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High Protein Food Products

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It is well known that malnutrition, due to the lack of high-quality protein, exists in many parts of Central and South America, as well as in developing countries in Asia and Africa. There is an urgent need to develop high-protein foods to meet these nutritional needs. Such products should be high in protein quality, acceptable to the people, and inexpensive. Animal protein foods seem to be unsuitable products for this purpose because of their high price, especially in cost per gram of protein. As practical protein sources for this purpose, fish and soybeans will be considered because they contain large amounts of high-quality proteins and are much cheaper than animal meats. In these cases, however, the flavor and acceptability will be of the utmost concern.

For centuries in Japan, fish and soybeans have been processed into various types of foods, such as "kamaboko", "chikuwa", and "hanpen" (paste products of fish); "shoyu" (soy sauce), "miso", and "natto" (fermented products of soybeans); and "tofu" and "kori-tofu" (soy-milk curd products). In addition, recently, fish sausage and fish ham, which do not contain meats other than fish, have been developed using the techniques of the traditional fish-paste products. These fish and soybean products have been popular in Japan have have played an important role in nutrition as sources of high-quality protein. Most recently, a product from dried soy-milk curd has also been developed with good acceptability for the westernized young generation and is becoming familiar to people in general.

Of the various soybean and fish products available in Japan, soybean curd products and fish sausage and ham products might be expected to be acceptable, economical, high-protein foods for people in this hemisphere. These products and the marked progress in their technology in recent years are described.

SOY-MILK CURD PRODUCTS

Generally, soy-milk is produced by grinding soaked, whole soybeans with water, heating the resulting mixture, and then removing the residue. About 65%, 83%, and 73%, respectively, of total solids, protein, and fat contained in whole soybeans are found in the soy-milk, which is a milky, stable emulsion.[1] Anti-nutritive factors in soybeans are also extracted, but they are inactivated easily by heating.[2] Soy-milk contains a good quantity of high-quality protein. Animal experiments also confirm the high-nutritive value, though sulfur amino acids are limited.[3] Therefore, soy-milk is qualified as an economical high-protein food, especially for children. However, acceptability may be a problem. Soy-milk is not consumed as a beverage in Japan.

Soy-milk has some off-flavors, ie, green, beany, and rancid flavors. Besides these, there is a throat-catching chalkiness in soy-milk. Some of these off-flavors can be removed easily by heating or evaporating, but chalkiness cannot be so removed. Recently, it has been found that most of the rancid flavor in soy-milk is brought about by the oxidation of the soybean oil by the lipoxidase during the low temperature extraction process.[4] A new process has been developed which inactivates the lipoxidase by extraction with hot water. The resulting soy-milk is very much improved in flavor.[4] However, the soy-milk is still chalky and is not as bland as cow's milk.

The most bland product may be obtained not as the milk but as the coagulated form. The wet curd produced by coagulating the heated soy-milk with calcium sulfate is not chalky. Since most of the constituents of soy-milk are held in the curd, it is a very nutritious product. This product, called "tofu", has been eaten for centuries by Japanese people. Further, the very unique process for the easy dehydration of this gelatinous curd was originated in ancient time, and the resulting dried-curd product, called "kori-tofu", has also been popular in Japan. Recently, various improvements have been accomplished in the technology of these products, as described below.

1. Wet Soy-Milk Curd Products

a. Ordinary tofu (traditional product)

Ordinary tofu is produced as follows[5]: Soaked whole soybeans (one-night soaking) are ground with water, heated at 100°C for a few minutes after adding water to give an 11-fold dilution of original soybeans, filtered or centrifuged, and cooled to 70°C. Calcium sulfate, 0.3-0.4%, is then added. After the resultant coagulated curd has been kept for 10 minutes, the curd mixture is put into a coarse cloth set in a wooden box, and the water is drained off under a pressure of 5 g/sq cm for 20 minutes. The pressed curd is soaked in water and cut to 300gm square pieces.

Tofu, thus obtained, is a white, gelatinous curd with a unique texture in which the large amounts of water are held. The texture is soft, smooth, and properly elastic. The percentages of water, protein, oil, carbohydrate, and ash in tofu are 88.0, 6.0, 3.5, 1.9, and 0.6, respectively. Ninety per cent of the protein and 95% of the oil in soy milk are recovered as tofu. The chalkiness which is felt in soy milk disappears completely, and therefore, tofu is very bland in taste and in mouth-feel. However, tofu is very fragile and perishable, and, accordingly, it is not transportable and not mass-producible. A new and improved product, bagged tofu, has recently appeared.

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b. Bagged tofu (new product)

In ordinary tofu making, 40-50% of the whey of the soy-milk is removed from tofu curd as the supernatant from the coagulation. However, it is possible to make soy-milk coagulate as a whole without any separation of the supernatant, when the concentration of soy-milk is high enough. Bagged tofu is a product in which whole soy-milk was developed, which provides an easy supply of the high-concentrated soy-milk solution.

The powdered soy-milk is produced by spray-drying (below 60°C) of the concentrated soy-milk which was kept below 60°C throughout the processing.[6] This powdered soy-milk is completely dispersible in hot water and available commercially in Japan (commercial name: Proton M, Nihon Tanpaku Kogyo Co., Kodaira-shi, Toyo-to) at a cost of 66¢ per kg (30¢/lb). The composition of this product is protein, 43%; fat, 22%; carbohydrate, 27%; ash, 4%; and water, 3%.

Bagged tofu is produced as follows[7]: Powdered soy-milk is dispersed in hot water in 11% concentration and cooled, followed by the addition of 0.6% calcium sulfate. About 300 gm of the resulting soy-milk is put into a polyethylene or vinylidene chloride film bag as soon as possible after the addition of calcium sulfate, because the soy-milk solution containing calcium sulfate becomes viscous, even in cold temperature. Most recently, glucono-lactone has been developed as a new precipitant[8] which does not react with soy-milk before being heated, and this new precipitant has been used instead of calcium sulfate in bagged tofu making. The soy-milk, which is packed tightly in the bag after the addition of the precipitant, is heated in a water bath of 95°C for 50 minutes and then cooled. The bagged tofu, thus prepared, is a homogeneous gel of soy-milk. The texture of the curd is rather smooth and softer than ordinary tofu, but it is not broken in the transportation because of the protection of the bag. The 5 ppm addition of 2-(2-furyl)-3-(5-nitro-2-furyl) acryl amide is permitted as a preservative. The bagged tofu can be preserved for several days at 20°C. The chemical composition of bagged tofu is water, 88.5%; protein, 5.7%; fat, 2.3%; carbohydrate, 2.8%; and ash, 0.8%.

The bagged tofu can be enriched by vitamins, essential amino acids, minerals, etc. It is also possible to make seasoned and/or flavored bagged tofu, if desired.

c. Tofu derivatives (traditional products)

There are several traditional tofu derivatives which are prepared by the deep-fat frying of tofu. When tofu is deep-fat fried, it swells to give a texture which is porous, meshy, and elastic, quite different from original tofu. It is possible to prepare a product having various chewing characteristics, depending upon the water content of tofu before frying, the temperature and time of frying, etc. "Aburage" is made by a two-step frying of 110-120°C and 180-200°C, and "Namaage" is made by a one-step frying of 180-200°C from ordinary, well-pressed tofu. "Gammodoki" is made by a two-step frying from tofu-mash mixed with ground vegetables. In making these products, tofu from defatted soybean meal can be used satisfactorily.

These products are not fragile and are low in water content. Therefore, they can be transported, especially where antioxidants are used in making.

d. Consumption of tofu and its derivatives:

In Japan, 270,000 metric tons of whole soybeans and 65,000 metric tons of defatted soybean meal are consumed as tofu and its derivatives per year. Of this soybean consumption, over half is assumed to be consumed for tofu derivatives. Ordinary tofu is produced on a small scale because of its fragility and perishability, whereas its derivatives, ie, deep-fat fried products, are made on a large scale, because of their preservability. Bagged tofu is also produced on a large scale, since it is transportable and preservable. The retail price of ordinary tofu is 1.9¢ per 100 gm equivalent to 30¢ per 100 gm protein. The very small scale production prevents the price of ordinary tofu from lowering.

Since tofu is very bland in taste, there are many ways to eat it. Tofu can be served after the mere sprinkling of seasonings and condiments without further cooking, as well as after boiling, roasting, or scrambling with seasonings. Tofu is also used in soups and many other dishes. Tofu derivatives described above are served after cooking with seasonings or used as the ingredients of soups and many other dishes.

2. Dried Soy-Milk Curd Products

a. Kori-tofu (traditional product)

Tofu holds a great deal of water in a thick, gelatinous texture, and it is very hard to make a dried product by economical water removal without any damage to the constituents. However, we can see how elegantly this difficult problem is solved in the traditional kori-tofu making. This was originally developed in ancient Japan in the regions with severe, cold winters. Kori-tofu is made as follows[9]: The tofu, made with calcium chloride as a precipitant (water content, 80%), is brought into square block, frozen rapidly to -10°C within 3 hours, kept at -1 to -3°C for 2-3 weeks, and then thawed. Through this aging at the frozen state, the unique sponge-like texture, composed of the freeze-denatured proteins, is formed by the growing of the fine ice crystals, and consequently most of the water can be squeezed out easily after thawing. The removal of the remaining water from the pressed curd can be made very easily by the usual hot air drying because of the sponge-like texture. The kori-tofu, thus obtained, swells two times in volume and six times in weight by soaking in hot water. Usually, a small amount of ammonia gas is added to the dried product before packaging in order to facilitate the swelling in soaking.

A piece of kori-tofu is usually a 20 gm square and contains 53% protein, 26% oil, 7% carbohydrate, 26% ash, and 10% water.

b. Kori-tofu derivatives (new product)

Recently, a new frozen food from kori-tofu has been developed with good palatability for western-

ized young people. To the kori-tofu cake, from which water was squeezed after the thawing process, a concentrated seasoning solution is added, sometimes with sandwich cheese or ham, following by freezing, covering with flour and crumbs, packaging and shipping in a frozen state. This product is served after deep-fat frying.

c. Consumption of kori-tofu and its derivatives

In Japan, 30,000 metric tons of soybeans are used for kori-tofu per year. Since kori-tofu is a dried product and, therefore, stable and transportable, it is mass-produced. Consequently, the price per 100 gm protein is much lower than that of ordinary tofu, in spite of the more complicated process of kori-tofu. The retail price of kori-tofu is 10¢ per 100 gm, which corresponds to 18¢ per 100 gm protein.

The chewing properties and mouth-feel of kori-tofu are quite different from those of ordinary tofu. The sponge-like texture of kori-tofu, in which large amounts of seasoning solution can be held, gives meat-like chewiness. Before using, kori-tofu is soaked in hot water, pressed out, and then cut. The resulting kori-tofu is used as an ingredient in various dishes after cooking with seasonings. The powdered kori-tufu is suitable as an ingredient of potage soup.

The new frozen product of kori-tofu has become increasingly popular through mass feeding in schools, factories, popular restaurants, etc., though it has only recently appeared on the market (commercial name: Tofu-furai and Abekawa-furai, Haburae Tofu Co., Kanazawa City). This product is served with or without seasonings after deep-fat frying. The price before deep-fat frying is 2¢ per 60 gm piece (water, 56.0%; protein, 10.0%; fat, 4.2%; carbohydrate, 26.8%; and ash, 3.0%). It is worth noting that this product has a meat-like texture and flavorings. If one takes the trouble to season, similar dishes can be homemade from usual dried kori-tofu.

FISH SAUSAGE AND FISH HAM

In contrast to the very traditional foods of tofu and kori-tofu, fish sausage and fish ham are unique products which were newly developed after World War II. The key to success was (1) the advent of ryphan casing (rubber film casing treated with hydrochloric acid), though it is substituted by other film at present, and (2) the accumulation of scientific findings on the processing of Japanese fish pastes "kamaboko", "chikuwa", "hampen", etc., which have been eaten by Japanese people from ancient times. Since the first appearance of fish sausage and ham in the food market in 1954, the annual output of these products has been increased very rapidly with an average increase of 15,000-16,000 metric tons every year to 190,000 metric tons in 1966 in Japan. Such a remarkable increase in a short time was brought about by the products' similarities to usual sausage and ham, the low price, and the extraordinary long preservability at room temperature, all of which were results of the positive and ceaseless application of new scientific findings and technology. The fact that fish sausage and ham go well with bread should be considered as one reason for the rapid growth of these industries. At present, these products are produced in ratio of 7 (sausage) to 3 (ham) mainly by the large fish companies, such as Taiyo Gyo-gyo Co., Nihon Suisan Co., Nichiro Gyo-gyo Co., Nihon Reizo Co., etc. Advances in the technology of fish sausage and ham[10,11] are described below.

1. Materials

a. Main materials

The fish used in making fish sausage and ham must be inexpensive, abundant in supply, and have properties for forming an elastic texture after processing. In an earlier period of this industry, the fish used were confined to tuna (yellowfin and big-eye tuna), marlin (blue marlin and sailfish), whales, and sharks. The reason is that other kinds of fish easily lose their qualities to form an elastic texture when stored in a frozen state before using. However, the special storage techniques for preserving these qualities were developed, and, since then, many kinds of fish which could not be used before have been employed. This method is as follows: The flesh portion of fresh-caught fish is collected and leached with water. After a centrifugal removal of water, the resulting leached flesh is mixed with 5% sugar, 0.2% polyphosphate or 10% sugar and 2.5% NaCl, followed by freezing. The frozen fish jelly, thus prepared, can be stored for months without any practical change of quality. Thus, Alaska pollack, Atka mackerel, Pacific Ocean perch, horse mackerel, turbot, and squid have also been employed industrially, stored as a frozen fish jelly. Any kind of fish can be used for fish sausage and ham if the proper preliminary treatments are applied to the fresh-caught fish.

The various fish are mixed in making fish sausage and ham. An example of the prepration is as follows: whale meat, 30%; tuna, 20%; shark, 10%; frozen Alaska pollack jelly, 20%; Pacific Ocean perch, 10%; and frozen Atka or horse mackerel jelly, 10%.

b. Sub-material

For the improvement of the flavor, fresh pork fat tissue is added to fish meats in the amount of 10-15%. A small quantity of pork skin gelatin, frozen egg yolk, soybean protein, and gluten are also used to improve the texture. The addition of starch below 10% is permitted to improve the texture.

c. Additives

Preservatives permitted include 0.2% of sorbic acid and 0.002% of its derivative, 2-(2-furyl)-3-(5-nitro-2-furyl) acrylamide. Whale meat contains myoglobin which is changed to a brown color by heating. The addition of sodium nitrite (0.02-0.04%) is used for improvement of the texture.

2. Processing

a. Fish sausage

Frozen whale meat is thawed, sliced into 2-cm cubes, leached with water to remove blood, crushed, and then mixed with a solution containing 0.02-0.04% $NaNO_2$, 0.05-0.10% sodium ascorbate, and 1.0-1.5% NaCl, followed by curing for 12-24 hours at 5°C and then grinding. Frozen fish, such as tuna,

shark, etc., are thawed, filleted, and ground. Frozen fish meat jellies are semi-thawed and ground. First, these ground meats, other than whale, are put into a silent cutter in definite proportion and kneaded with water which contains seasonings, spices, starch, enrichment agents, preservatives, and food color. Next, the cured, ground whale meat and chopped pork fat are successively added to this slurry and mixed homogeneously. The temperature is controlled between 5-10°C through the kneading and mixing. The resulting slurry is stuffed in polyvinyliden chloride film, sealed tightly with aluminum wire, heated in hot water at 88°C for 60 minutes, and then cooled in chlorinated cold water at 15-20°C for 30 minutes. Finally, the resulting cooled fish sausage is heated again at 95-98°C for 20 seconds to smooth the casing, followed by cooling for 1 minute, drying, and wrapping in red cellophane paper to prevent light deterioration.

b. Fish ham

The fish ham processing differs from that of fish sausage on the points of the preliminary treatments of fish meats, the kneading operation, and heat processing. The leached whale meat is more coarsely sliced than when used in fish sausage. Tuna meat is diced into the 0.8-1.0 cm cubes. These cut meats are put together into a mixer, and the seasonings, spices, ascorbic acid, and Na-nitrite are added to them successively. After mixing, the meats are cured for 2 days at 10°C to develop and fix the color. Next, the diced pork fat and the raw meat slurry, which was prepared in the same way as fish sausage, are added to the prepared whale and tuna meats. This sausage slurry works as a binder among meat cubes. Stuffing and sealing procedures are almost identical with those in fish sausage making. The resulting pack is heated in a metal retainer in the case of fish ham.

3. Nutritive Value and Preservability

Fish sausage and ham are ideal high-protein foods; the protein quality is as high as that of other animal proteins. These products can be enriched very easily by other nutrients, if necessary, such as vitamins, minerals, etc. Fish sausage is composed of water, 68%; protein, 13%; fat, 8%; carbohydrate, 8%; and ash, 3%. Fish ham contains water, 63%; protein, 16%; fat, 11%; carbohydrate, 6%; and ash, 3%.

It should be noted that fish sausage and ham can be stored for 2-3 months, even in summer (30°C). The long preservability is one of their most advantageous characteristics in regions where refrigerators are not yet popular. Many detailed scientific investigations have been conducted on the mechanisms of the putrefaction and the deterioration of fish sausage and ham. From the results of these investigations, various means for increasing the preservability have been developed. These include: (1) the finding and application of effective preservatives against thermoresistant bacteria, which are mainly responsible for the putrefaction, (2) the pasteurization of the spices and starch, which are the main sources of contamination by the thermoresistant bacteria, (3) the use of the heat-shrunk and air-tight film, which delays both the growth of surviving bacteria and the chemical deterioration during storage, (4) the settling of heating conditions on the basis of detailed experiments about heat conduction to the inside, (5) the development of the accurate, tight, and speedy packer of aluminum wire and the use of the chlorinated cooling water, by which the secondary contamination of bacteria from sealing parts are prevented, and (6) the covering by red cellophane paper to inhibit the chemical deterioration by light.

Fish sausage and ham are served in the same way as usual sausage and ham. The retail price of these products is 8¢ per 100 gm and 50-60¢ per 100gm protein.

SUMMARY

Two kinds of very economical high-quality protein foods are universally popular in Japan, and these are expected to be acceptable to people in this hemisphere. One type is made of soy milk, such as tofu and kori-tofu, and the other includes fish sausage and fish ham, which were developed after World War II.

Tofu is a curd comprising the whole protein and oil from soy-milk and is made by heating soy-milk with calcium salts, while kori-tofu is a dry product produced by aging the curd in a frozen state, thawing, and then drying. Both are very nutritious products, but their textures are quite different. Tofu is soft, smooth, and gelatinous and is bland, fragile, and perishable. Recently a tofu has been developed, prepared by coagulating the soy-milk in a tight bag with out any separation of whey. It is less perishable, more sanitary and transportable than usual tofu and, therefore, suitable for mass production. The commercial development of a soy-milk powder completely dispersible in hot water and the discovery of new precipitants (glucono-lactone, etc.) resulted in the process of bagged tofu making. Kori-tofu has a unique sponge-like texture, brought about by aging in the frozen state, which permits the squeezing of water from the curd and facilitates drying. Kori-tofu contains 55% protein and 25% oil, and the retail cost is 18¢ per 100 gm protein. Kori-tofu is served after cooking with seasonings or other ingredients, but tofu can be served without cooking. Recently, a commercial frozen food with meat-like texture has been developed from kori-tofu. The thawed and squeezed curd is seasoned, sometimes with cheese or ham, covered by starch and/or crumbs, packed, and then frozen. This product is served after being deep-fat fried without preliminary thawing, with good palatability for the westernized young generation.

Fish sausage and ham are produced by crushing and/or grinding fish meats (including whale meat) with seasonings, condiments, polyphosphates, and preservatives such as sorbic acid and its derivative, followed by casing in air-tight and heat-shrinkable polyvinylidinechloride film, then heated. The use of film and preservatives protects the fish sausage and ham a very long time at room temperature, and this brought about a surprising popularity in a short time in Japan. Since fish sausage and ham resemble usual

sausage and ham, they might be accepted more rapidly by people of this hemisphere as the economical high protein food to solve the protein deficiency problem.

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