of food preparation in Central Africa, has written a chapter describing the foods prepared in this area. Dr. Batra, a native of India who regularly returns to the region and who has published on fermented Indian foods, has written a most fascinating chapter on this region. Much important research is needed in this region to learn basic information about these foods and how they can be improved in their microbial and nutritional quality.

Dr. Mheen discusses the traditional fermented food products of Korea, while Dr. Fukushima has done the same for Japan. Dr. Ulloa, who has spent his whole career studying the microorganisms and fermented foods of Mexico, describes some interesting and unique products of his country. Dr. El-Gendy covers the Middle East and Egypt, where fermented foods are important to the area’s people; the West is not well informed about these foods even though there is an extensive literature that has been written by regional scientists. A further chapter on Africa is the contribution of Dr. Novellie, who has been responsible to a large degree in the development of kaffir beer from a village process to a large industrial fermentation industry.

The next portion of the publication deals with more general aspects of fermented foods. Dr. Steinkraus, who has an international reputation on the study of soybean foods such as tempeh, discusses the industrialization of home and village fermentations. Professor Wood discusses the introduction of traditional foods into Western culture. He has written extensive reviews and has had students in his department working on fermented foods. The question of fermented food safety is the subject of the next chapter by Dr. Yokotsuka, who has directed much research on the possibility of aflatoxin getting into products made with the koji molds, *Aspergillus oryzae* and *A. sojae*. We have discussed the nutritive factors in fermented foods in one chapter and, in another, we have taken a look at the direction in which the fermented foods industry is going and what we may expect in the future. This chapter has appeared in “Process Biochemistry” at its editor’s request.

The last chapter is a catalog of fermented foods. Almost from the beginning of our work on foods made by fermentation, we have collected names and information about them from visitors, trips abroad, institute reports, and the literature. We have attempted here to update the list of fungus food fermentations that appeared in an earlier review (Hesseltine 1965). We have cited the names of the products, the countries involved, the microorganisms used, and the way the food is consumed.
Literature Cited


Fifth International Conference on Global Impacts of Applied Microbiology, Bangkok, Thailand, November 21-26, 1977.


