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ID/WG.[illegible]
1 September 1969

ORIGINAL: ENGLISH

Expert Group Meeting on
[illegible] Soya Bean Processing and Use
Peoria, Illinois, USA, 17 - 21 November 1969

INDUSTRIAL PRODUCTION OF SOYBEAN FOODS IN JAPAN 1/

by

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INDUSTRIAL [illegible] SOYBEAN FOODS [illegible]

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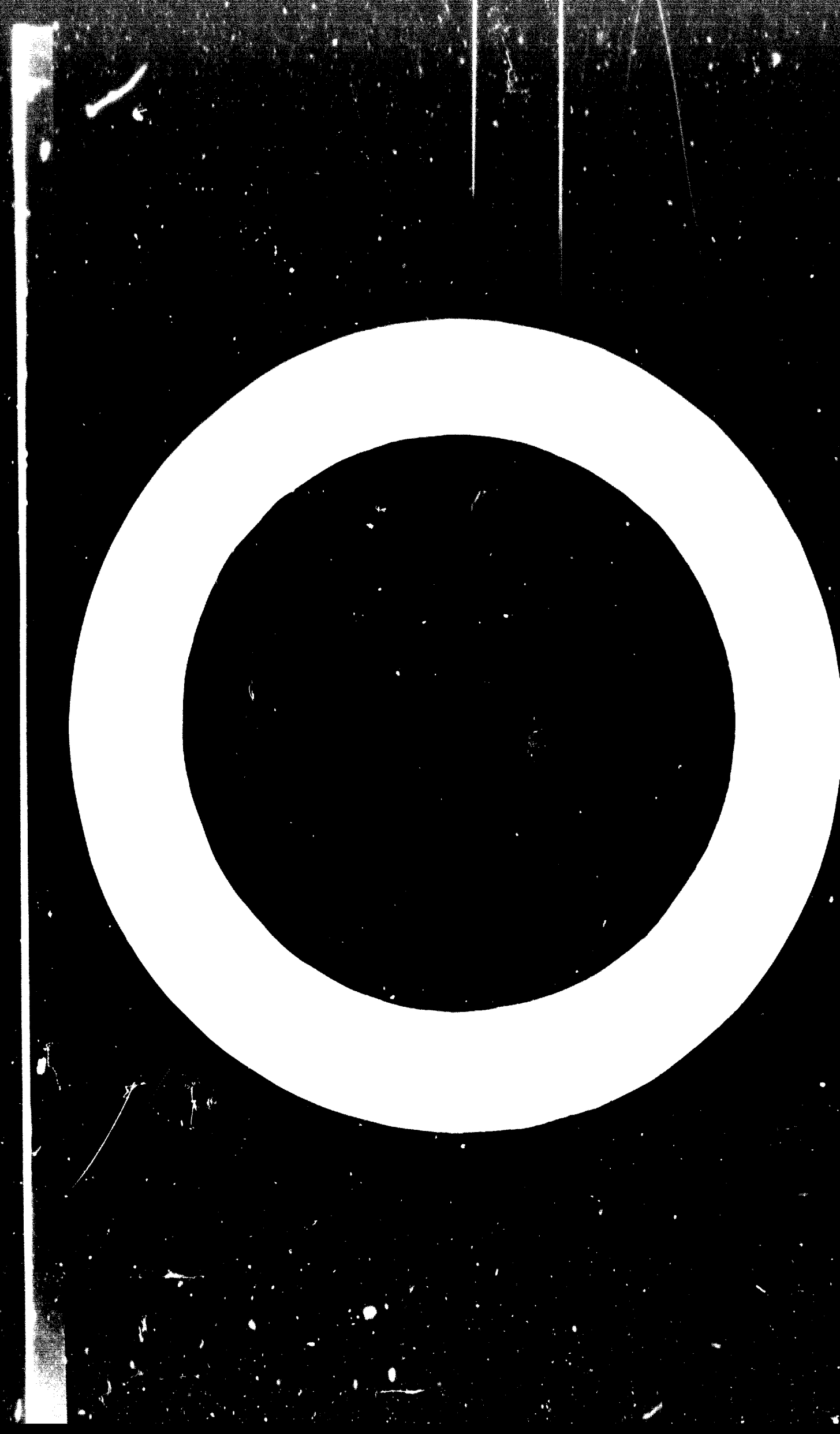

Introduction

The amount of soybeans consumed in Japan in a year is about 2,300 thousand metric tons, half of which is used for foods. We have several kinds of traditional soybean foods such as miso, soysauce, tofu, kori-tofu, natto and kinako, which are fitted for cooked rice. Protein intake by Japanese people from soybean is about [illegible]% of the total. It means that those traditional soybean foods are still consumed by Japanese people in fairly large quantities. As the domestic production of soybeans is decreasing year by year, perhaps below 100 thousand metric tons, the amounts imported from U. S. and Communist China is over two million metric tons last year. Table 1 shows the recent trend of supply and demand of soybeans in Japan. From this table it is apparent that over half of soybeans consumed in this country is crushed to extract oil and about 70% of resulting meal is used for feed. But remaining 30% is for foods including traditional and new ones. It must be noted that new food use of soybeans especially of defatted meal as a substitute in meat and fish products is increasing. This trend is perhaps for shortage and high cost of meat and some fish products. Whole soybeans not crushed for oil is almost used for traditional foods.

Here the production of traditional and new soybean foods in Japan will be described with the consideration of industrial viewpoint. We usually group these foods into two, namely, non-fermented and fermented foods. As the first group we have kinako, tofu, fried tofu, kori-tofu, yuba and new foods such as isolated soybean protein, textured protein and spun protein. Soysauce, miso and natto belong to the second group. Because of high humidity and warm wether Japan is very suitable for growing of microorganisms, and so we have many kinds of fermented foods as stated above. Generally speaking production of soybean foods which have fairly large demand and furthermore longer shelf-life is becoming rapidly large in scale by mechanization and automation.

In tofu, kori-tofu and yuba almost of insoluble matter in soybeans are removed as residue in the preparation of soybean milk and beany flavor disappear by cooking of ground soybeans. Characteristic odour of cooked soybeans is removed by fermentation in miso and natto, and acceptability and digestibility of these foods are better than cooked soybeans. Trypsin inhibitor of soybeans is decomposed by heating or removed in the process

of preparation. Therefore these are reasonably processed foods, except possibility of amino acid destruction in some extent by drastic treatments such as overheating.

Before detailed explanation of food values of each soybean food in Japan, a phrase from Dr. A.M. Altschul's "Proteins, their chemistry and politics" is cited here. He says about soybean foods in Orient as follows. "This is a lesson in successful food technology, even though the means of arriving at the solutions may have been empirical. A potential food resource has in fact been rendered effective by proper processing. In so doing the Orientals have shown consumate skill in adapting a plant source of protein in an economy where there is a scarcity of animal protein. The wonder is that others have not shown equal skill and imagination, and that the soybean is not as well utilized in other areas where there is scarcity of animal protein." Dr. M.L. Anson's description in "Processed plant protein foodstuffs" edited by Dr. Altschul is also worthwhile to cite here. He says that "In general, man does not consume any great amount of soybeans, cottonseed, or peanuts either as such or after the removal of the oil. The only oilseed protein consumed by man on a large scale in any form is soy protein. This has been done for thousands of years in the Orient as a basic part of the way of life for large populations, but only because methods were discovered for converting soybeans into acceptable products by radical processing beyond the mere removal of oil ..... There are two main forms of traditional soybean products eaten by man: soybean curd and soybean fermentation products, such as soysauce, soybean cheese."

Table 2 shows chemical composition of soybean foods which are very popular in Japan. Details will be explained at each section, but general features of these foods can be caught from this table, for instance, their moisture content, protein and fat content in comparison with that of soybean itself.

It is apparent that cost of the soybean foods as source of protein is fairly low compared with that of animal protein foods. Table 3 is cost of 100 g of these foods and also 100 g protein of these foods. Cost of 100 g protein is calculated without considering other nutrients such as oil and sugar. Difference of the cost among soybean foods is caused by difference of their processing and also degree of mechanization.

The prime cost of these soybean foods including production cost, transportation, salary, depreciation, propaganda and others are estimated as Table 4 and the percentage of the cost of materials in the prime cost are shown in the same table.

Table 1 Supply and demand of soybean in Japan

Whole soybean (1,000 metric tons)

		1964	1966	1967
Supply	Domestic production	100	92	88
	Imported	1,649	2,130	2,205
	Total	1,749	2,222	2,293
Demand	Crushed for oil	1,247	1,577	1,626
	Miso	145	158	169
	Shoyu	16	15	15
	Tofu & fried tofu	271	277	295
	Kori-tofu	24	28	34
	Natto	30	38	47
	Kinako	6	9	12
	Others	10	70	70
	Total of foods	502	595	642
	Feed (kinako)	0	50	[illegible]
	Grand total	1,749	2,222	2,293

Defatted soybean (1,000 metric tons)

		1964	1966	1967
Foods	Miso	15	10	8
	Shoyu	165	152	154
	Tofu & fried tofu	64	77	77
	Others**	43	43	45
	Total of foods	287	292	284
Non-foods	Chemical industry	0	5	5
	Fertilizer	29	23	13
	Feed	669	941	946
	Others	5	3	4
	Total of non-foods	703	972	968
	Grand total	990*	1,264*	1,252*

* corresponds to whole soybeans crushed for oil

** over 10,000 metric tons is for chemical shoyu

Table 2 Chemical composition of soybean foods (%)

	Moisture	Protein	Fat	Soluble Carbohydrate	Fiber	Ash
Tofu	88.0	6.0	3.5	1.9	0	0.6
Aburage	44.0	18.6	31.4	4.5	0.1	1.4
Kori-tofu	10.4	53.4	26.4	7.0	0.2	2.6
Yuba	8.7	52.3	24.1	11.9	0	3.0
Kinako	5.0	38.4	19.2	29.5	2.9	5.0
Natto	58.5	16.5	10.0	10.1	2.3	2.6
Miso						
Salty light	50.0	12.6	3.4	19.4	1.8	12.8
Salty red	50.0	14.0	5.0	14.3	1.9	14.8
Soybean	47.5	16.8	6.9	13.6	2.2	13.0
Soybeans	12.0	34.3	17.8	26.7	4.5	5.0

Table 3 Cost of soybean foods and other proteinous foods (retail cost in 1968)

	Yen/100 g	¢/100 g	Yen/100 g protein	¢/100 g protein
Tofu	8.3	2.4	138	38.3
Aburage	40	11	215	59.8
Kori-tofu	45	12.4	84	23.3
Yuba	250	69.5	420	116
Kinako	30	8.3	78	21.6
Natto	20	5.5	121	33.5
Miso	14	3.9	110	30.5
Spun protein*	12.5	3.5	50	13.9

* Spun protein contains 75% moisture and 25% protein.

City milk	12	3.3	413	114
Egg	30	8.3	236	65.5
Ham	80	22.2	497	138
Pork	75	20.7	559	155
Chicken	60	16.6	285	79
Beef	100	27.8	476	132
Mackerel	40	11.5	222	61.5
Chikuwa*	60	16.6	461	128

* A kind of fish paste gel

Table 4 The prime cost of the traditional soybean foods and percentage of the cost of materials in it.

Food	Prime cost	Unit	Percentage of cost of materials*	Note
Tofu	228,100 yen	1 metric tons of soybeans	44.5	1967
Kori-tofu	281,980	1 metric tons of kori-tofu	46.6	1967
Natto	193,040	1 metric tons of soybeans	47.2	1968
Miso	57,388	1 metric tons of miso	60.6	1969
Shoyu	98,062	1 kl of shoyu	44.3	1967

* Materials include those for packaging.

Tofu and its industrial production

Tofu is one of the most popular soybean foods in Japan. The amount of soybeans consumed for tofu and its derived foods (not include kori-tofu) is about 350,000 metric tons in a year including defatted soybean meal. Increase of its total production in a year is about 5%, not so high, perhaps because of recent increase of variety of foods. Tofu is white, soft and geletinous mass which hold much water as shown Photo. 1. It is fairly perishable and fragile, but it is very digestible and nutritious, because insoluble components of soybeans are all removed and rich in protein and oil (Table 2).

Process of tofu making (See Fig. 1)

To make tofu soybeans are washed and soaked overnight in water, and then ground with continuous addition of water in small quantities. The mash is then cooked with a definite amount of water and small amounts of antifoam and water is added to make the ratio of water to beans at 10 to 1, based on the original weight of soybeans. A milk of 5-6% solids is obtained by filtration. A water suspension of powdered calcium sulfate ($CaSO_4 \cdot 2H_2O$) is added at a level of 2-3% of the soybeans to the soybean milk of about 70°C. Protein in soybean milk reacts with calcium sulfate

and precipitates. After discarding separated supernatant which corresponds to the whey in cheese making, the curd is transferred to wooden or aluminium box or mould which has holes and pressed to remove the excess water. The draining off is continued for a definite time, and the curd is taken out from the box in water. The curd is soaked in water to remove free calcium sulfate and then cut into thick slices of about 300 g and sold while fresh, usually at the shop where the tofu is made. From 10 kg of soybeans tofu of 40-50 kg is obtained. Quality and yield of tofu are affected by variety of soybean. Beside its protein content protein quality and phosphorus content must be considered for evaluating its suitability for tofu-making. Nitrofuran devivatives is permitted to be used (2.5 ppm).

Tofu production as industry

As tofu is perishable and difficult to transport for long distance as already mentioned, scale of tofu production is fairly small in spite of its large demand. There are over 40,000 plants in Japan and average consumption of soybeans per day in one plant is about 30 to 40 kg.

Development of packaging film and packaging machine are making tofu such food that can be sold at the supermarket and also production scale of tofu much more larger. There are already plants which consume over 600 kg soybeans per day (Photo. 2). Packaging of tofu is also desirable from sanitary. "Packed tofu" which will be explained later in details is being developed in these several years and it will take main part of tofu at the supermarket. Each piece of tofu weghing 300 g is 30 yen (8.3 cents).

Equipments for tofu production

At the tofu plants of average scale they use emery-coated grinder for grinding soybeans, cooking kettle by steam or direct heating for cooking soybean mash and press by hand, water, oil, electricity or air and also sometimes by centrifuge for filtration to get soybean milk. There are several factories facilitated with continuous cooker shown in Photo. 3 and also decantor which is one of the continuous centrifuge shown in Photo. 4. Coagulation of soybean milk and moulding in the box are all hand-work even at the large scale plants. From the sanitary viewpoint convenient type packers are increasingly popular in the small plants.

Throughout the production of tofu of any kinds it is necessary to con-

trol processing conditions, namely concentration of the soybean milk, amounts of coagulant, coagulation temperature and others. Almost of tofu plants they do it only by their experience, but with enlarging of the production scale severe and hopefully automatic control using measuring instruments will be necessary.

Variety of tofu

There is different type of tofu named kinugoshi which is made by gelation of condensed soybean milk by coagulant without separation of whey. The ratio of water to beans to make soybean milk is about 5 to 1, less water compared with ordinary one. Kinugoshi tofu has homogeneous texture and soft on tongue. Chemical compositions of kinugoshi is not so different from ordinary one, although higher in vitamin B_1, sugar and soluble nitrogen compounds.

With a view to maintain better sanitary conditions, "packed tofu" has been developed. Soybean milk of high concentration as kinugoshi is, after being cooled down, put in polyethylene or vinylidene chloride film bag, together with calcium sulfate. Each bag contains about 200 to 300 g of the milk. After closing the bag they are heated in a water bath of 90°C for 40 to 60 minutes. The milk coagulates gradually without separation of whey as in the case of kinugoshi. They are cooled down soon after completion of coagulation. The packed tofu made by this way is sanitary, as it is screened off from all pathogenic bacteria. This is easy to transport and somewhat preservable, although heat-stable microorganisms may still alive. As the demand for packed tofu is on increase, several factories which can produce 20,000 per day are now in work. These factories are facilitated with new-developed equipments already mentioned and also with automatic packer which can make 40 products per minutes by making bag from film sheet, putting soymilk to the bag and then closing successively. At the process of packed tofu making even cold soybean milk become viscous by admixture with calcium sulfate, care must be taken to mix these two only just before putting them in the bag. But if glucono-delta-lactone, which is newly developed coagulant, is used instead of calcium sulfate, the milk does not become viscous but start to coagulate after heating. The milk coagulates to gel by gluconic acid which separates from glucono-delta-lactone by heat. This coagulant is also available for making kinugoshi. Packed tofu is suitable for fortification of

some nutrients, such as vitamin B_1 and water-dispersible vitamin A, because whey is not wasted.

New materials of tofu

Defatted soybean meal, which have high nitrogen solubility are often used as supplement of whole soybeans in tofu making, because soybean milk can be made from this meal also. Oil mill companies are producing these products. The defatted meal is usually used for mixing with whole soybeans. Advantages of the defatted meal are that no soaking or grinding is necessary for making the soybean milk.

Spray dried soybean milk powder made from the water extract of whole soybeans are now in the market and can be used as a material of tofu, especially packed tofu. New type tofu plant to make packed tofu are now operated where there are no soaking tank, grinder and filter (Photo. 5).

New type tofu

Lyophylized tofu is produced commercially in small scale though it is fragile and small piece. This can reconstitute the original white tofu but it is not so gelatinous nor soft on tongue. Therefore instant tofu is practically not available in market. Spraydried soybean milk packed in 100-200 g unit with separated package of glucono-delta-lactone as coagulant is now commercially sold. This can be used by housewives for home-made tofu. Soybean milk is prepared by dissolving the powder in water and boiling. The soybean milk is coagulated into kinugoshi tofu gel in the small bowl or box only by mixing with the coagulant at 80-90°C.

Spray-dried soybean milk preliminarily mixed with glucono-delta-lactone can be dissolved in cold water and coagulated to gel by heating for the separation of gluconic acid. Although it is not commercially prepared it is a semi-instant tofu.

A new type tofu developed by the Food Research Institute is to coagulate soybean milk in paper cup with glucono-delta-lactone by heating in electron range. It is eaten by spoon directly from the cup.

Aburage and other deep fried tofu

There are several kinds of deep fat fried tofu products, which are mainly made at the tofu factories. About one third of soybeans consumed for tofu and its derived products is for deep fried tofu. Aburage

is made from thin-sliced tofu. It has yellow surface and porous texture. Frying consists of two stages, at about 120°C and then at 180°C. By the former frying tofu swells and become porous. By the latter the surface of swollen tofu become hard and it prevents fried tofu from the shrinkage. Defatted soybean meal can be used in aburage making much more than in fresh tofu. Because aburage is more preservable and can be transported for longer distance than tofu, aburage plants are sometime very large scale consuming 2,000 kg soybeans in a day. Continuous deep frier of several types were developed already ten years ago (Photo. 6). This frier has endless conveyer on which metal frame of definite size are fixed. The thin-sliced tofu are put in the frames and deep fried when the conveyer is moving in oil bath of lower and then higher temperature. Aburage are continuously thrown out from the frame soon after finishing the frying. Aburage is also digestible and nutritious, rich in oil and protein. Ganmodoki is made from ground tofu mixed with pieces of vegetables, sea weeds and sesame. Texture of this product is very different from the original tofu. Feeling on tongue and teeth are somewhat similar to those of chicken. It is interesting that this name means wild-goose analogue. We also have Namaage which is made from tofu by one stage frying at 180°C. Its surface is yellow but its texture is almost the same with original tofu.

Kori-tofu and its industrial production

Kori-tofu is dried tofu which is made by special way, that is to dry up tofu into porous sponge without case hardening by the process of freezing, aging, thawing and squeezing. It is yellow, porous and therefore light cake of square size as shown Photo. 7. It swells in large size when cooked in hot water and becomes like sponge. It is more popular in western Japan. The amount of soybeans consumed for kori-tofu is about 30,000 metric tons in a year, about one tenth of fresh tofu. But demand for kori-tofu is recently increasing at the rate of 10% each year. It is digestible and nutritious, rich in oil and protein as shown in Table 2.

Process of kori-tofu making (See Fig. 1)

Tofu used for making kori-tofu is much harder and more sandy, and for this purpose soybean milk is desirable to be lower concentration and coagulated by calcium chloride instead of calcium sulfate, and the resulting curd must be ground vigorously after removing the whey. The ground curd is then transferred to wooden box and pressed to remove whey from the bottom of the box. After taking out hard tofu from the box it is soaked in cold running water to precool and remove excess calcium chloride. Then it is cut into pieces of 80 mm x 60 mm x 20 mm size weighing about 90 g. Cut tofu are then frozen at -10°C by forced chilled air brast in 1 to 2 hr, and then moved to aging room to keep them at -1 to -2°C for 2 to 3 weeks. By thawing the aged tofu their texture become like sponge and easy to be squeezed out by press. Then they are dried by forced hot air, taking care for preventing from cracking and shrinking. One piece of kori-tofu weighs 17 to 20 g. From 100 kg soybeans about 45 to 50 kg of kori-tofu is obtained. To meet consumers demand to make it soft after cooking it is exposed to ammonia gas from bomb in a closed chamber before packaging. By this treatment ammonia gas penetrate into the sponge texture of kori-tofu and is hold in it. By cooking in hot water it swells more largely and become softer. There is no problem from physiological view point, because ammonia gas is vapourized or neutralized during cooking.

Kori-tofu production as industry

Production of kori-tofu is in much larger scale than fresh tofu, because it is more preservable and easier to transport. There are about forty factories and average consumption of soybean is about 2 to 2.5 metric tons per day and there are 5 to 6 big factories which consume over 10 metric tons of soybeans per day. Market share of these factories in total production is over 80% and their capacities are expanding. Each piece of kori-tofu is 7-8 yen (3 cents). As shown in Table 3 cost of 100 g protein of kori-tofu is cheaper than that of fresh tofu in spite of its more complex and time-consuming process. It is apparently because of its labor-saving mechanization of over-all procedure. Aging for three weeks is a disadvantage for this industry, but there is still no way to shorten this period.

Equipments for kori-tofu production

The big factories consuming over 10 metric tons per day have usually several floor building as shown in Photo. 8. Cleaner and washer of soybeans are fairly popular in kori-tofu factories. Soybeans soaked in water overnight is transferred to the top floor, and grinding, heating, filtering, coagulation and moulding are successively done at next downstairs being moved by gravity. Preparation of soybean milk in these factories is made in batch system, each batch being 1 sack (60 kg) soybeans. Equipments in this process are steel grinder, steam cooker, air press or basket type centrifuge, but recently continuous cooker, oliver-type filter or decantor (continuous horizontal type centrifuge) became available for labor saving and better quality control. Continuous processes are more widely introduced to the process after the coagulation. Ground curd in the box is continuously dehydrated by moving in long steel frame. After precooling (Photo. 9) and cutting of tofu, its freezing, thawing, squeezing and drying are made continuously and automatically (Photo. 10 - 11). As it takes 2 to 3 weeks for aging they need fairly large space for this process. Kori-tofu making consists of many stages, so it is now difficult to make entire stages completely continuous. The problem is that how to treat a large number of small cakes which are fragile and easy to be broken. Severe control of processing conditions including temperature and time of freezing and aging is necessary for keeping better quality and yield of the product.

Distribution of kori-tofu

Kori-tofu has longer shelf life than fresh tofu, but brown spots appear on its surface when it is stored under undesirable conditions, namely high temperature, high humidity, especially at the presence of heavy metal ion such as ferric ion. Sometimes the surface is completely covered by brown color. The browning is reported to be reaction products of oxidized oil with amino groups of protein. Use of antioxidant is not permitted and so low temperature as well as low humidity are effective to prevent the browning, although oxidation of oil easily progresses at lower humidity.

Utilization of by-products

Residue at the preparation of the soybean milk is used for cattle feed as it is, and whey is discarded as it has no payable use. But they are trying to find new uses of the whey, because the discarded whey containing nitrogen compounds and carbohydrate sometimes damages growth of crops and call comments of farmers.

Yuba and its industrial production (See Fig. 1)

Yuba is a film which is formed on the surface of soybean milk during heating just as in the case of cow's milk. It is high in protein and oil as in Table 2. Yuba is sold in various types, for instance, sheet, roll or tied ribbon. It is rather a local food, made at definite districts, Kyoto in western Japan and Nikko in eastern Japan. In Tokyo only several plants is now working. Demand for yuba is lowest among the traditional soybean foods in Japan. Soybeans consumed for yuba is perhaps several hundred metric tons in a year. Yuba is made in very small scale, using about 10-30 kg of soybeans per day. Soybean milk which is prepared in the same way as tofu is poured into shallow bat and gently heated directly or by steam jacket. The film formed on the surface is scooped up carefully by fine stick using hand and dried at room temperature if necessary (Photo. 12). After getting 10-20 sheets soybean milk is finally dried up to solid which is yuba of low grade. Therefore almost all of the soybean milk is made into yuba. Yuba is much more expensive compared with other soybean foods, because it is made almost by hand work.

Kinako and its industrial production (See Fig. 1)

Kinako is powder made from roasted whole soybeans. Sometimes soybean hulls are preliminarily removed. It has characteristic roast flavor and used as a kind of cake base. It is also very popular for putting on baked rice cake with sugar. About 12,000 metric tons of soybeans is used in a year for producing kinako. Factories of kinako is not so large. Average consumption of soybeans per day by one factory is about 200 kg.

Cleaned soybean is roasted in a rotary drum by sending hot air until characteristic flavor come out. The roasted soybean is then ground by a impact steel grinder which has a steel screen to make fineness of kinako even. One hundred grams of kinako is about 30 yen.

Kinako is more digestible than roasted or steamed whole soybean, but some amino acid such as lysin and arginine may partly decomposed by overheating.

New soybean food materials and their industrial production

The annual consumption of soybeans for non-traditional foods in Japan is much less compared with that for traditional one. But it is noteworthy that the consumption is rapidly increasing, mainly for producing substitute in meat products and meatless meat. Background of this increase may be shortage and high cost of meat and meat products in Japan. Over twenty companies have announced the production of these foods or food materials and some of them have already start the production. At present products are mainly substitute in meat products but meatless meat will be also manufactured in industrial scale in the near future.

New soybean food materials

There are three types of materials used. These are dried soybean milk, soybean protein concentrate and isolated soybean protein. To make dried soybean milk whole soybeans or defatted soybean meal is used as starting material. Its hot or cold extract is concentrated and spray-dried. There is a plant which can produce 3-5 metric tons powder per day. Soybean protein concentrate made by using alcohol to remove non-proteinous compounds is in the market. Other type of the concentrate is prepared by heating defatted soybean meal at first with 10 times weight water of soybean meal to make its protein dissolved. Then, before filtration, calcium sulfate or organic acid is added to precipitate the protein. By filtration or centrifugation mixture of protein and insoluble carbohydrate is obtained being separated from whey which contains beany flavor and bitter substance. The mixture is called "curd", but it may be rather a kind of protein concentrate. Production process of isolated soybean protein in Japan consists of extraction of solubles from defatted

soybean meal, separation from insolubles, precipitation by acid, removing of whey and drying if necessary, as usual way. Before extraction of solubles washing of the meal with dilute acid to remove whey at first is reported to be effective for removing beany flavor more completely.

Usage of new soybean food materials

Among these materials isolated protein powder, spray dried soybean milk and wet-curd type concentrate are used as is for supplementing meat and meat products, and also fish paste products, because they can be mixed with ground meat or fish homogeneously and form elastic gel by heating. On the other hand these materials can be converted to textured protein or protein concentrate by drastic physical treatment such as extrusion, pressing and agitation in the presence of small amounts of water. Several textured protein foods including imported one are already in market. Spun protein which is manufactured from isolated soybean protein is made by one company now, being 20-30 metric tons per day. This contains 75% water and distributed in frozen state, each 5 kg being packaged. This is used by meat processor as substitute of meat. Meatless meat which are flavored, seasoned and colored, and ready to eat by simple cooking are now test-marketed by several companies.

In Table 5 moisture content, protein content and price of new soybean food materials and their derived products are shown. Recently perhaps over 1,000 metric tons calculated as whole soybeans are consumed monthly for these new food materials.

Future of new soybean foods

From the present and future situation of protein supply and demand in Japan as well as in the world new food use of soybean and soybean protein are promising. Research work to develop new textured foods of soybean are necessary. Fundamental research on soybean protein is rapidly progressing and it should contribute to the development of new food uses of soybean protein.

Table 5 Moisture, protein content and price of new soybean food materials

Materials	Moisture %	Protein %	Price (yen/kg)	Price (cent/kg)
Spray-dried whole soybean milk	3-5	40-44	230	64
Spray-dried defatted soybean milk	3-5	51-56	200	55
Soybean protein curd	81-83	12-13	30-40	8.4-11
Soybean protein concentrate	5	68-70	300	83.5
Isolated soybean protein	5	above 90	400-500	110-139
Textured protein from soybean	7	53-68	500-600	139-166
Spun protein from soybean	75	25	125	34.6

Other food uses of soybeans

Other use of soybeans for non-traditional foods is to add to popular foods such as bread, cake, noodle, candy and ice cream applying the functional properties of soybean protein. As per centage of soybeans in these foods is fairly low, total amounts of soybeans including defatted soybean and soybean milk used in these foods is not so much, perhaps several thousands metric tons per year.

Natto and its industrial production

Natto is one of the most popular fermented soybean foods in Japan. It is a very unique food, because bacteria is used for fermentation. Surface of cooked soybean is covered with viscous sticky substance, which has property of forming long stringy threads when mixed up (Photo. 13). The longer the strings, the better the quality of natto. Natto has characteristic flavor containing ammonia. Its chemical com-

ponent is shown in Table 2. Texture of cooked soybeans is softened by enzymes of Bacillus natto, a kind of Bacillus subtilis, and their protein partly hydrolyzed resulting in its high digestibility. It is reported that vitamin B content increases during the fermentation. It is usually eaten with cooked rice seasoned by soysauce or salt. The amount of soybeans consumed for natto in a year is about 50,000 metric tons and more popular in eastern Japan.

Process of natto making (see Fig. 2)

To make natto whole soybeans are soaked in water overnight and heated in a pressure cooker at 1.5 kg/cm² for 20-30 minutes until they become soft. Suspension of spores of Bacillus natto which is obtained by pure culture is inoculated on the cooked soybeans. Five to ten ml of the suspension is necessary for 5 kg of raw soybeans. At first the inoculated soybeans are divided into 100 g unit and each 100 g is put in a polyethylene bag and then fermented. Wooden slice box and rice straw are also used as containers. Traditionally they wrapped cooked soybeans with bundled rice straw to use wild Bacillus natto grown on the straw. The bags are incubated at 40° for 18-20 hr in the fermentation room (Photo. 1).

Equipments for natto production

The natto plants of average scale are facilitated with washing machine, soaking tank, pressure cooker, inoculator (a kind of rotary mixer) and fermentation room. The most labor consuming process is dividing as well as packaging process. No effective method or machine for this process is developed. At natto plants of average scale, temperature of fermentation room is automatically controlled, because quality of the products depends largely on the fermentation process, especially temperature control.

Natto production as industry

Natto is fairly perishable, as ammonia will be produced too much by overfermentation. Therefore, production scale is not so large in average. There are about 1,300 plants in Japan, and the average consumption of soybeans is about 100 kg per day. Recently, however, there are several factories consuming 2-3 metric tons of soybeans per day. These

factories intend to save labor by mechanization of each process, although continuous process is not yet established. They locate at suburbs of large cities and have store hause of low temperature to control the distribution of their products.

From 10 kg of soybeans about 16 kg of natto is produced. One bag of natto containing 100 g is 15-20 yen (about 4-6 cents).

Miso and its industrial production

Miso is a fermented food made from soybeans, rice and salt, although their ratio are different depending on its varieties. Koji which is made from steamed rice by inoculation Asp. oryzae on its surface and incubating for two days is mixed with cooked soybean, salt and water to make its final water content about 50%. This mixture is fermented after filling up in wooden or concrete tank. As the fermentation progresses in the state of semi-solid the chemical change of substrate is much milder compared with that of shoyu in which the fermentation progresses in the state of liquid. Protein, carbohydrate and oil in rice and soybeans change into tasty and flavoring substances by enzymes of koji and added or wild microorganisms, and its pH is 4.5 to 5.5. Miso is paste-like food (Photo. 5) and usually used as miso soup and sometimes seasoning as is mixed with sugar and some other ingredients. As miso is rich in protein as well as oil (Table 2) and digestible, it contributes to protein and oil intake of Japanese people. Amount of soybeans consumed for making miso in a year is about 180,000 metric tons including defatted soybean meal. Besides, 60,000-70,000 metric tons of soybeans is used for home made miso.

Variety of miso

There are many varieties of miso in Japan just like in the case of cheese. From the view point of raw materials for miso, however, there are three major groups manufactured at present, namely rice-miso, barley-miso and soybean-miso. Salt and soybeans are used for all varieties. Besides salt and soybeans rice is used for rice-miso, and barley for barley-miso. Of the total amount of miso prepared at factories, nearly 80% are consisted from rice-miso, and remained 20% are barley- and

soybean-miso. Rice- and barley-miso are classified into sweet, medium salty and salty depending on the amounts of salt and rice or barley used. Miso can be also classified by the color, for example, white, light yellow and red miso, and by the place of production, for example, Sendai, Shinshu, Sado, Saikyo and Hatcho miso. Sweet white miso is the lightest and sweetest among all varieties. Prewar it was manufactured only in winter due to the short shelf life. Salty light yellow miso is typical variety with the following salty red miso. The color is light yellow and flavor is rather simple without any characteristics unfavorable for wide use. Shinshu-miso is one of the most typical of this group produced in Nagano prefecture which is called Shinshu conventionally. Salty-red-miso is the most popular throughout Japan. The characteristic reddish color is produced during soybean-steaming and fermentation with brine at least 3 months at 30 °C. With the production of color, characteristic flavor produced by the fermentation of salt-resistant yeasts and lactic bacteria during the long time fermentation and ripening. Soybean-miso has been traditionally produced in Aichi prefecture, where Nagoya is located, Gifu and Mie prefecture. It is extremely dark red and of strong flavor.

Process of miso making (See Fig. 1)

Although the manufacturing method is different from variety to variety, the principle is the same. The outline of the process of salty rice miso is consisted of cooking of soybeans, preparation of rice koji, mixing cooked soybeans, rice koji and salt, fermentation in vat or tank, blending and packaging for market.

Soybean cooking: Soybeans are sifted to remove foreign matters and cleaned to take out the dust over the surface of hull. Effective cleaner and washer are widely used. For white miso or light yellow miso dehulled soybeans or soybean grits (in their process the soybeans are cleaned and then cracked by a roller-type crusher or other suitable apparatus; the hulls can then be readily removed or separated from the remainder of the soybeans; the part of the soybean free of the hulls is referred to as grits) are used in order to make the color light at the expense of some part of water soluble matter of soybeans. Soybeans, after being washed by water, are soaked in water over-night to absorb 1.2 times water by weight. Thus soaked soybeans are cooked in water or steam. For white miso or light yellow miso cooking in water is em-

ployed and for the other miso steaming is employed. Cooking is proceeded under the pressure of 0.75 kg/cm^2 for 20 minutes until adequate softness is obtained. Thus cooked soybeans are cooled for mixing with rice-koji and salt. The cooked soybeans are often roughly chopped through a chopper prior to cooling. Rotary cooker in Photo. 16 is large-scale batch-type cooker which is capable of cooling rapidly cooked soybeans to prevent from its over-browning. Soybean which become soft by cooking is preferred by miso industry and soybean rich in carbohydrate seems to meet this requirement.

Koji preparation: Milled rice is widely used for making koji. Rice is cleaned with enough water and soaked in water of which temperature is 15 °C for 15 hr or more. Thus soaked rice is drained off to be steamed generally under atmospheric pressure for 40 minutes. When the inner part of the rice is fully gelatinized, the rice is taken out from the cooker to be cooled to 35 °C for inoculation with spores of Aspergillus oryzae which is called tanekoji and sold commercially. The inoculated rice is conveyed into a fermenter in order to grow the inoculated mold over the surface of rice. The temperature is kept at 30 °C and the relative humidity is over 90% during fermentation by circulating the air passed through a air conditioner. The incubation is carried on 40 hr until the rice is fully covered by the mold. The koji is then mixed with salt immediately after transference from the fermenter in order to stop the further development of the mold.

Mixing: Cooked soybeans are mixed with salted koji and inoculum in a mixer until uniformity is obtained. The inoculum including lactic acid bacteria and yeast of salt resistance is employed in order to accelerating the fermentation. Calculated amount of water so as to regulate the water content to 48% for salty-rice-miso is added with the inoculum.

Fermentation: The mixture of koji, steamed soybean and salt water is packed into fermenting vat or tank of which capacity is 4 tons or more and then covered with a plate on which weights are placed to press out the miso juice on the plate. Fermentation is run at around 30 °C in a fermentation chamber of which temperature is capable to regulate. The duration of fermentation differs depending on variety, and for light yellow miso at least one month and for red miso at least 3 months are requested. During fermentation transference to another fermentation

vat or tank is carried out at least twice in order to accelerate the fermentation and make the constitution uniform. After finishing of fermentation miso is transfered to ripening vat or tank at room temperature. Ripened miso is blended and mashed, if necessary, to be packaged for market. For packaging in small plastic bags miso is pasteurized to prevent from swelling and added by sorbic acid or its potassium salt.

Soybean-miso is made by somewhat different method from that stated above. Soaked soybeans are cooked in steam to be mashed and moulded in several shapes and sizes. At present cylindrical shape of 15-20 mm diameter and [illegible]-50 mm hight is widely employed. Then these moulds are inoculated and fermented in the same manner with rice koji. Soybean koji is dried and crushed to be mixed in brine for fermentation lasting ten months or more. The miso juice separated during fermentation is called "Tamari" which is used as a condiment just like soysauce.

Although the yield of miso varies widely depending on its varieties, moisture contents and ripening periods, from [illegible] kg of soybeans, 600 kg of rice and 130 kg of salt about [illegible],[illegible] kg of light yellow salty miso is obtained.

Miso production as industry

The amount of miso of industrial production shows slight increase in past five years. Besides industrial products, home made miso are consumed principally at farms. At present home made miso is roughly estimated 700,000 metric tons, whereas commercial miso is about 500,000 metric tons per year. Due to the shortage of labor at farm industrial miso have gradually substituted for home made miso. The average comsumption of miso indicates slight decrease in the past ten years.

The industrialization of miso making was proceeded remarkably after 1960 and some of small factories began to amalgamate to a big factory. The number of factory in 1965 was about 2,400, whereas in 1959 was about 3,000. The total amount of miso produced by the top ten factories marked 140,000 metric tons corresponding to 26% of the grand total production. Twenty three factories have a capacity of 3,750 metric tons per year, headed by the top of which capacity is 22,000 metric tons. Cost of products depend largely on variety and grade. Salty rice miso is 100-300 yen (28-83 cents) per kg, whereas white rice miso is 250-400 yen (70-110 cents) per kg.

Industrialization of miso making

In these ten years equipments for continuous processing have been introduced into miso industry especially in big factories. Special equipments for continuous processing are seen in the process of the cooking of rice and soybeans.

There are several types of continuous rice cooker and a typical one is shown in Photo. 17. The principle of this cooker is as follows. Soaked rice is fed continuously on the belt conveyor of stainless steel net to be spread to a depth of approximately 8 cm and then steamed under atmospheric pressure during conveyance at a certain speed. Thus steamed rice is transfered onto the belt conveyor of stainless steel net to a depth of 3 cm and cooled in the forced stream of cool air passed through the moving rice belt. Continuous soybean cooker which was first employed at shoyu factory for cooking soybean flakes or meal. Recently it was introduced into miso industry for cooking defatted meal. Details of this equipment are described in "shoyu and its industrial production". Rotary fermenter is popular for making koji in miso plant. Inoculated steamed rice is put in large trommel in which forced air of controlled temperature is continuously sent. The trommel is rotated several times to prevent rice from agglomeration and accordingly from local heating. After finishing of fermentation koji is mixed with salt in the trommel by rotation at higher speed (Photo. 18).

Preparation of koji by a large number of wooden tray has now become somewhat old-fashioned and almost of koji are prepared by new-developed method such as that explained above. An automatic measuring mixer is used for mixing cooked soybeans, salted koji, inoculum and water.

There are several problems in industrialization of miso making. The control of microorganisms during fermentation seems to be the most important and difficult, since the fermentation is proceeded under so-called open system liable to be contaminated by microorganisms besides the useful microorganisms including salt resistant yeast and lactic acid bacteria. As the result of the investigation Saccharomyces rouxii and Torulopsis, Pediococcus halophylus and Streptococcus faecalis were identified as useful microorganisms for miso. Pure culture of these microorganisms is available now as starter just like as lactic starter when cheese is prepared in Europe.

Distribution of miso

Miso was packed in a wooden cask of which capacity was 40 kg to be sold by measure at retail. At present, 20 kg of miso are packed in a polyethylene bag covered with paper container as bulk package to be sold by measure. Besides, small plastic bags are employed for packaging, especially for distribution through supermarket. To prevent swelling of bags during distribution packed miso is pasteurized in hot water of 70 °C for 30 minutes to raise the temperature of the center to 60 °C. For this purpose heat resistant plastic film, for example, saran film is suitable. Specially designed pasteurizers were introduced with a purpose to pasteurize continuously prior to packaging into film bags (Photo. 19). In order to ensure the effect of the pasteurizer sorbic acid or its potassium salt is officially allowed to use at the level of less than 1 g per kg of miso. Packed miso was sometimes browned during distribution and it was claimed by consumers, but it was solved by employment of packaging film of the least permeability of oxygen, storage at low temperature and prevention from metal contamination.

Future prospect of demand for miso

Although the production of miso is increasing slightly, the consumption per head has obviously decreased in amount, perhaps because of remarkable increase in the varieties and quantity of foods at the post war. As already mentioned, the appearance and consistency seems not suitable for handling, packaging, transportation and storage, and some improvement in this respect is expected to be undertaken as modern food. Dehydration by freeze drying procedure gave dehydrated powder miso of which moisture level is 4% or less. The flavor of the miso soup made from dehydrated miso is employed as principal ingredient of so-called instant miso soup. Although the amount of miso used for dehydration is estimated about 1% of the total miso, it is growing at high increasing rate. The flavor of dehydrated miso is so characteristic and tasteful that it has potential to be used widely as ingredient of soups including not only miso soup but also general soups.

Mycotoxins and fermented soybean foods

Since the International Symposium of Oilseed Protein Foods in 1964 active researches on the possibilities of presence of mycotoxins such

as aflatoxin by Asp. flavus in the fermented soybean foods are being done at the Food Research Institute and other research organizations. Many samples of miso, shoyu and rice-koji were collected from all over Japan for this purpose. Until now no aflatoxin was detected from any of them. It may be, therefore, concluded that no contamination of aflatoxin is observed in the fermented soybean foods in Japan.

Shoyu and its industrial production

Shoyu (soysauce) is one of the most important seasoning in Japan. The materials of shoyu are soybeans, wheat and salt. This is salty, transparent liquid, usually reddish brown in color and has a characteristic flavor which is produced during fermentation. Salt content is about 18%, nitrogen 1.5% and carbohydrate 3-4%. Its pH is 4.6-5.1. It is widely used in restaurants, feeding facilities and at home. They use shoyu as seasoning for cooking and sometimes on the table. About 170,000 metric tons of defatted soybean flakes are used per year for the production of shoyu. Consumption of shoyu in a year is almost the same in these several years.

Shoyu is consisted of amino acid, sugar and other organic compounds which are produced from protein, carbohydrate and other constituents of defatted soybeans and wheat by the enzymes of Asp. oryzae and also of yeast or bacteria developed during fermentation. Growth of undersirable microorganisms is prevented by salt and also organic acid such as lactic acid produced by lactic acid bacteria at the processes of fermentation.

Process of shoyu making (See Fig. 1)

The normal process of shoyu making starts from shoyu-koji making. At first defatted soybean meal or flakes are cleaned and made free from foreign matter. After spraying water of a certain amount on the surface of the meal or flakes, it is steamed under the pressure of 0.9 kg/cm^2 for 50 to 60 min., taking care to prevent from local heating. It is mixed with roasted crushed wheat and then with inoculum (tanekoji), which is spores of Asp. oryzae and commercially available, after being cooled to 35-40 °C. The mixture is incubated in a warm chamber to pro-

mote the growth of the mold. In the process of growing of Asp. oryzae the mixture is almost covered by the mold within 45 to 65 hr and become yellow in color. This is shoyu-koji, and mixed with salt water for fermentation. Koji prepared from 1,200 kg soybean meal and 1,200 kg wheat is mixed with 4,300 litre of 19Be salt solution. It is necessary to agitate vigorously to make the mixture homogeneous. This mixture is called "moromi". Fermentation of moromi is made in large concrete tank (Photo. 20) or wooden vat for 8 to 12 months. Frequent agitation and aeration of moromi are necessary to proceed normal fermentation, preventing the growth of anaerobic microorganisms. Usually fermentation starts from April and finish within a year. The change of temperature during this period is important for the progress of fermentation.

After the fermentation is finished, moromi is separated into a liquid part and solid cake by press. When whole soybeans are used as raw material, the oil is separated at the upper layer of the liquid. The main component of the separated oil is ethyl ester of the fatty acids of soybean oil, which has a undesirable odor and has no promising use. Consequently, at present, defatted soybeans moderately toasted are used instead of the whole soybeans. The separated liquid, which is called raw shoyu is pasteurized at 65-80 °C. As precipitate is formed by pasteurization it is removed by filtration. The transparent liquid thus obtained is bottled in two litre jars, 100-200 ml plastic container for home use (Photo. 21) and also 18 litre wooden cask. Preservatives such as butyl ester of p-hydroxy benzoic acid and sodium bezoate is permitted to use to prevent the growth of mold-like yeast (Zygosaccharomyces) during storage.

Shoyu production as industry

From 1 metric ton of defatted soybean meal, 1 metric ton of wheat and 1 metric ton of salt, about 5,000 litre (sp. gr. 1.18) shoyu is obtained. Commercial production of shoyu in a year is about 1.2 million kl. This figure may be too much for corresponding to 170.000 metric tons of defatted soybean meal. Perhaps this discrepancy may be for mixing chemical shoyu (acid hydrolysate of soybean meal) in commercial shoyu.

As shoyu is preservable and can be transported to any places by bottling in jars, tanks and other containers, its production scale is fairly large. There are over 4,000 factories in Japan and the average con-

sumption of soybean is about 140 kg per day. But there are several large scale factories and some of them consume 120 metric tons of soybeans per day. Market share of the biggest five factories is about 42.5%.

Nitrogen utilization ratio in shoyu making

In shoyu making nitrogen utilization ratio is practically very important. This ratio means how much nitrogen in the materials become soluble in shoyu and this is usually about 70% but varies depending on many factors, such as steaming condition of soybean meal, quality of tanekoji and also fermentation process. It was found that overheating of soybean meal lower this ratio, perhaps because of difficulty of enzymatic degradation of over-denatured protein. By limiting the steaming condition of soybean meal this ratio can be raised over 90%. Treatment of soybean meal with 6% hydrochloric acid without adding wheat and then mixing with wheat or wheat bran inoculated by Asp. oryzae is also effective to raise the nitrogen utilization ratio. After neutralization with sodium carbonate they are mixed together with salt. Three months are enough for complete fermentation. NK-type steam cooker is developed for preventing overheating of soybean meal. Soon after pressure cooking of soybean meal outlet pipe of the cooker is opened to decrease the inner pressure and then the steam in the cooker is exhausted and evacuated by jet condenser to cool down the meal rapidly (ref. 2).

Industrialization of shoyu making

Continuous cooker is also being used in several large factories. As shown in Fig. 3 soybean meal is preliminarily sprayed by water and moved slowly by conveyer to adsorb water completely. Then it is transfered by elevator to continuous cooker, which is set inclined. During moving of the meal in the cooker by screw conveyor it is completely cooked by steam which is injected from the top of the cooker. The cooked meal is cooled down rapidly by taking out from the cooker and prevented from overheating.

In the small scale shoyu factories koji is made still by traditional way using a large number of wooden tray. As this method apparently needs much time and labor, new equipments for making koji are developed recently. Several kl of the material is incubated on large perforated

shallow case which is set in closed chamber (Photo. 22). By sending forced air of controlled temperature to the material and occasionally breaking of agglomerated rice koji of high quality containing less bacteria can be prepared.

Instead of natural fermentation shorter (six months) fermentation become possible by controlling temperature. Starting from fermentation at 15 °C for one month, followed by 28 °C for four months and finishing by 15 °C for one month, shoyu can be obtained which is the same in quality and yield with those by natural fermentation. When fermentation finishes moromi is carried to the press by plunger pump. Hydraulic press using nylon cloth is most popular. It takes 4-5 days for pressing, because by repeating the press several times in these days water content of the residue can be made below 30%. Steam-jacketed cooker has been widely used for pasteurization, but recently continuous pipe heater or plate heater become more popular in large scale factories. Automatic bottle washer and bottler have been very popular in shoyu factories so long time.

Special shoyu

There are several special shoyu beside above mentioned normal shoyu. In western Japan light-colored shoyu is fairly popular, though its amount is below 10% of the total shoyu production. To make color of shoyu light, whole soybeans are desirable and they must be cooked in water instead of in steam. NK-type cooker is satisfactory for this purpose. High salt moromi is also favorite to prevent browning.

Tamari is soysauce which is made only from whole soybeans or defatted soybean meal. The method is similar to that of soybean-miso which is described already, because formerly in the process of soybean-miso making tamari was made as juice from the miso. At present the both are made separately.

Chemical shoyu which is made by acid hydrolysis of soybean meal and other proteinous materials is being used for mixing with shoyu, though high quality shoyu does not usually contain chemical shoyu. Soybean meal is heated with 18% hydrochloric acid for 8-10 hr to hydrolyze protein into amino acids. After neutralization with sodium carbonate it is filtered to remove insoluble substance. Chemical shoyu is rich in amino acid and tasty, but has undesirable odor rather than the flavor

of shoyu.

Summary

Traditional soybean foods such as miso, shoyu, tofu and natto and also new soybean food materials including spun protein were described from industrial view point. The traditional soybean foods are still consumed in large quantities in Japan and it is noteworthy that some of them which have been somewhat local are becoming popular by development of mass production and also advancements in packaging process and distribution system.

Several kinds of new soybean food materials are now being produced in industrial scale to be used as supplements in meat products. From the situation of supply and demand in animal industry, it is true that soybean is now finding new promising fields of use in Japan.

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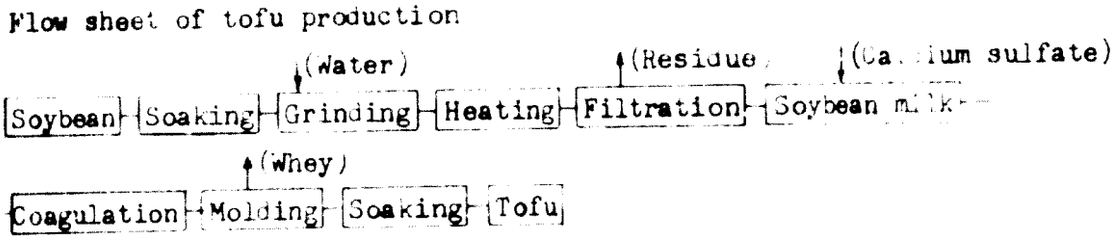
Acknowledgement

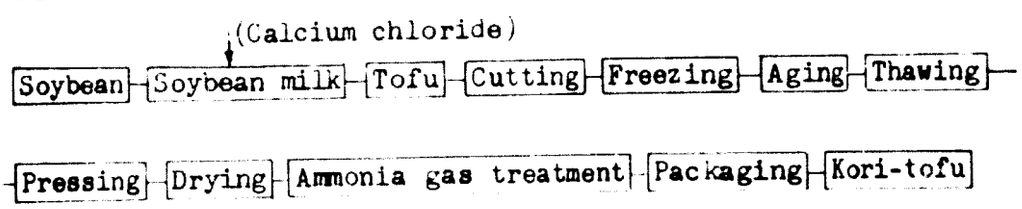
The author wishes to express his sincere thanks to Dr. Isao Umeda of Japan Shoyu Research Institute, Drs. Hideo Ebine, Shinji Matsuura and Teruo Ota of the Food Research Institute for their kind cooperations and useful advices in preparing this paper, and also to companies which have presented him photographs and illustrations of the equipments.

Fig.1 Flow sheets of production of traditional soybean foods in Japan.

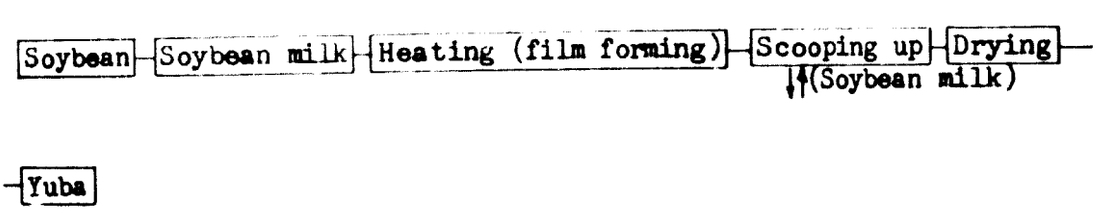
Flow sheet of tofu production



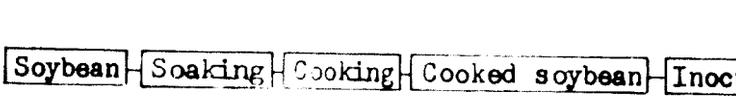
Flow sheet of kori-tofu production



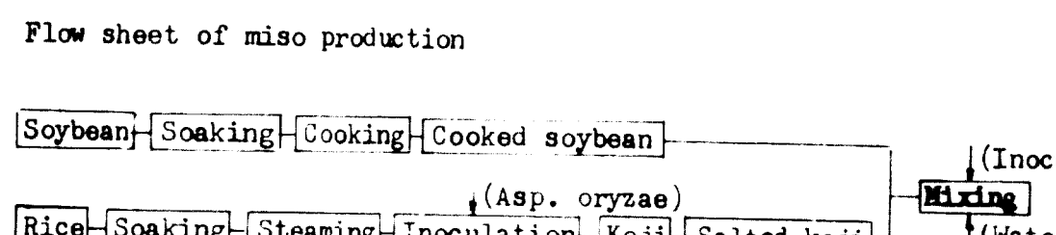
Flow sheet of yuba production



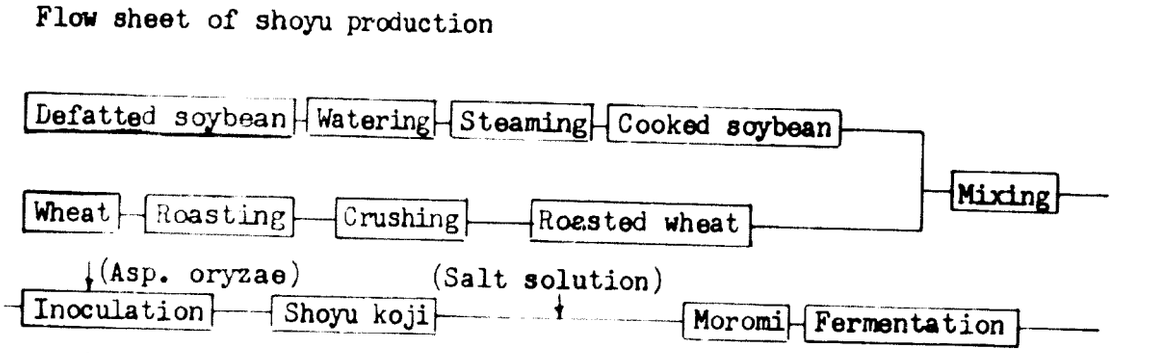
Flow sheet of kinako production



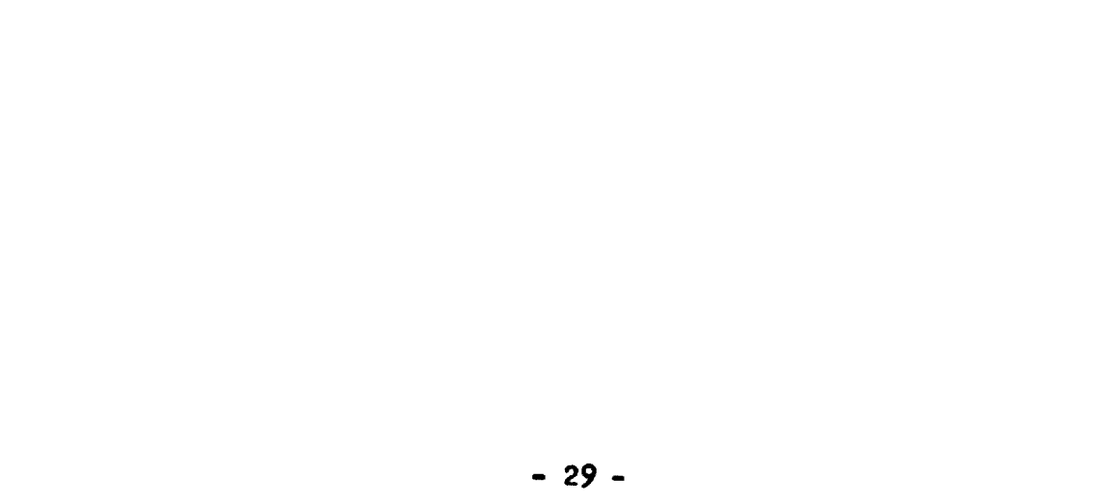
Flow sheet of natto production

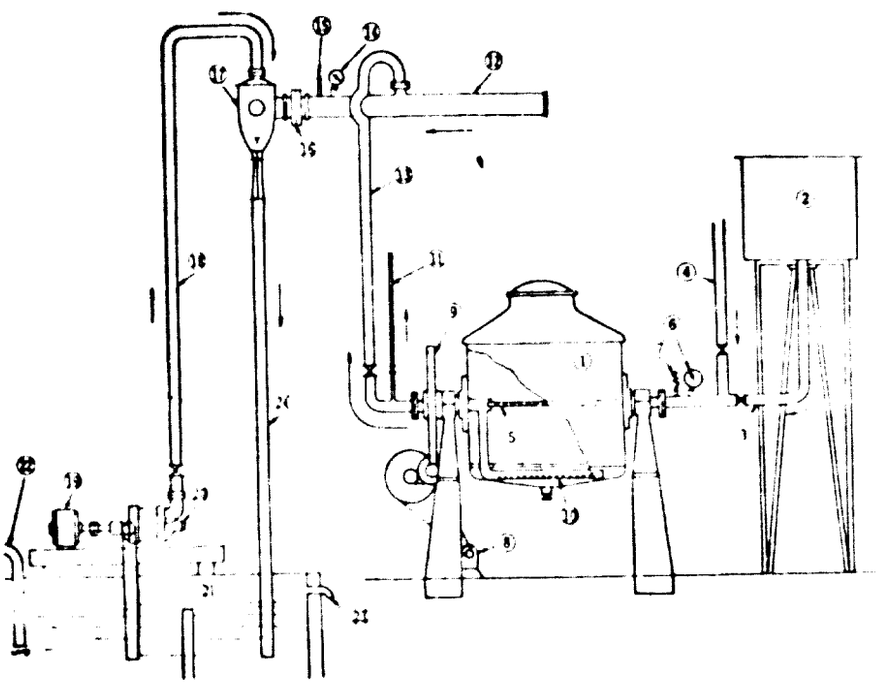


Flow sheet of miso production



Flow sheet of shoyu production





1: cooker
2: water tank
3: water pipe
4: steam pipe
5: exhaust pipe
6: pressure guage
7: safety valve
8: motor
9: worm wheel
10: outlet pipe
11: outlet pipe
12: vacuum pipe
13: suction pipe
14: pressure guage
15: thermometer
16: chack valve
17: jet condenser
18: cooling pipe
19: motor
20: turbine pump
21: water tank
22: water pipe
23: overflow outlet

Fig. 2. NK-type soybean cooker (by courtesy of Kikkoman Shoyu Co. Ltd.). (capacity: 1 metric ton of defatted soybean meal)

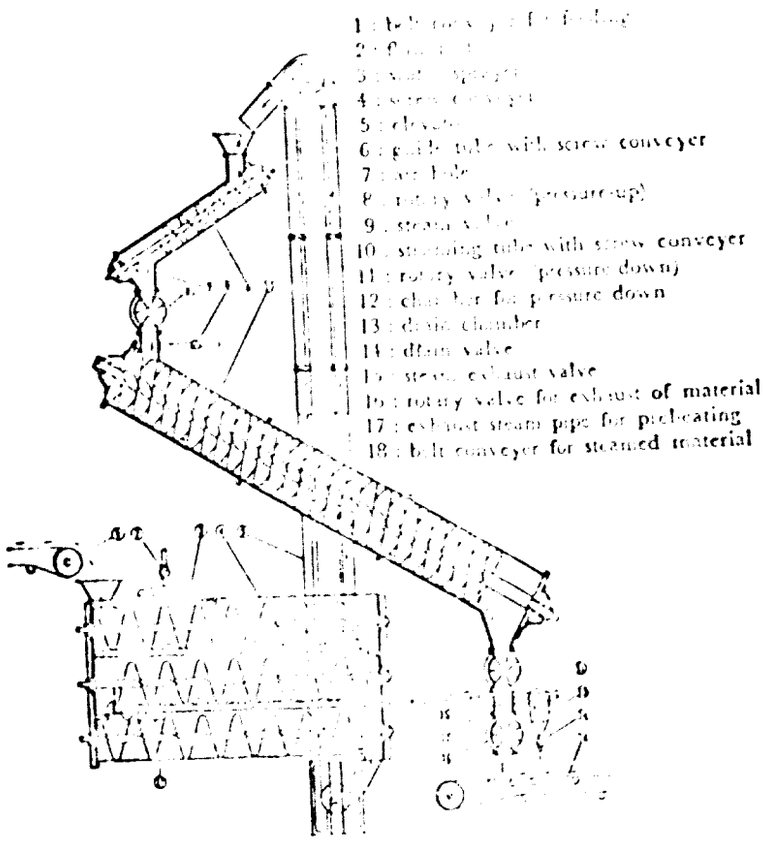


Fig. 3. Continuous cooker of soybean meal (by courtesy of Yamasa Shoyu Co. Ltd.). (capacity: 1 metric ton of defatted soybean meal per hour)

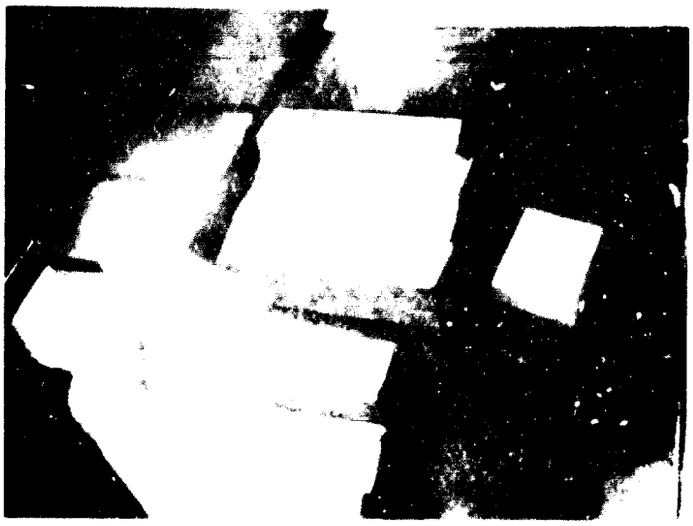


Photo. 1. Tofu soaked in water for sale.

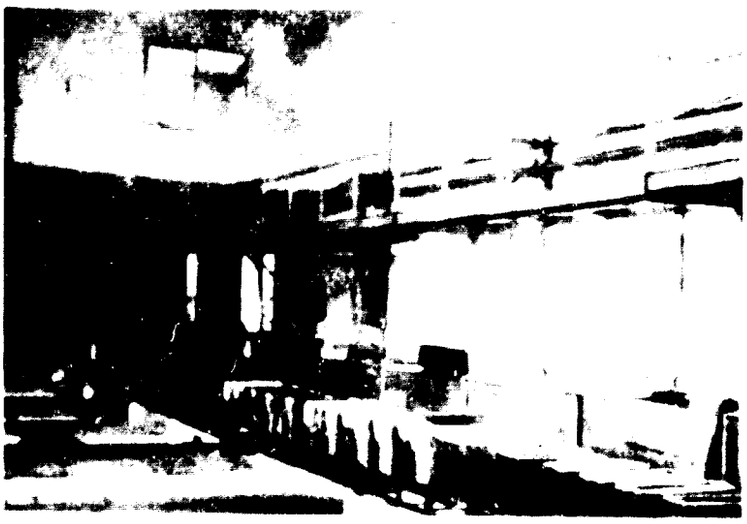


Photo. 2. Large-scale tofu factory (by courtesy of Tokyo Tofu Co. Ltd.).

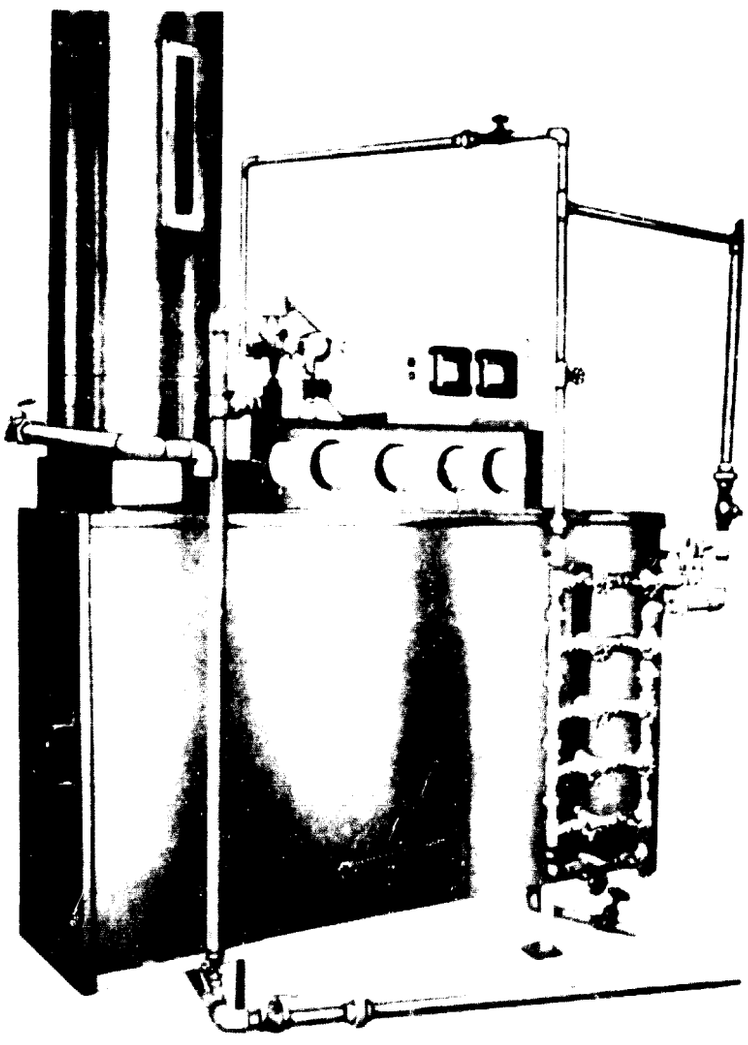


Photo. 3. Continuous cooker of ground soybean (by courtesy of Masuko Sangyo Co. Ltd.).

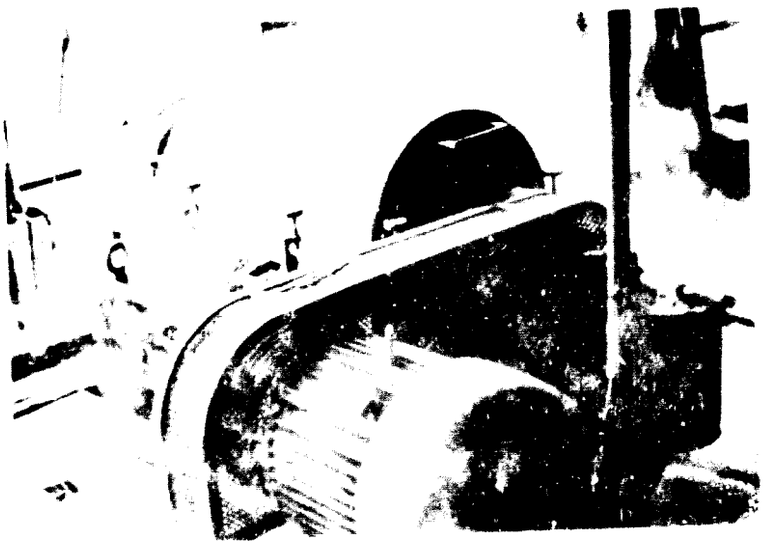


Photo. 4. Decanter, a kind of continuous centrifuge (by courtesy of Kokusan Seiko Co. Ltd.). (capacity: 3,000 kg of ground soybeans per hour)

Photo. 5. Factory of packed tofu from spray-dried soybean milk (by courtesy of Nippon Tanpak Kogyo Co. Ltd.).

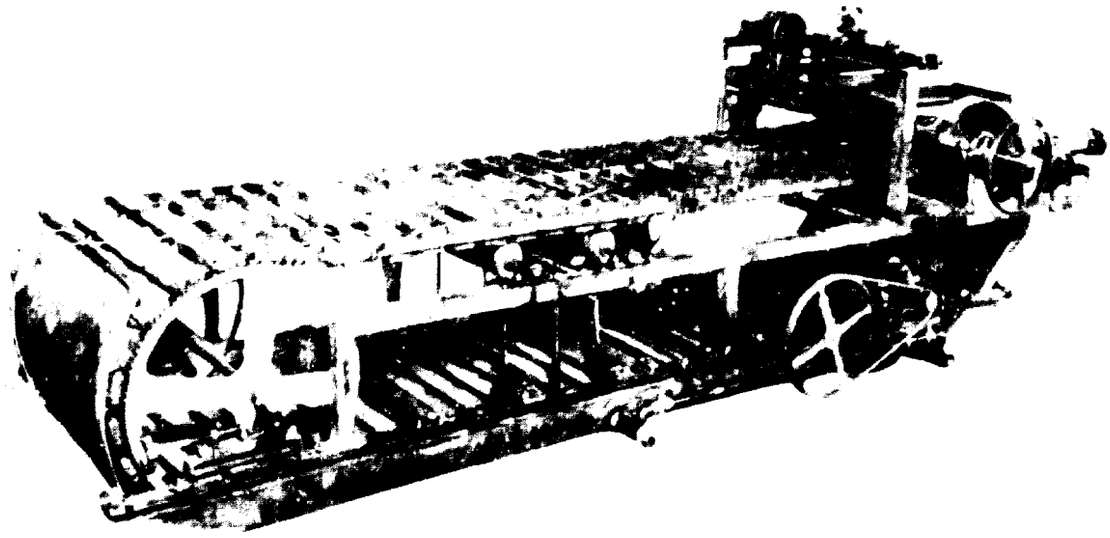


Photo. 6. Continuous deep-frier for aburage (by courtesy of Iwase Tekkosho Co. Ltd.). (capacity: 1,000 to 1,500 products per hour)

Photo. 7. Kori-tofu (Left one on the dish is swollen by hot water).

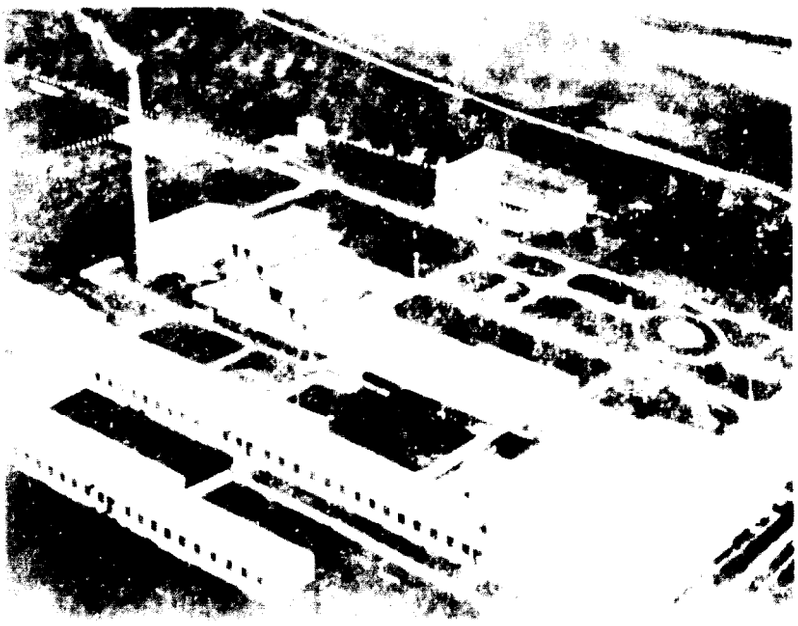


Photo. 8. Birds-eye view of large scale factory of Kori-tofu (by courtesy of Misuzu Tofu Co. Ltd.). Capacity: 10 to 15 metric tons of soybeans per day

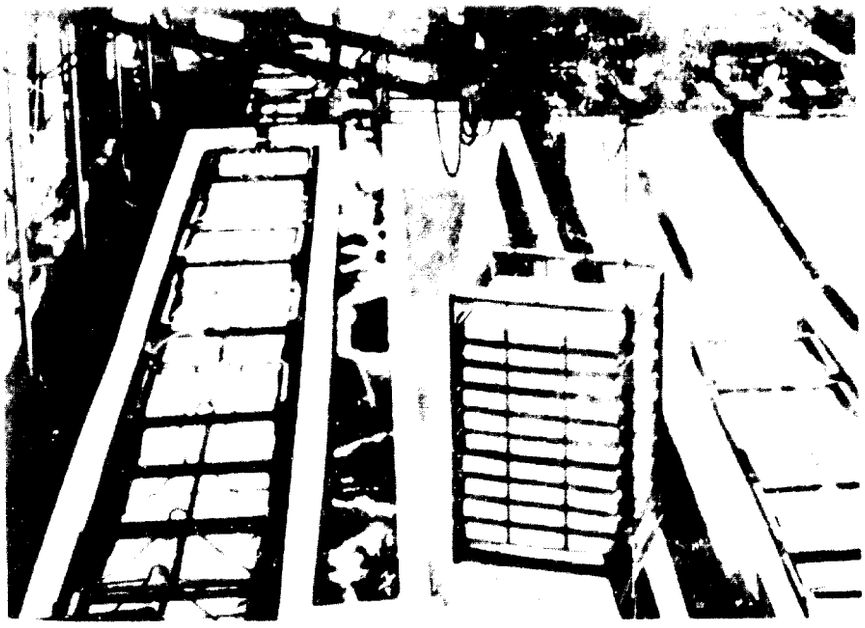


Photo. 9. Soaking of large cake of tofu for precooling (by courtesy of Misuzu Tofu Co. Ltd.).

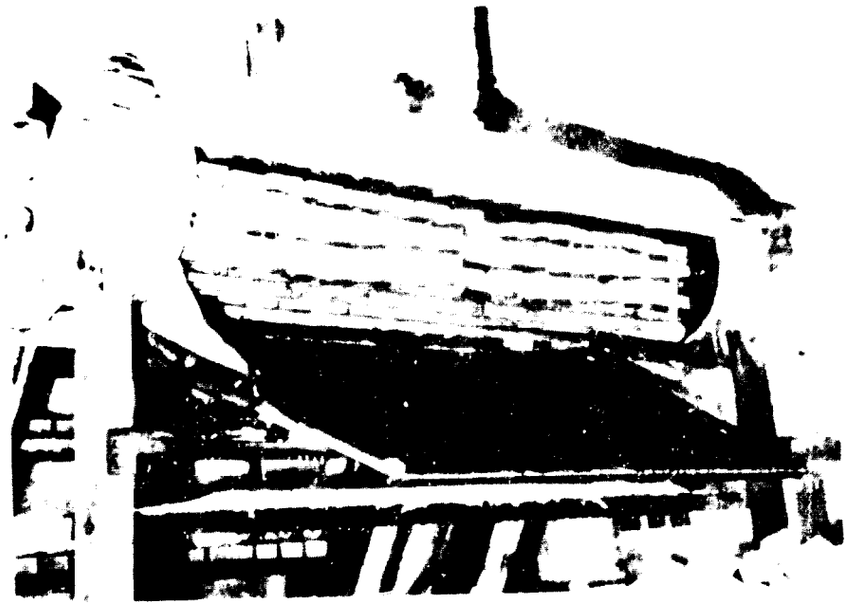


Photo. 10. Continuous freezing equipment of tofu (by courtesy of Misuzu Tofu Co. Ltd.).

Photo. 11. Continuous thawing apparatus of frozen tofu (by courtesy of Misuzu Tofu Co. Ltd.). (capacity: 10,000 to 15,000 pieces per hour)

Photo. 12. Yuba plant (by courtesy of Ohara Co. Ltd.).

Photo. 13. Natto mixed up by chopsticks.

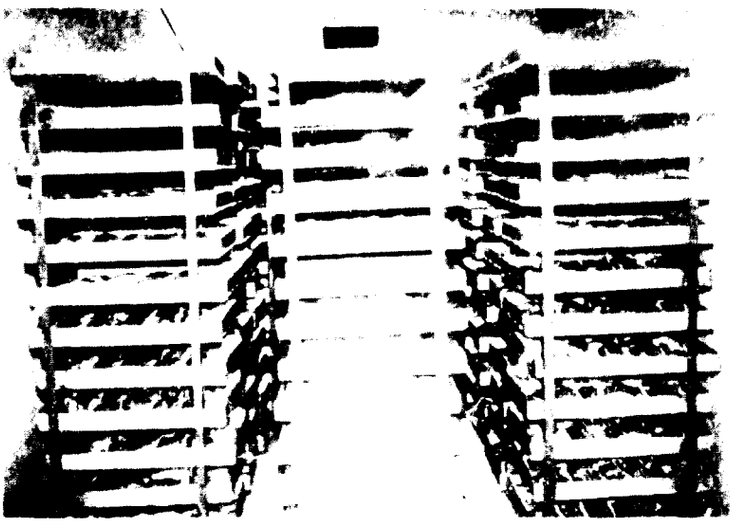


Photo. 14. Inside of fermentation room for natto making (by courtesy of Suzuyo Kogyo Co. Ltd.).

Photo. 15. Miso taken out from package.

Photo 16. Rotary cooker of soybean (by courtesy of Hinode Miso Co. Ltd.). (capacity: 1 metric ton of soybeans)

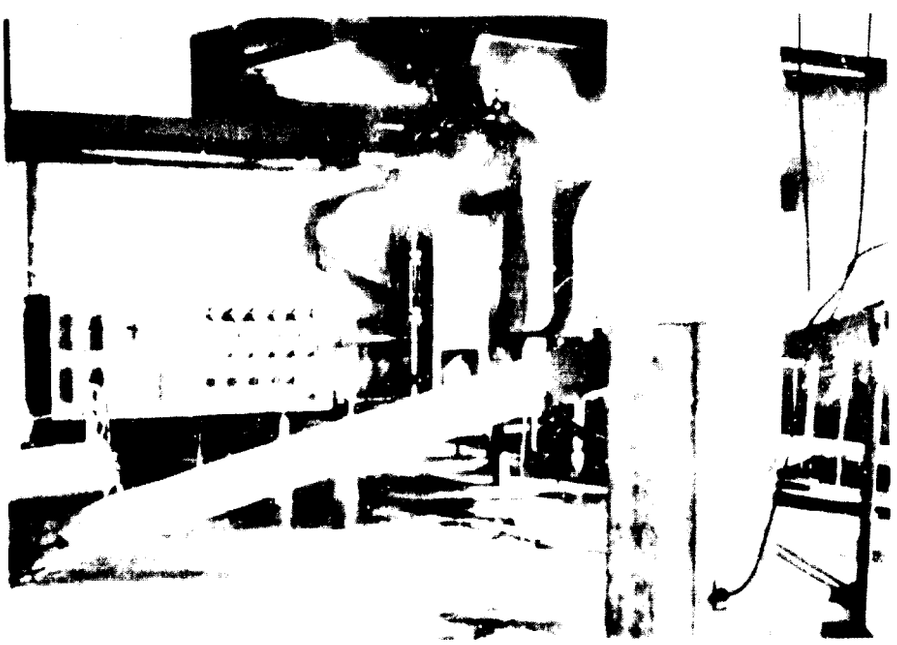


Photo. 17. Continuous rice cooker (by courtesy of Hinode Miso Co. Ltd.). (capacity: 1.5 metric tons of rice per hour)

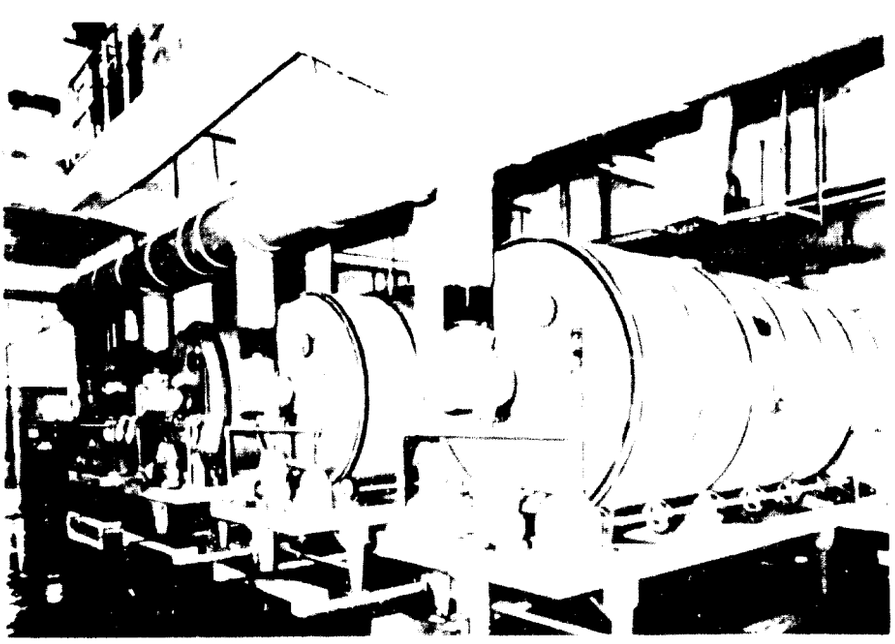
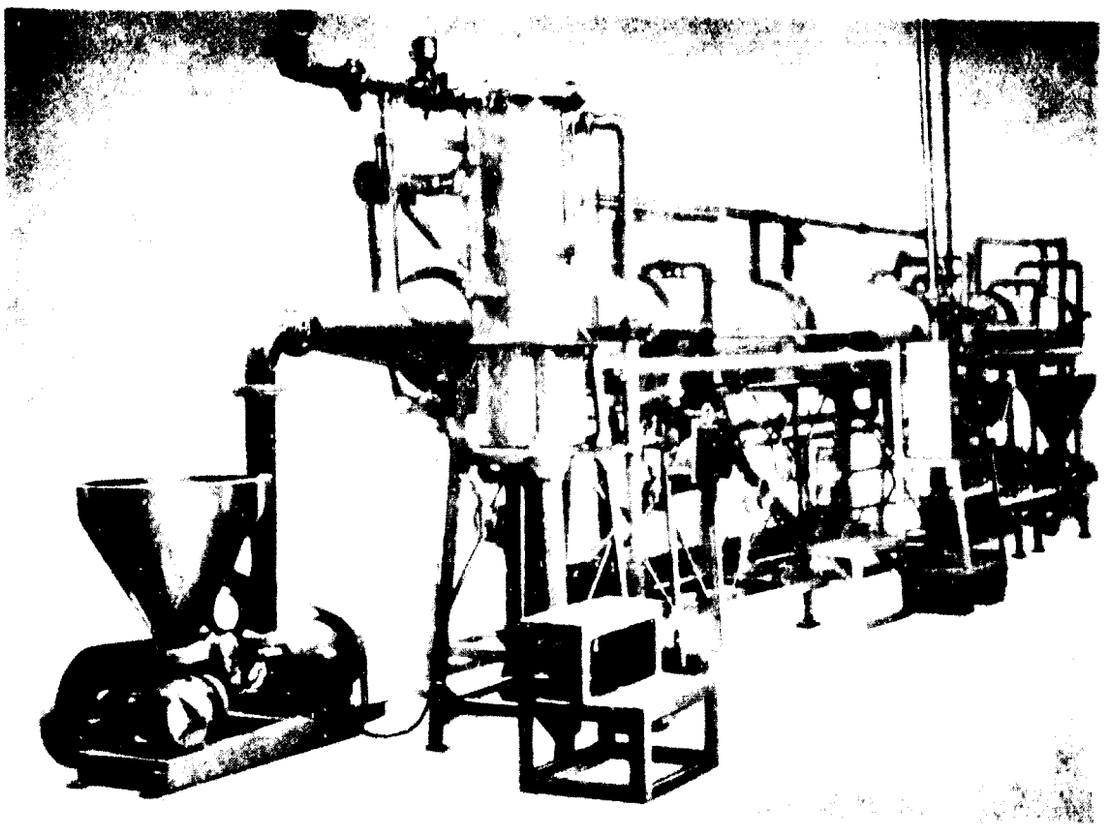


Photo. 18. Koji fermenter (by courtesy of Miyasaka Miso Co. Ltd.). (capacity: 1.8 metric tons of rice by each fermenter)

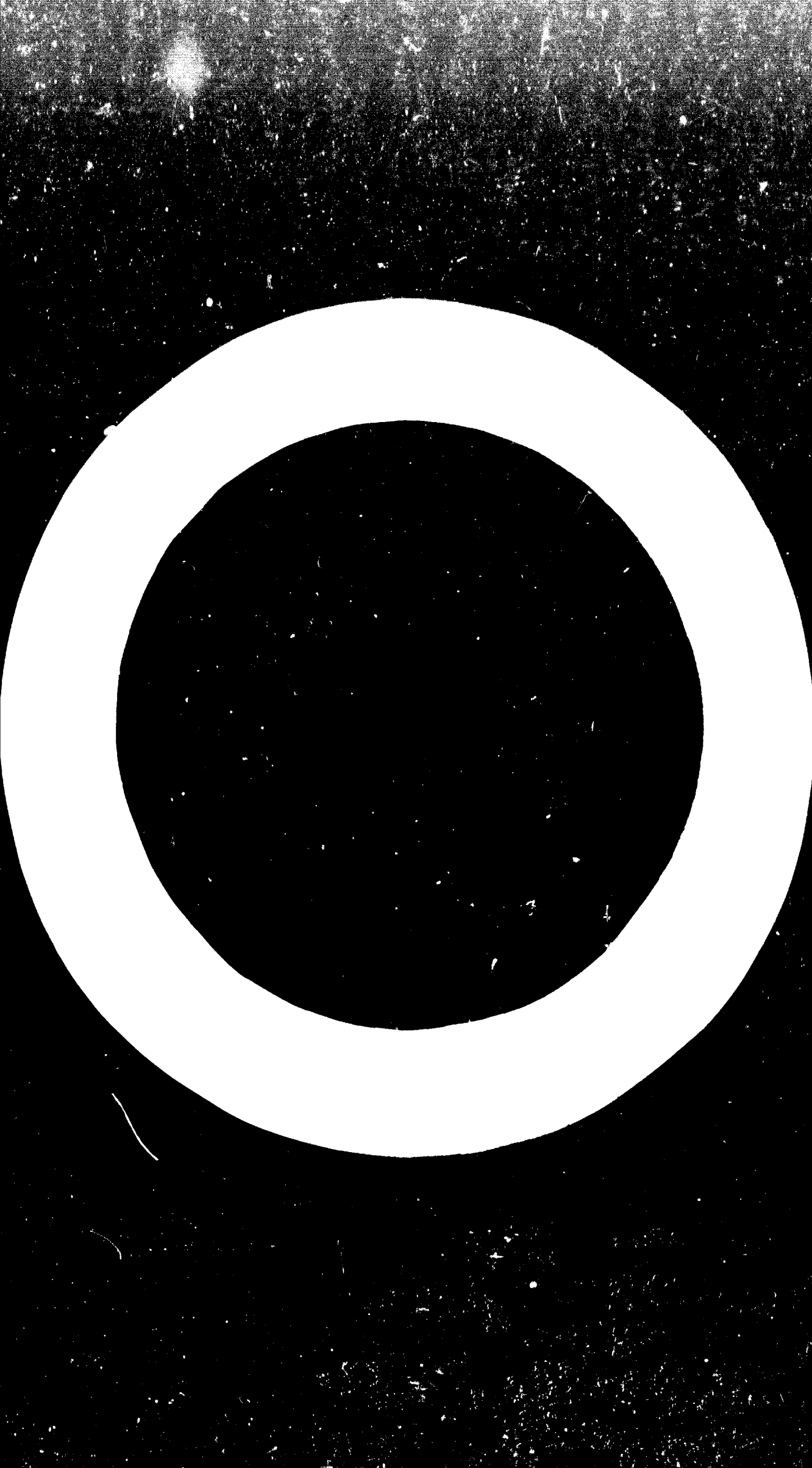


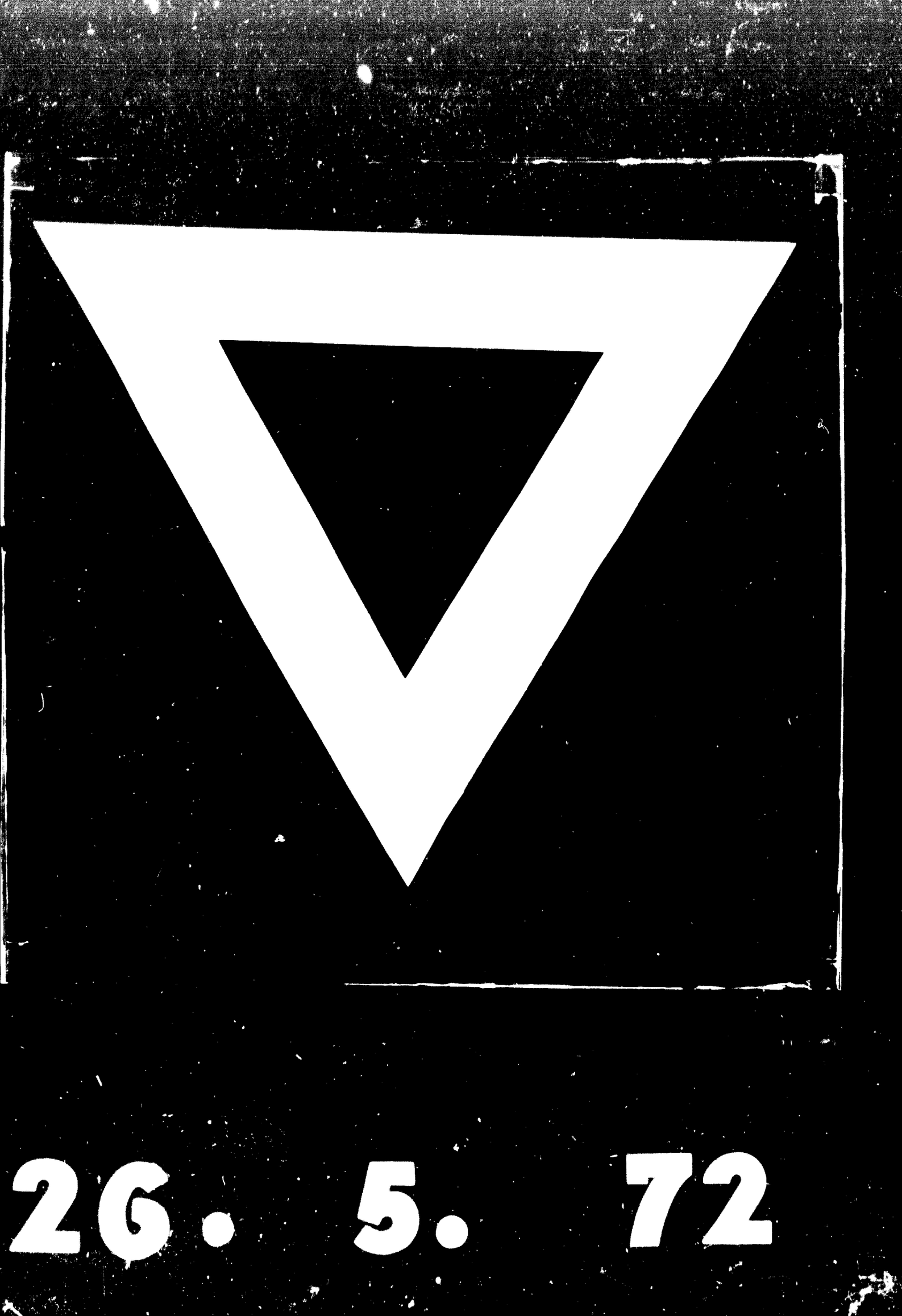
(Photo. 19. Pasteurizer of miso (by courtesy of Nagata Machinery Co. Ltd.). (capacity: 1 metric ton of miso per hour)

Photo. 20. Fermentation tank of moromi (by courtesy of Kikkoman Shoyu Co. Ltd.).

Photo. 21. Shoyu in bottle and plastic container.

Photo. 22. Large-scale koji fermenter (by courtesy of Yamasa Shoyu Co. Ltd.).





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