Alaskan Pollock Roe Processing — A Description of Current Japanese Industrial Methods and Their Adaptation to the Fishery in British Columbia

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Fisheries and Marine Service

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TABLE OF CONTENTS

	Page No.
List of Tables	iv
Abstract	v
Introduction	1
Materials and Methods	2
Source of fish	2
Removal of roe	2
Storage of roe	3
Laboratory method of processing tarako	3
Analysis for water and salt content	4
Measurment for firmness	5
Measurement of egg diameter	5
Industrial processing of tarako in Japan	5
Tabulation of chemical additives used by the Japanese tarako processing industry	9
Results and Discussions	
Criteria for determining optimal maturity of roe for processing	10
Concentration of food dye	11
Development of color in fresh roe with additives	11
Effect of additives on color after one month frozen storage at -28°C	12
Quality of processed product prepared from fresh roe	13
Frozen roe - effect of pretreatment of roe before freezing	14
Frozen roe - quality of product prepared from roe treated with additives before freezing	15
The effect of firming agents	16
The effect of salt concentration, salting time, and drain temperature on firmness	16
Conclusions	17
Acknowledgements	18
References	19

LIST OF TABLES

Table		Page No.
1	Spawning times of pollock harvested by the Japanese fishery	20
2	Changes in water content, yield and egg diameter with maturity of fresh pollock roe	21
3	Comparison of chemical additives used by the Japanese tarako industry	22
4	The relationship of water content and yield to the state of maturity from the Japanese literature	23
5	The relationship of grade of roe to maturity and water content from the Japanese literature (Mimura et al., 1962)	23
6	Fresh roe. Water content, salt content, firmness and yield of processed roe	24
7	Frozen roe. Color change of roe after 3 to 5 days, water content, salt content, firmness and the yield of processed roe	25
8	Frozen roe. Color change of roe after 3 to 5 days, water content, salt content, firmness and the yield of processed roe	26
9	Effect of calcium lactate, sodium polyphosphate and monosodium glutamate on firmness	27
10	Effect of combinations of calcium lactate, sodium polyphosphate and monosodium glutamate on firmness	27
11	The effect of amount of salt, salting time and drain temperature on the firmness of the processed product	28

ABSTRACT

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The egg diameters, water content, and yield of pollock roe from the immature stage up to partial spawning have been monitored and the optimum harvest time for the preparation of high quality processed product was established. Methods of removing the roe from the fish, washing, storage, and other procedures required to prepare the roe for processing are described.

A laboratory scale method of processing pollock roe, improvised from several industrial procedures currently in use in Japan, has been devised to evaluate the various factors which affect quality of the processed product. The amounts of chemical compounds used both directly and as components of trade name additives, as well as the actual techniques employed by industrial processors of pollock roe in Japan, are described in detail.

The effects of freezing rates and storage on the quality of frozen roe for processing purposes are evaluated. The advantages of dipping the roe in ascorbate, erythorbate, or in both, prior to freezing, for preservation of color and for other positive effects on quality are pointed out.

The influence of salt concentrations, salting times, and draining temperatures on the relative firming qualities of products processed from both fresh and frozen roe is described. The effects of other additives such as calcium phosphate and polyphosphates on enhancing firmness of products prepared from frozen roe have been evaluated.

Key words: pollock, roe, processing, color, firmness, quality, maturity, freezing, additives.

RÉSUMÉ

La production, le diamètre et la teneur en eau des oeufs de colin, de l'immaturité à la ponte partielle, ont été mesurés, et la période optimale de récolte pour la préparation de produits de haute qualité a été établie. Les auteurs décrivent des méthodes d'extraction, de lavage, de conservation des oeufs et d'autres, requises pour leur préparation en vue d'un traitement ultérieur.

Une méthode de traitement des oeufs de colin à l'échelle du laboratoire inspirée de plusieurs méthodes industrielles employées actuellement au Japon a été mise au point afin d'évaluer divers facteurs dont dépend la qualité du produit manufacturé. Les quantités de composés chimiques employés directement ou présents dans les additifs commerciaux ainsi que les techniques employées actuellement pour le traitement industriel des oeufs de colin au Japon sont examinées en détail.

Les effets des vitesses de congélation et de l'entreposage sur la qualité des oeufs congelés en vue d'un traitement ultérieur sont évalués. Les avantages du trempage dans de l'ascorbate, dans de l'érithorbate ou dans les deux produits avant la congélation afin de préserver la couleur et d'améliorer la qualité des oeufs sont soulignés.

L'influence de la concentration de sel, de la durée de salage et de la température d'égouttage sur la fermeté relative des produits manufacturés à partir d'oeufs frais et congelés est décrite. L'efficacité d'autres additifs comme le phosphate de calcium et les polyphosphates pour l'amélioration de la fermeté des produits préparés à partir d'oeufs congelés a également été evaluée.

Mots clés: colin, oeufs, traitement, couleur, fermeté, qualité, maturité, congélation, additifs.

INTRODUCTION

In recent years, the near and far seas fisheries of Japan have harvested annually about 3 x 10^6 metric tons (m.t.) of Alaska pollock (Theragra chalcogrammus) which represents 30% of the total landings of 10 x 10^6 m.t. of that country. From this fishery, 35,000 to 40,000 m.t. of roe (tarako) is recovered annually from fish landed between the months of November to June. Pollock is the main source material for the preparation of surimi which goes into the production of kamaboko, chikuwa, and other traditional fishery products of Japan. The value added from the recovery of roe subsidizes this vast pollock fishery. While high grade tarako can be produced for only a short period during the maturation of roe in any one population, the roe season is longer as the fishery is based on various stocks with widely different spawning times (Table 1).

By quantity, tarako is by far the largest of any roe products consumed annually in Japan. In contrast, about 12,000 m.t. of herring roe and 5,000 - 6,000 m.t. of salmon roe are consumed annually. The price is no doubt a contributing factor, although the flavor of tarako is distinctly different and preferred by many. The value of tarako relative to salmon and herring roes, however, has risen to more than double the 1976 figures of 1/10 to 1/7 respectively. The price of tarako has increased from about $1.40 per lb in April of 1976 to $3.35 during the ensuing 12 month period.

Commercial pollock fishery off the coast of British Columbia has been marginal, with landings of 38.2 m.t. in 1974, 101.8 m.t. in 1975, 1301.2 m.t. in 1976, and 912 m.t. in 1977. The size of the stocks or their numbers existing off the coast of British Columbia is under investigation. Except for a stock around the Gulf Islands in southern Strait of Georgia and Dixon Entrance, the time when the roe is mature enough for the preparation of high quality product has not yet been established. Finally, the technology of processing pollock roe to the exacting tastes of the consumer nation must be established and adapted to suit the fishery in our waters. The processing method used in this laboratory was based on the published literature, on discussions with fisheries scientists in Japan, and from personal surveys and discussions with the technicians in half a dozen of the largest plants in Hachinohe in northern Honshu, and Rumoi and Kushiro in Hokkaido. Each of these areas produce about one-third the total production of the country. This is not surprising as Kushiro with a landing of 900,000 m.t., Hachinohe with a little over 500,000 m.t., and Wakkanai (near Rumoi) with 450,000 m.t., rank first, second and third as principal fish landing ports in Japan.

Processed roe appears on the Japanese market undyed as well as colored with different combinations of red and yellow food dyes. In southwestern Japan, roe colored bright red, often with red pepper, is preferred while less color is traditionally preferred in the northern areas. Tarako is also marketed in the unprocessed form. Only high quality fresh roe free of external blemishes is used in this way.

MATERIALS AND METHODS

SOURCE OF FISH

Pollock was harvested by both on-bottom and mid-water trawl near the Gulf Islands in southern Strait of Georgia during the last week of February to the middle of March. Other roe samples were obtained from the commercial pollock fisheries during 1978.

REMOVAL OF ROE

Various techniques were used in an attempt to minimize the time required for removing the roe. During the early part of this investigation, filleting knives with and without protective tips were used. Shortly after capture, the fish was held with the ventral part up and the belly cavity was opened either from behind the gill cover or from the anal opening. Fresh roe is, however, very soft and the ovarian sac is readily cut unless extreme care is practiced by ensuring that the abdominal wall is held clear of the roe during the cutting process. Even under these conditions damage to the roe often occurs. Knives become dull and the skin more difficult to penetrate. The oviduct of pollock is rather large and tough and the knife point protected with a small ball tends to travel inside the oviduct and into the ovarian sac where the cutting edge damages the roe. Unless the blade immediately adjacent to the protective ball is maintained razor sharp, the oviduct is not severed and the point is guided into the ovarian sac.

Surgical scissors were also tried. Damage to roe was less but the time required to remove the roe was prohibitively long for a routine commercial operation.

A satisfactory cutting tool was devised from a No. 8 Bard-Parker scalpel handle fitted with a large No. 60 blade. A removable blade guard was made from a 3 mm diameter stainless steel rod attached lengthwise to a short piece of 1/4 inch copper tubing slit longitudinally along the opposite side and compressed slightly so that it can be slipped on readily along the back edge of the blade and snugly over the blade holder for firmness. The rod is shaped to fit the contour of the back edge of the blade and extends about 5 mm beyond the point.

The fish is held in one hand with the ventral side up and head pointing away. The scalpel is held with the cutting edge up and the tip of the blade guard is inserted into the anal opening. The blade is turned slightly away from the middle and the abdominal wall is lifted slightly away from the enclosed roe with the blade guard tip which simultaneously functions as a device to hold and guide the blade just under the belly wall during the slitting process. The scalpel is now pushed forward in one firm motion at an angle of about 15° to the fish and through the cartilaginous base of the pectoral fins. The exposed roe is removed after severing the arteries at the head of the skeins and the oviduct attached to the anal opening.

This technique is fast and is less damaging to the roe. By replacing the blade when needed, the cutting edge adjacent to the blade guard tip is always razor sharp to cut through and across the oviduct so that the blade will not follow it into the ovarian sac.

STORAGE OF ROE

Upon excision from the fish, the roe is rinsed quickly in sea water, drained, placed in barrier or polyethylene bags, and deep frozen as soon as possible. Rinsing time is kept to a minimum as the flaccid skeins of roe imbibe water and tend to become turgid. Some roe from the last day of fishing was usually brought to the laboratory unfrozen for immediate processing. The formation of black tips from the diffusion and oxidation of bile pigments is a function of post-mortem age and exposure to atmospheric oxygen and can be minimized by use of barrier bags and immediate freezing. Extensive black tipped areas measuring about 4 - 5 cm^2 are not uncommon both in processed tarako displayed for sale in Japanese food stores and in roe used by the processors.

When roe is to be treated with antioxidants such as sodium ascorbate and its isomer, erythorbate, to prevent discoloration during frozen storage, it is dipped in sea water containing the appropriate amount of the additives and is carried out at the rinse stage. It is then drained and frozen immediately.

LABORATORY METHOD OF PROCESSING TARAKO

In the laboratory, an adaptation of the Japanese industrial method was used to evaluate the effect of different additives on pollock roe harvested from southern Strait of Georgia. The scale of processing was reduced from 25 kg to 1.5 - 2.0 kg at a time. An automatic rotator capable of holding 6 five liter polyethylene jars, and rotating 180° over any pre-set interval, usually 15 minutes, for as long as desired, was improvised. The special wide mouth screw cap jars with inner seals to minimize leakage was obtained from Japan as were the food dyes and special additives like pinfish and glycymine which are not available here. Additives were added in lots of two, as a salt mixture and mixed with a coloring solution as listed below. All proportions refer to percent of roe weight.

<u>Salt mixture</u>:

(1) sodium chloride, 12 - 16%

(2) sodium ascorbate, 0.1 - 0.2%

(3) sodium erythorbate, 0.05 - 0.1%

(4) nicotinamide, 0.1 - 0.2%

These 4 chemicals are mixed thoroughly in the dry form and added to the roe.

Coloring Solution:

(1) food dyes are mixed in the following proportions: Red No. 102, 75%; Red No. 3, 10%; Yellow No. 4, 5%, and Yellow No. 5, 10%. The total amount of dye used with respect to roe weight ranged from 0.0007 - 0.03%. Usually 0.007% was used. Each of the 4 dyes is weighed out separately on the day the roe is to be processed as fading occurs if stored in solution even for a short period

(2) calcium lactate, 0.24 - 0.48%

(3) monosodium glutamate, 0.08 - 0.16%

(4) sodium polyphosphate, 0.08 - 0.16%

(5) propylene glycol, 0 - 0.5%

(6) pinfish, 0.08%

(7) glycymine, 0.08%

(8) sodium nitrite, 15 ppm

Additives 1 - 8 for the coloring solution are dissolved in an amount of water equivalent to 5 - 10% of the weight of roe to be processed. The water content of processed roe and hence the firmness, can be controlled somewhat at this step.

Experimental Processing Method:

- 1.5 kg of roe is put into the 5 liter mixing jars;
- the required amount of salt mixture and 75 - 150 ml of coloring solutions are added;
- the rotator is set for 180° turns every 15 minutes for 4 - 6 hours at room temperature;
- after salting, the roe is washed with fresh water for 10 - 20 seconds, transferred to wooden baskets to drain and picked clean of loose tissue and other debris;
- roe is straightened and arranged in a parallel position by pushing gently from the sides so that the oviducts are facing together;
- the basket is covered with polyethylene bags and allowed to drain overnight at temperatures between 4 - 10°C;
- the processed roe is packed in polyethylene sandwich containers lined with Saran wrap to minimize air oxidation.

ANALYSIS FOR WATER AND SALT CONTENT

Roe was cut into small pieces and ground by mortar and pestle. A known amount (usually 10 g) was dried in an oven at 110°C for 24 hours, dessicated for 2 additional hours with silica gel in a dessicator, and the dried material reweighed.

Exactly 10 g of the same ground roe was boiled in 90 ml of water and mixed vigorously. The mixing was repeated 30 seconds later. The sodium chloride content was determined with Quantab paper (Ames Co., U.S.A.).

MEASUREMENT FOR FIRMNESS

The Ottawa texture measuring system (OTMS) model D-1203 was used. A plunger similar to the one used by Tamoto et al. (1968) was constructed. The roe surface was flattened to a uniform thickness of 1.5 cm with a plastic mold and the plunger allowed to penetrate to 3 mm from the bottom. Usually 6 - 8 penetrations were made on different parts of the skein of roe. The values obtained were averaged and recorded as the number of grams required for the compression.

MEASUREMENT OF EGG DIAMETER

Egg diameters were determined only on 1976 samples. In samples A, B, C, and F (Table 2), roes frozen for one week were used to compare with similar studies in the Japanese literature (Tamoto et al., 1968) which were also carried out on frozen roe. Samples D, E, and G were used in the fresh state. The diameters were estimated microscopically in a 1% saline solution as well as from histochemically fixed samples. The eggs were fixed with bouins or bouins hollande sublime, embedded in paraplast with a melting point of 56°C, sectioned in 5 - 10 μ thickness, stained with hemotoxylin and eosin and the diameter estimated microscopically.

INDUSTRIAL PROCESSING OF TARAKO IN JAPAN

The method described here is based on personal observations and discussions of industrial techniques currently used by a half a dozen of the major processors in northern Honshu and Hokkaido.

Source of Roe:

From the Japanese pollock fishery during November to May when different stocks approach sexual maturity, the roe is extracted and processed from fish harvested from the near seas and from areas like Kamchatka, several days sailing distance from the major fish landing ports. The quality of roe is a function of post-mortem age, provided storage methods are adequate. The fresher undamaged roe is often marketed unprocessed as high grade fresh pack. The older roe, often showing dark green discoloration at the points from diffusion of bile products, is dyed red during processing. Frozen roe is also used for processing during the season and at other times of the year as market forces require. These roes are both imported and produced from the extensive domestic far seas fishery. Often the quality of frozen source material is superior as the roe is deep frozen aboard freezer vessels within 24 hours and may make up for any differences in quality of the terminal processed product as a result of freezing. In quick frozen roe, the formation of the dark green discoloration at the tips of the skeins is minimized as the area of the dark tips is a function of post-mortem age.

During the early part of the season, the roe is small and immature with a water content of 75 - 80%. During the ideal stage of maturity for processing, the water content drops to 67 - 70% and the yield increases to about 10% or more of body weight of female. Towards the end of the season the roe is overmature (mizuko), the skeins are large and unattractive with a water content of 75 - 90% and result in low quality processed product. As both salt penetration and extent of food dye uptake vary with maturity, the roe is initially graded before processing.

Cleaning:

At the factories, where either the extracted roe is brought in or removed from the fish, the roe is sorted, attached tissues such as the oviduct removed, and finally washed to remove mucoidal substances, lipoidal materials, excess blood, and visceral contaminants, by various techniques depending on the processors. A mild detergent, Kao Fish Clean No. 2[1], is often used. Fresh water, sea water, 3% solution of NaCl, 0.1% alum, or 0.2% sodium polyphosphate are also used. About 10 kg of roe is placed in perforated plastic trays or baskets of appropriate size and washed for 10 seconds by the dip-drain or dip-swirl-drain method in a tank of the washing solution. The washing solution is rinsed off with running water and roe allowed to drain for 5 - 10 minutes. Initial grading is carried out at this stage, according to shape, size, maturity, and physical damage. The highest quality roe is packed unprocessed for the fresh market. The lower quality immature, overmature (mizuko), damaged, heavily discolored roes, or roe partially frozen during transit by vehicle from the strippers to the processors in cold winter months, or partially frozen during harvesting, are processed further to the salted product.

Preparation of Salted and/or Dyed Tarako:

Roe is usually processed in 25 kg batches in 30 liter polyethylene buckets equipped with a rubber gasket along the rim. To this is added 4 kg of salt mixture[2] consisting of NaCl, sodium ascorbate, erythorbate, and nicotinamide. Next, 2.4 liters of a coloring solution[3] is added.

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1 Manufactured by Kao Soap Co. Ltd., Tokyo and consists of esters of fatty acid sugar, 5%; potassium pyrophosphate, 37%; phosphoric acid, 4.7%. One liter of this detergent is used for every 200 liters of water.

2 A mixture of 60 kg NaCl, 400 g sodium ascorbate, 200 g erythorbic acid, and 400 g nicotinamide. Nicotinamide can be replaced with 400 g sodium ascorbate. The dry powder is mixed for 10 - 15 minutes in a mechanical mixer.

Proportion of NaCl to roe by weight: the common proportions are 15%, 12 - 18% and 18 - 25% for immature, mature, and overmature roe respectively. An increase in the addition of calcium lactate is recommended for immature and overmature roe to make the product firmer.

3 The proportion and composition of dyes used vary somewhat from factory to factory. One typical example for processing frozen roe is as follows:

Dissolve in 80 liters of warm water, 60 g Red No. 102, 8 g Red No. 3, 4 g Red No. 104, 4 g Yellow No. 4, and 8 g of Yellow No. 5, 500 g polyphosphate, 500 g Pinfish*, 500 g sodium glutamate, 500 g glycymine**, 1.5 kg calcium lactate. Add 38 liters of a vegetable extract*** just before use, for otherwise the coloring capacity will be reduced with time. Red. No. 102 has relatively low dying ability but easily penetrates into the roe. Red No. 3 and 104 have high dying properties but penetrate with difficulty and are unstable to sunlight. Combined use with Red No. 102 is recommended to develop the desirable pink coloration. Yellow No. 5 is as penetrating as Red No. 102, while Yellow No. 4 tends to dye only the surface areas. Both are used to give the yellowish tint.

Some processors use the following composition: Red No. 102, 70%; Red No. 3, 10%; Red No. 104, 5%; Yellow No. 5 and 4, 15% (Yellow No. 5, 15% or Yellow No. 5 10 and No. 4, 5%). Proportions of Red No. 102 and Yellow No. 5 and 4 may be changed depending on the market and on the quality of the roe. The total amounts of dyes are 60 g/ton and 100 g/ton for fresh and frozen roes respectively. The penetration of dye in fresh roe is faster. Processors color the roe to the tastes of the marketing area; for example, 60 g/ton for Tokyo and neighbouring districts and 100 g/ton for Osaka and surrounding areas.

Dye composition adopted by Sanriku Alaskan Pollock Roe Association as of December, 1973: Red No. 102, about 80% (25 to 40 g); Red No. 3, 10 to 12% (3 to 5 g); Yellow No. 5, 8 to 10% (2 to 4 g). Dissolve these dyes together with 300 g sodium ascorbate in 41 liters of water. Prepare a coloring solution by adding 19 liters of the vegetable (radish leaf) extract. Final volume of dye solution is 60 liters. About 500 kg of roe can be dyed with this amount of coloring solution.

Dye composition adopted by Hokkaido Fisheries Experimental Station as of 1968:
(a) Red No. 102, 81%; Red No. 103, 10%; Red No. 104, 3%; Yellow No. 5, 5%.
(b) Red No. 102, 60%; Red No. 103, 20%; Red No. 104, 10%; Yellow No. 5,10%.
Dissolve as in previous paragraph.

* Manufactured by Sankyo Pharmaceutical Co. Ltd., and is composed of 25.5% natural product (tennen butsu), 68.8% sodium citrate, 4.2% fatty acid esters of sucrose, and 1.5% monobasic calcium phosphate. Pinfish imparts an attractive finish by emulsifying lipids and fatty acids that stick to the surface of the roe.

** Glycymine: composed of di- and tri-sodium glycyrrhizinate, 17.5%; sodium citrate, 35.5%; and dextrin, 47.0%.

*** Vegetable Extract: the use of nitrite in tarako processing was prohibited in September, 1971, and an extract prepared from radish leaves which contains nitrite has been permitted to be used as a substitute. This extract, which is not for general sale, is manufctured by Kyokuyo Co., Ltd., and Fishermen's associations of various districts and distributed only to Alaskan pollock roe manufacturers and is prepared in 19 liter cans each of which contain nitrite ions corresponding to 4 g of sodium nitrite.

The buckets are placed on automatic rotators, covered by inverting empty ones of the same size and sealed water tight with clamps attached to the mixing device. The apparatus is rotated gently 10 to 15 times to mix the roe, salt mixture, and coloring solution thoroughly so that the roe is dyed uniformly. The automatic mixer is timed to turn every 15 minutes for 4 - 6 hours in a room or an enclosure within the plant heated to 15 - 20°C. Elevated temperatures are necessary during winter months to ensure curing in the time indicated. Some plants raise the temperature to 30°C. After removal from the mixing buckets, the roe is transferred to perforated plastic trays, rinsed for 15 - 20 seconds in running water, and arranged in a straight position with oviducts facing together and in neat rows while still pliable, and allowed to drain for variable periods of time depending on the practice of the processors. The shaped roe is covered with polyethylene film to minimize drying and drained for 1 - 3 days in a cool area.

Overmature roe or "mizuko" which contains a higher amount of water (75 - 90%) is cured with 16% salt and with double strength dye solution. The amount of water used for curing is halved. These variations are necessary to prepare acceptable products from overmature roe.

In first grade roe, the individual grains of eggs are clearly visible and the color is uniform. Both immature roe and mizuko can be distinguished easily as the color is noticeably lighter. The mizuko is also much larger in size. Immature roe is softer and the individual grains of eggs are not readily visible.

Grading:

While the criteria for grading differ slightly according to the practices of each plant, the roe is generally divided into 4 grades and each grade is further subdivided into 3 size categories. The requirements for the different grades are as follows:

Grade 1: ovaries full of eggs, immature and/or overmature roe absent, free of contamination with blood, prominently visible vascularization absent in ovarian sac, color uniformly bright, bile and other stains absent, cuts and/or scratches on roe absent, well-drained and firm.

Grade 2: ovaries full of eggs, immature and/or overmature roe absent, roe only slightly discolored with blood or bile, color uniformly bright, ovaries slightly cut or scratched.

Grade 3: slightly immature or overmature, greater tolerance for bile and other stains permitted, scratches and cuts permitted but not in excess of 2/3 the length of ovary, ovary can be ruptured but not collapsed.

Grade 4: immature and/or overmature roe, watery, heavily colored with bile, roe more physically damaged, much like grade 3 in other respects.

Below Grade 4: discolored, watery, broken, water content of roe not less than 67%.

At one of the larger plants, a team of graders separates the roe into 4 grades in rectangular plastic trays which are subsequently hauled to the packers who grade each lot further into the 3 size categories - large, medium and small - and pack them into shallow circular wooden kegs or in rectangular wooden boxes. The containers are lined with plastic and the roe is arranged side by side for rectangular boxes and radially for circular kegs. Glazing material consisting of propylene glycol, sorbitol, and water in a ratio of 1 : 2 : 3 by volume is brushed on the surface. Imitation bamboo leaves are placed on top, covered with plastic liners and the lid fastened. The circular kegs and boxes were bound with twines of 4 different colors, each denoting a different grade. Additional labels indicate the three size categories for each color coded binding twine. At retail outlets, the roe is displayed in 100 - 300 g lots in styrofoam trays.

At one plant we observed a process by which individual grains of eggs resulting from a normal processing operation were being recovered. Much of this product goes into the preparation of food products utilizing loose pollock roe.

Storage:

It is generally understood that tarako is processed and consumed within its storage life in the refrigerator. However, one large plant in Hokkaido kept their processed product frozen for up to one year. While good quality tarako can be produced at any time of the season from fresh frozen roe, discoloration of the undyed or the fading of dyed processed roe have often been cited as reasons for not freezing. Exposure to light and the rate of thawing influence the fading of color from frozen processed roe.

Until 5 to 6 years ago, the salt content of processed tarako was around 10%. Partly as a result of more widespread use of refrigeration and consumer preference trends, today the salt content has been lowered to 5 - 6%, a level approaching the borderline of drip problem encountered in frozen storage of processed tarako.

TABULATION OF CHEMICAL ADDITIVES USED BY THE JAPANESE TARAKO PROCESSING INDUSTRY

Compared to salmon or herring roe processing where little or no additives other than salt are used, the traditional Japanese method of processing pollock roe involves the use of a bewildering array of over 20 different chemical additives. Some of these, like ascorbate, erythorbate and nicotinamide are involved in color formation by reaction with hemoglobin. Others are used to improve firming characteristics, to add taste, and to improve the appearance. Different processors omit some of the additives and use varying amounts of the chemicals. Food dye mixtures are varied in accordance with the traditional requirements of different regional markets. In Table 3 are listed the chemical additives and their proportions used by two of the processors. The amounts used in our experimental processing are also included for comparison.

RESULTS AND DISCUSSION

CRITERIA FOR DETERMINING OPTIMAL MATURITY OF ROE FOR PROCESSING

During October of 1974, the ovaries of pollock from the southern Strait of Georgia were still only 1 - 2 inches in length and individual eggs were not distinguishable. In November, the ovaries were longer with a larger cross-sectional diameter but the eggs were still not visible. Growth continued through December, and in January, the ovaries attained minimal commercial size and the grains of eggs became visible to the eye for the first time.

In early 1975, roe was collected during the month of February and in 1976 during early February to early April (Table 2). While the 1975 collection tended to be slightly immature, the 1976 samples were thought to include all stages of maturity of roe that can be used for commercial processing. The water content of roe, percent yield, and the egg diameters were used as criteria for determining the best time of the year for harvesting for purposes of preparing high quality processed products.

The water content of the roe is, in general, significantly higher in less mature roe harvested in early February and rises sharply in over-mature roe harvested in late March to early April in the Swanson Channel area. The 1976 samples remained low and nearly constant in water content during mid-February to mid-March (samples A, B, C, D and E, Table 2). These values, however, were generally a little higher than those reported in the Japanese literature (Table 4) for mature roe and would, by this criteria, correspond to their 2nd and 3rd grade (Table 5). Differences could well exist between the various stocks of pollock harvested by the Japanese commercial fisheries, and samples of minimum water content from our stock could well be the equivalent of Grade 1 quality roe from other stocks with slightly lower values. Indeed such was deemed to be the case by an independent experienced Japanese technician who examined our processed product. In samples obtained during mid-March and early April (F and G, Table 2), both mature and over-mature roe were observed. The water content of the over-mature roe was higher with increasing hydration.

The roe weight based on females alone ranged between 8.4 and 9.9 during the times when the water content remained nearly constant (samples A to E, Table 2). These values are therefore considered to be the maximum when Grade 1 roe can be obtained from fish in this area. The yield began to rise sharply with increasing hydration of the roe (samples F and G, Table 2).

The egg diameters were still increasing rapidly up to the 3rd week in February (samples A and B) but reached a slow phase of increase (571μ to 642μ, Table 2) from the last week in February to mid-March (samples C, D, E and F). A sharp increase in egg diameters occurred with increasing hydration (samples F and G). Roe sampled on February 23, 1978, from the commercial pollock fishery near the Apex of statistical area 18, measured 638μ in average egg diameter. Very few hydrated roe were observed. These egg diameters are slightly larger than the 1976 samples from Swanson Channel about the same time of year. Stock differences, even within such close geographic areas, are not excluded at this early stage of study.

Histologically, sample G (Table 2) showed very few nuclei (J.R. McBride, personal communication). Samples A to F (Table 2) were very close to sample G in the stage of development.

The egg diameters of samples of roe from Dixon Entrance obtained on Februay 14, 1978 averaged 687μ . A second sample from fish caught in the same area on February 27, 1978 averaged 606μ for eggs from small and medium skeins and 682μ from large, but not hydrated, skeins. High quality processed roe was obtained from these samples. The egg diameters for high quality roe in the Japanese literature (Tamoto et al., 1968) ranged from 620 - 920μ . These values are in general higher than those from the British Columbia coast but the ranges overlap.

It would appear, therefore, that the optimum maturity of roe for the purpose of preparing a high quality processed product is governed by several criteria. These are as follows: when the water content of roe reaches a minimum value between 67 - 70%; when the yield figure reaches 8.5 - 10% based on females alone in the Swanson Channel area; and finally and more importantly, when the egg diameters range between 500 - 800μ .

CONCENTRATION OF FOOD DYE

The concentration of food dye in the proportion used for this investigation was varied from 0.0006, 0.0015, 0.003, 0.006, 0.03 and 0.15% in a volume of water equivalent to 10% the weight of roe. Sodium chloride was added at a level of 15% and sodium nitrite at 15 ppm. Mixing was carried out for 4 hours.

The color and the quality of the processed roe was evaluated by an experienced pollock roe processor from Japan. It was judged that the strong red color achieved with 0.006% dye was suitable for southwestern districts of Japan if a shade more yellow was introduced. The lighter color roe obtained with 0.0015% dye was stated to be suitable for the Tokyo district. The remainder of the dye concentrations were either too pale or too dark.

DEVELOPMENT OF COLOR IN FRESH ROE WITH ADDITIVES

Salted pollock roe processed with nitrite results in a product with an attractive pink color which develops by the reaction of nitrite with hemoglobin to form nitrosohemochrome. However, because nitrite may form the carcinogen nitrosamine, its use as an additive in pollock roe processing has been prohibited in Japan since September of 1971. A search for nitrite substitutes for pollock roe processing was intensified (Nakamura et al., 1972). Nicotinamide, nicotinic acid and its derivatives also form hemochromes with hemoglobin in the presence of ascorbate and/or its isomer, erythorbate (Fukumi et al., 1971a). Various concentrations and combinations of these additives have been examined to establish the optimum proportions required for maximum color formation. For fresh and frozen roe, nicotinamide to erythorbate ratios of 1.0% : 1.5% or 0.7% : 1.0% respectively were reported to be effective. Likewise, nicotinamide, ascorbate and erythorbate ratios of 1.0% : 0.1% : 1.4% or 0.7% : 0.1% : 0.75% were equally successful.

A combination of 0.7% nicotinamide, 0.1% sodium ascorbate and 0.75% sodium erythorbate with two levels of food dye (0.003 and 0.006%) both in the presence and absence of 15 ppm nitrite were all effective in developing an attractive red color in fresh roe. Sample B (Table 2) was used with 10% salt and 10% water during the processing. The product was generally an attractive red in color immediately after processing. During the ensuing few days the color faded and then returned to the original red color after 5 days. The higher level of dye improved the redness only slightly. Nitrite generally developed a brighter and more permanent redness in the product in contrast to a mixture of nicotinamide, ascorbate and its isomer. The processed roe was wrapped in Saran film before storing in polyethylene containers to avoid darkening around the peripheral area in contact with the container.

Despite all the effort by the Japanese investigators, the use of these additives in the absence of nitrite did not result in a successful commercial application, for the pink color developed was stable only under anaerobic conditions. A recent study indicated a more stable derivative resulted from processing fresh roe with a combination of 0.5% imidazole and 0.3% ascorbate (Koizumi and Nonaka, 1977) although the method is not yet approved for commercial use and it is not known whether it ever will be.

Much lower levels of reducing agents and nicotinamide are used in commercial processing in which, until recently in any case, small amounts of nitrite were permitted to be used in the form of a natural component of radish leaf extract. Nitrite was responsible for most of the stable red color, for the amounts of nicotinamide and the reducing agents used in commercial practice are too low to contribute much to color formation.

EFFECT OF ADDITIVES ON COLOR AFTER ONE MONTH FROZEN STORAGE AT -28°C

Sample C (Table 2) was processed with 10% water and a higher 12% level of salt with the combination of additives shown as follows:

Lot No.	Nicotinamide (%)	Sodium erythorbate (%)	Sodium ascorbate (%)	Nitrite (PPM)	Remarks after one month storage at -28°C
1	1.0	1.4	0.1	0	red color faded slightly
2	1.0	0	1.5	0	redness faded more than Lot 1
3	1.0	1.4	0.1	15	retained stable red color

Fukumi et al., (1971b) also reported other combinations of the 3 additives which were effective in developing acceptable color. After processing all lots developed good color. However, after 1 month storage at -28°C, all lots without nitrite faded to various degrees. The lot in which sodium erythorbate was replaced with 1.5% sodium ascorbate faded the most. A particular combination of ascorbate and its isomer therefore appears to be necessary. Enzymic degradation of ascorbate is indicated. For stability of the red color, nitrite seems essential.

QUALITY OF PROCESSED PRODUCT PREPARED FROM FRESH ROE

Portions of roe samples A to G harvested the day before returning were brought unfrozen to the laboratory for studies to determine the properties and the quality of the product processed from fresh roe. In Table 6, sample A was processed with 0.7% nicotinamide, 0.1% ascorbate, and 0.75% erythorbate and salted for 4 hours with 10% salt. Samples B to G were treated in duplicate with different combinations of additives. Sample numbers 1 and 3 were processed with 1.0% nicotinamide and 1.5% ascsorbate while 2 and 4 were processed with 15 ppm nitrite and 1.5% ascorbate. Each combination of additives was salted for 4 hours with 12 and 16% salt.

The Japanese standards for water and salt content of processed roe of the different grades are as follows:

Grade	Water Content (%)	Salt Content (%)
1	58 - 60	5.0 - 7.5
2	60 - 64	5.5 - 9.0
3	64 - 68	6.0 - 9.5
4	70 - 75	7.0 - 12.0

On this basis the water contents of processed products from samples A to G fall into both grade 1 and 2 categories. However, it is emphasized that fluctuations in the water content from grade 1 to 2 occur in all samples harvested during the beginning of the season when the egg diameters were smaller, to the latter part when they were larger. Stock differences are indicated and our samples with water content just higher than that of grade 1 could well be of comparable grade.

The salt contents, except that of sample B-4, are all within the grade 1 category. The higher levels of salt used during processing generally result in higher salt content in the product.

The product was firm enough in each case. Our arbitrary Texturometer value of 400 g or more was considered to be of acceptable firmness by a Japanese technician experienced in the processing of pollock roe. All products prepared from fresh roe are well above this value. Higher levels of salt during processing generally result in a firmer product.

The Japanese standard for yield of processed product from mature roe ranges between 90 - 95% and for immature roe, 80 - 85% based on the weight of the processed product relative to weight of fresh roe used. All of our products were over 90%.

These results lead us to the conclusion that all of the 1976 samples from A to G are in the optimum state for production of grade 1 processed product. The smaller egg diameters of the earlier samples indicate that considerable differences exist in different stocks of pollock and in the range of egg diameters leading to high quality product.

FROZEN ROE - EFFECT OF PRETREATMENT OF ROE BEFORE FREEZING

Portions of the roe from collections A to G were washed immediately with sea water and with sea water containing additives as indicated below:

		Washing Method			
Samples	Date of catch	Sea water	1% Sod. ascorbate	2% Sod. ascorbate	1% Pot. Sorbate
A	Feb. 9 - 11	+	+	-	-
B	Feb. 23 - 25	+	+	-	-
C	Feb. 28 - Mar. 2	+	+	-	-
D	Mar. 8	+	+	-	-
		+	-	+	-
E	Mar. 10*	+	+	-	-
		+	-	+	-
F	Mar. 16 - 17	+	+	-	-
		+	-	+	-
		+	-	-	+
G	Mar. 29 - Apr. 1	+	+	-	-
		+	-	+	-
		+	-	-	+

* roe was left inside of fishes for 2 days after catch.

The samples were then packaged immediately in polyethylene bags and frozen the same day with dry ice, transported to the laboratory and stored at -28°C for 2 months or more. After this period of time, the roe was thawed and examined for color prior to processing and assessed for quality. The network of blood vessels visible on the ovarian sac as well as the general appearance of the roe itself was brownish in color in roe washed with sea water alone. The use of ascorbate resulted in the retention in the blood vessels of the original red color observed in roe freshly extracted post-mortem. Ascorbate, therefore, prevents oxidation of the red colored hemoglobins to the brown colored methemoglobin during frozen storage. The higher level of ascorbate did not result in noticeable improvement in color but caused problems during subsequent processing. Sorbate generally resulted in poor to negative effect on color.

FROZEN ROE - QUALITY OF PRODUCT PREPARED FROM ROE TREATED WITH ADDITIVES BEFORE FREEZING

While roe washed with sea water resulted in a processed product of acceptable color, those dipped in 1% ascorbate generally developed a more attractive pink-red color (Tables 7 and 8). A higher ascorbate concentration (2%) often resulted in a darker color and in some cases led to deposition of white powder on the surface of the roe. Moderate levels of the reducing agent thus prevent hemoglobins from oxidizing to the brown colored methemoglobins. While it may have some beneficial effect on retarding bacterial growth and odor control, sorbate did not improve the appearance of roe in frozen storage.

The other qualities of the product processed from frozen roe are recorded in Tables 7 and 8. Water content of the product processed with both 12 and 16% salt ranged from 57 to 63%, corresponding to grades 1 and 2 quality by Japanese standards.

Salt content of all the roe processed with the lower level of salt coincided with grade 1 standard. Those processed with the higher level of salt likewise were within grade 1 except samples C1, 2 and 4 which fitted into grade 2. Generally, processing with lower levels of salt resulted in products of lower salt content.

Once frozen roe processed with 12% salt generally resulted in products almost half of which were borderline in firmness using the criteria of 400 g as the acceptable standard. Most of these softer products were in samples A and B which were collected earlier in the season and showed smaller average egg diameters. All samples of lot E, in which the roe was left inside the fish for 2 days before freezing, were soft. Thus the less mature roe frozen within one day of catch, and mature roe frozen after 2 days post-mortem, result in products of borderline quality in firmness if processed with 12% salt. Variations in firmness are encountered since it is not always possible to obtain skeins of roe of uniform maturity during every collection. Dipping the roe in ascorbate prior to freezing resulted in products which tended to be slightly firmer more often than not compared to those washed with sea water alone. Ascorbate could well be affecting the frozen storage quality of the roe as well as the color. Frozen roes processed with 16% salt were mostly firm enough. A higher level of salt is therefore necessary to achieve the required standards of firmness when processing once frozen roes which were slightly immature or mature roe of longer post-mortem age.

A striking difference in firmness is observed betweeen products processed from fresh (Table 6) and frozen roe (Tables 7 and 8). Even the use of 10% salt in processing fresh immature (sample A, Table 6) roe result in a firm product.

Both fresh and frozen roe processed in the presence of 15 ppm nitrite and 1.5% ascorbate developed a more attractive and stable pink-red color than those processed with 1% nicotinamide and 1.5% ascorbate. Qualities other than color, however, were not noticeably affected.

While the yield of product from fresh roe never dropped below 90% (Table 6), approximately 15% (8 out of 56 samples) of those from once-frozen roe dropped below this figure. Increasing drip loss from frozen roe with increasing storage time (Tamoto, 1969) could well account for the lower yield. We have observed that the freezing process results in roe that, when thawed, is generally softer than fresh roe, even those that are 2 or 3 days old. From the 1978 commercial samples, we have also noted that roe of longer post-mortem age (3 - 4 days) at the time of freezing led to roe which upon thawing were too soft for subsequent processing.

THE EFFECT OF FIRMING AGENTS

Calcium lactate, polyphosphate and monosodium glutamate (MSG) alone (Table 9) or in combination (Table 10) affected to different degrees the firmness of the product processed from roe frozen for 5 months at -28°C. Calcium lactate at a level of 0.08% resulted in noticeable increase in firmness while polyphosphate was effective at a higher level of 0.16% (Table 9). The effectiveness of MSG even at 0.16% was not as noticeable. The effectiveness of combinations of calcium lactate and polyphosphate on firmness tended to be additive while the addition of MSG to these two additives resulted in only a slight increase or even a negative effect.

THE EFFECT OF SALT CONCENTRATION, SALTING TIME, AND DRAIN TEMPERATURE ON FIRMNESS.

The roe used in this experiment was frozen for 4 months at -28°C. Processing was carried out in the usual manner with 5% water, 0.007% food dye and 15 ppm sodium nitrite. In each of the 3 levels (12, 15 and 20%) of salt used, the salting times were varied from 4, 6, 8 and 10 hours (Table 11). After salting, each lot was divided into 2 groups. One was drained at 0°C and the other at 10°C. Firmness was measured after 3 weeks storage at -28°C.

With the exception of a few, mostly at the lowest salt concentrations and the shorter salting time, all processed roe were in excess of 400 g in firmness. Draining at the higher temperature of 10°C generally resulted in only a slightly firmer product although in a few instances the values were reversed. With 12% salt, all but the 4 hour salting time resulted in firm roe. Generally, the longer salting time favored firmness. With 15% salt, the trends were similar but the firmness greater. At the highest salt level of 20%, the trends were as in the first two concentrations except that the roe was very much firmer.

The water content of the product was generally fairly stable and corresponded to Grade 1 standards, but dropped noticeably with increased salting time at the highest salt level. The salt content generally increased with both increasing salting times and increasing levels of salt used during processing. In most cases, however, the values were well above the specification for grade 1 quality product. While higher levels of salt used in processing frozen roe may favor the firming characteristics, the lower levels and the shortest salting time result in a product more suitable for grade 1 with respect to salt content.

CONCLUSIONS

Roe from populations of pollock in southern Georgia Strait reaches acceptable states of maturity for commercial processing purposes during February and early March. Commercial samples of roe harvested from Dixon Entrance in 1978 were also in the same state during the month of February. Further studies of pollock in different geographical areas are required, however, to establish the times of maturity more definitely.

Several criteria exist for judging when the roe reaches the ideal state of maturity for the preparation of high quality processed product. The percent yield based on females alone reaches a plateau in the range of 8.5 - 10% before rising sharply as a result of hydration from overmaturity. The water content of roe passes through a minimum value in the range of 67 - 70% before rising sharply from hydration. Roe with average egg diameters from around 500 - 800μ result in high quality processed product. Hydrated overmature eggs reach average diameters of 1200 - 1500μ and result in soft, low quality products.

Industrial methods used in Japan for processing pollock roe are quite complex compared to methods for processing salmon or herring roe, and involve the use of up to 20 chemical additives. Several of these chemicals are associated with developing color. Food dyes are used in different amounts and proportions to prepare products ranging in color from the natural state to dark red to satisfy regional market preferences. During frozen storage of the processed product, however, food dyes tend to fade somewhat. In the past, stable color was provided by the direct addition of nitrite. Since 1971, its use as a direct additive has been prohibited. However, the use of nitrite in the form of a constituent in the extracts of Japanese radish leaves, which are rich in nitrite, was permitted. In addition to food dyes and nitrite in radish leaf extracts, color formation is enhanced to some extent by additives such as nicotinamide which combine with hemoglobins to produce pink color in the presence of the added reducing agents, ascorbate and its isomer, erythorbate.

Combinations of ascorbate, erythorbate, and nicotinamide in relatively high levels result in the formation of pink color. The color produced, however, is not of the same shade as the pink-red resulting from the reaction of nitrite with hemoglobin to form nitrosohemoglobin and is also unstable and subject to fading when exposed to atmospheric oxygen or during frozen storage unless protected by oxygen barrier films.

Glycymine, pinfish, and monosodium glutamate are used to improve organoleptic properties. Propylene glycol and sorbitol are brushed on the surface of the product to add sheen.

In addition to its preservative properties, the concentration of salt influences the quality of the processed product. Both fresh and once frozen roe processed with 16% salt result in products which are generally firmer and which are higher in salt content than those processed with 12% salt. Products from once frozen roe, however, are considerably softer than those from fresh roe. Indeed, in many instances, processing with the lower 12% salt results in products which are either too soft or barely firm enough to be acceptable. The higher level of 16% salt is required to produce products of uniformly acceptable firmness from once frozen roe. It is important that the roe must be frozen as soon as possible after harvest and also at a fast rate.

Other additives such as calcium lactate and polyphosphates increase the firmness of processed products prepared from once frozen roe. Where the roe is a few days old before freezing, this firming procedure as well as the use of higher levels of salt may even be necessary to produce products of acceptable firmness.

The yields of the terminal product from fresh roe all exceed 90% while several of those from once frozen roe would not attain this figure. The Japanese standard for yield of processed product from mature roe ranges between 90 - 95% and immature roe, 80 - 85% relative to weight of fresh roe used.

Pretreatment of roe by dipping in a 1% solution of sodium ascorbate or its isomer in sea water prior to quick freezing preserves the appearance during extended frozen storage. Under reducing conditions, the red color of blood in the network of vessels on the ovarian sac is maintained and the diffuse pink coloration in the roe itself is also preserved. Higher levels of the reducing agent are not beneficial and are reported to cause darkening. Roe pretreated with ascorbate prior to freezing result in processed products which are not only slightly firmer but also a more attractive pink-red color. Sorbate dips are no better than a simple wash with sea water for preserving color during frozen storage although the procedure may improve quality in other ways.

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Table 1. Spawning times of pollock harvested by the Japanese fishery.

Eastern part of Korean Bay	November to January
Iwanai Bay	Late November to mid-February
West Coast of Hokkaido	Mid-December to late March
West Coast of Sakhalin	Late February to late April
Tartar Strait	Mid-March to late April
Uchiura Bay	Late November to mid-February
East Coast of Hokkaido	Early February to late April
South of Kuril Island	Mid-February to mid-April
Nemuro Strait	Early February to mid-April
Off the coast of Kitami	Early March to mid-May
Southern part of W. Kamchatka	Mid-March to late May
Northern part of W. Kamchatka	Mid-April to mid-June
Northern part of Okhotsk Sea	May to June
East Kamchatka	Late March to late May
Southeastern Bering Sea	Mid-March to late May
Northeastern Bering Sea	April to June

Table 2. Changes in water content, yield and egg diameter with maturity of fresh pollock roe.

Samples	Catch date	Water content (%)	Roe wt. of female (%)	Egg diameter Range(μ)	Egg diameter Average(μ)	Storage condition of roe prior to measuring diameter
	1975					
	2/5	74.6	7.8			
	2/7	69.5	7.1			
	2/17	72.9	8.0			
	2/18-21	63.3	7.1			
	2/25-28	71.1	8.8			
	1976					
A	2/9-11	68.7	8.6	290 - 620	450.0	frozen for one week
B	2/23-25	70.3	9.9	380 - 620	508.6	frozen for one week
C	2/28-3/2	70.7	9.7	400 - 800	571.6	frozen for one week
D	3/8	67.4	9.4	500 - 920	635.6	fresh
E	3/10	68.8	8.4	400 - 800	597.7	fresh
F	3/16-17	68.2	12.0	500 - 900	641.8	frozen for one week
		71.7 [a]	12.0 [a]	650 - 1350 [a]	1290.2 [a]	frozen for one week
G	3/29-4/1	69.1	12.2	550 - 900	651.0	fresh
		86.9 [a]	12.2 [a]	730 - 1500 [a]	1179.4 [a]	fresh
	5/early [b]	70.2 [b]				
				800 - 920 [c]		frozen for one week
				620 - 920 [c]		frozen for one day
	1978					
	2/23 [d]				638	
	2/14 [e]				687	
	2/27				(606 - small and medium skein	
					(682 - large skein	

[a] Considered to be overmature roe.
[b] From pollock caught in Queen Charlotte Sound in early May.
[c] Pollock egg diameter range in the Japanese literature reported by Tamoto et al. (1968).
[d] Commercial harvest from lower Strait of Georgia.
[e] Commercial harvest from Dixon Entrance.

Table 3. Comparison of chemical additives used by the Japanese tarako industry.

Weight in g used for 25 kg batches of roe

	Processor 1	Processor 2		Our Method
Red No. 102	1.13	1.22	1.05	1.31
Red No. 3	.262	.162	.15	.175
Red No. 104		.0813	.075	
Yellow No. 4		.0813	.225	.0875
Yellow No. 5	.349	.162		.175
Total wt. dye	1.74	1.707	1.50	1.75
% of roe weight	.00696	.0068	.006	.007
Sodium chloride	3,000	3,934.4		3,000
Propylene glycol	87 ml			0 - 125
Glycymine	21.82	10.17		20
di- and tri-Na glycyrrhizinate	3.82	1.78		3.5
dextrin	10.26	4.78		9.4
sodium citrate	7.75	3.61		7.1
Pinfish		10.17		20.0
natural product	26.75	2.59		5.1
calcium phosphate		.153		.3
sucrose fatty acid ester		.427		.84
sodium citrate		7.0		13.76
Sodium ascorbate	25	26.23		25 - 50
Sodium erythorbate		13.11		12.5 - 25
Nicotinamide	25	26.23		25 - 50
Sodium polyphosphate	6.813	10.17		20 - 40
Sodium pyrophosphate	5.5			
Potassium lactate	3.25			
Calcium lactate		30.51		60 - 120
Sodium citrate	.94			
Monosodium glutamate		10.17		20 - 40
Total Sodium citrate	8.69	10.61		20.86
Sodium nitrite (added as veg. extract)		6.4 ppm		

Table 4. The relationship of water content and yield to the state of maturity from the Japanese literature.

Maturity of Roe	% Yield	% Water Content
Immature	5 - 8	75 - 80
Mature	10 - 16	60 - 65
Overmature	> 16	75 - 90

Table 5. The relationship of grade of roe to maturity and water content from the Japanese literature (Mimura et al., 1962).

Maturity	Grade	% Water Content
Close to mature	2 - 3	67 - 75
Just before spawning	3 - 4	76 - 82
Spawning	Off grade	83 - 93

Table 6. Fresh roe. Water content, salt content, firmness and yield of processed roe.

Sample		Salt Used (%)	Water Content (%)	Salt Content (%)	Firmness[1] (Gram)	Yield[2] (%)
A	-	10	61.9	6.3	451.2	-
B	1	12	60.8	4.0	564.4	94.4
	2		63.1	4.2	736.2	94.0
	3	16	61.5	6.3	817.8	96.3
	4		61.1	7.9	935.3	90.4
C	1	12	60.1	4.9	735.0	94.6
	2		60.9	5.0	1156.2	93.0
	3	16	58.8	5.6	902.0	93.0
	4		60.8	7.1	1241.9	93.4
D	1	12	59.8	4.9	1109.5	93.3
	2		59.1	5.6	1292.6	92.6
	3	16	59.4	6.1	1203.6	91.8
	4		58.1	6.1	1398.3	91.4
E	1	12	60.7	4.4	791.4	95.6
	2		60.3	5.1	949.0	95.1
	3	16	61.7	5.4	1069.7	91.5
	4		62.5	5.4	989.2	92.7
F	1	12	60.2	3.6	934.4	94.9
	2		59.7	4.3	1313.7	93.8
	3	16	58.5	4.9	888.4	92.0
	4		60.2	5.1	1223.9	94.0
G	1	12	62.0	4.5	929.9	92.1
	2		61.8	4.5	983.5	92.8
	3	16	60.5	4.4	887.8	90.5
	4		61.0	4.9	1173.7	-

[1] Firmness was measured with the Ottawa Texturometer Model D-1203. Values > 400 g considered acceptable.

[2] Processed roe/fresh roe x 100 = yield.

Table 7. Frozen roe. Color change of roe after 3 to 5 days, water content, salt content, firmness and the yield of processed roe.

Sample[1]		Salt used (%)	Wash[2]	Color change in 3 to 5 days	Water content (%)	Salt content (%)	Firmness[3] (gram)	Yield[4] (%)
	1		SW	Good	59.8	6.4	334.5	90.0
A	2	12	SW	Good	60.4	5.7	275.2	91.2
	3		1ASC	Orange	59.4	5.8	618.6	94.8
	4		1ASC	Good	60.7	5.0	688.8	96.8
	1		SW	Good	63.0	5.9	273.7	91.7
B	2	12	SW	Good	61.6	6.2	364.1	94.1
	3		1ASC	Good	61.3	5.0	393.7	91.6
	4		1ASC	Good	61.9	5.8	414.2	91.4
	1		SW	Dark	61.0	5.8	470.5	93.5
	2		SW	Slightly dark	61.8	5.7	371.3	93.8
C	3	12	1ASC	Some good Some dark	59.8	5.8	425.6	93.3
	4		1ASC	Good	61.4	6.0	573.9	92.7
	1		SW	Good	62.3	6.5	324.5	93.2
	2		SW	Good	63.3	6.1	378.8	93.1
E	3	12	1ASC	Good	61.1	6.2	289.9	92.1
	4		1ASC	Good	62.0	6.4	332.2	90.0
	5		2ASC	Good, but white powder on surface	61.3	6.2	388.9	95.0
	6		2ASC	Good	63.0	6.4	494.4	94.1
	1		SW	Fair	62.1	5.0	438.8	90.0
	2		SW	Good	61.0	5.7	364.2	87.6
F	3	12	1ASC	Slightly dark	63.8	5.5	400.2	87.0
	4		1ASC	Good	60.9	5.6	417.9	82.5
	5		1SOR	Slightly dark	61.7	4.4	386.6	92.4
	6		1SOR	Good	59.7	5.8	489.6	92.6
	1		SW	Fair	62.0	4.8	336.6	92.8
	2		SW	Good	61.8	4.7	416.9	91.8
	3		1ASC	Excellent	60.6	5.9	422.8	92.1
G	4	12	1ASC	Excellent	61.0	5.9	424.9	92.5
	5		2ASC	Fair to dark	60.4	4.9	367.3	91.2
	6		2ASC	Good	61.4	5.0	402.9	-
	7		1SOR	Poor and dark	59.7	5.4	458.4	93.0
	8		1SOR	Good	61.3	5.6	437.4	93.4

[1] Samples 1, 3, 5 and 7 were processed with 1.0% nicotinamide and 1.5% sodium ascorbate and 2, 4, 6 and 8 with 15 ppm sodium nitrite and 1.5% sodium ascorbate.

[2] SW = sea water, 1ASC and 2ASC = sea water containing 1% and 2% sodium ascorbate, 1SOR = sea water containing 1% potassium sorbate.

[3] Firmness was measured with the Ottawa Texturometer Model D - 1203.

[4] Yield = processed roe/unprocessed roe x 100.

Table 8. Frozen roe. Color change of roe after 3 to 5 days, water content, salt content, firmness and the yield of processed roe.

Sample[1]		Salt used (%)	Wash[2]	Color change in 3 to 5 days	Water content (%)	Salt content (%)	Firmness[3] (gram)	Yield[4] (%)
	1		SW	Slightly dark	62.0	6.5	431.6	94.3
B	2	16	SW	Good	61.8	6.5	472.2	91.6
	3		1ASC	Good	61.8	5.4	435.2	92.4
	4		1ASC	Good	60.0	6.2	521.9	93.2
	1		SW	Some good Some dark	60.6	7.6	418.8	92.1
C	2	16	SW	Good	60.5	7.8	568.7	92.5
	3		1ASC	Orange	60.4	6.8	373.4	89.7
	4		1ASC	Good	61.3	8.7	424.3	89.9
	1		SW	Fair	60.8	6.2	497.9	93.2
	2		SW	Good	61.8	6.4	369.1	93.9
E	3	16	1ASC	Good	60.5	6.6	432.2	92.3
	4		1ASC	Good	60.2	7.2	551.1	90.8
	5		2ASC	Good	59.5	5.9	556.2	92.2
	6		2ASC	Good	59.1	6.9	685.7	90.0
	1		SW	Fair	57.3	6.0	479.3	90.4
	2		SW	Good	61.6	6.4	479.8	89.6
F	3	16	1ASC	Slightly dark	61.6	4.4	416.4	90.0
	4		1ASC	Good	62.6	4.7	407.4	90.0
	5		1SOR	Orange	60.1	5.9	467.0	91.0
	6		1SOR	Good	61.7	5.4	498.0	89.1
	1		1ASC	Good	59.2	6.0	497.7	93.8
G	2	16	1ASC	Good	59.3	6.2	370.0	91.9
	3		1SOR	Excellent	59.8	5.5	326.8	88.5
	4		1SOR	Excellent	61.4	5.2	372.5	91.3

1 Samples 1, 3 and 5 were processed with 1% nicotinamide and 1.5% sodium ascorbate and 2, 4 and 6 with 15 ppm sodium nitrite and 1.5% sodium ascorbate.

2 SW = sea water, 1ASC and 2ASC = sea water containing 1% and 2% sodium ascorbate, 1SOR = sea water containing 1% potassium sorbate.

3 Firmness was measured with the Ottawa Texturometer Model D - 1203.

4 Yield = processed roe/unprocessed roe x 100.

Table 9. Effect of calcium lactate, sodium polyphosphate and monosodium glutamate on firmness.

Additive	Experiment No.					
	1	2	3	4	5	6
Calcium lactate	-	.08*	-	-	-	-
Sodium polyphosphate	-	-	.08	.16	-	-
Monosodium glutamate	-	-	-	-	.08	.16
Firmness (g)	392.8	499.1	401.8	517.0	398.9	421.7

* percent of roe weight.

Table 10. Effect of combinations of calcium lactate, sodium polyphosphate and monosodium glutamate on firmness.

Additive	Experiment No.					
	1	2	3	4	5	6
Calcium lactate	.24*	.24	.24	.48	.48	.48
Sodium polyphosphate	-	.08	.08	-	.16	.16
Monosodium glutamate	-	-	.08	-	-	.16
Firmness (g)	367.4	400.7	406.7	530.2	543.9	499.3

* percent of roe weight.

Table 11. The effect of amount of salt, salting time and drain temperature on the firmness of processed product.

Salt used %	Salting time (hour)	Drain temperature (°C)	Water content (%)	Salt content (%)	Firmness (gram)	Firmness after storage(g)
12	4	0	59.8	7.3	343.5	315.4
		10	59.6	9.4	385.6	304.2
	6	0	60.3	9.1	424.7	344.9
		10	61.2	9.5	433.2	366.4
	8	0	60.4	10.3	457.4	401.8
		10	60.1	9.9	433.7	334.0
	10	0	59.3	10.9	397.3	378.5
		10	61.2	11.4	401.4	376.6
15	4	0	58.1	8.8	367.6	393.1
		10	59.1	11.1	420.4	384.2
	6	0	59.7	9.7	472.3	468.4
		10	61.4	13.4	531.3	509.7
	8	0	60.0	12.0	525.0	468.5
		10	58.1	12.9	511.0	539.3
	10	0	58.7	11.9	582.4	547.0
		10	59.0	12.0	675.1	501.1
20	4	0	58.3	10.9	693.5	599.4
		10	59.4	11.2	408.5	526.4
	6	0	57.0	13.4	621.8	621.4
		10	57.6	18.8	625.3	579.2
	8	0	57.8	16.2	768.5	827.2
		10	55.4	15.0	746.5	745.3
	10	0	56.3	17.0	791.9	842.2
		10	55.2	15.3	806.6	851.9