# 5. The process of making lumpfish caviar

## THE PROCESSING PLANT

Before commercial production is started, a process has to be elaborated where the actual equipment, methods and recipes are considered, designed and verified. The main issue is to produce a high quality product with sufficient yield to provide a profit. Plants can be of various sizes, ranging from small manual production, up to huge, sophisticated, automated processing lines producing tens of thousands of units per shift. Usually the raw material is received in spring and summer, but production occurs mainly in late autumn. Refrigerated storage is needed to keep the barrels safe between reception and production, and the storage room should be big enough to hold enough raw material for at least one year of production or even more to be on the safe side.

### Receiving barrels at the production site

When the barrels arrive at the production site they should be opened and checked for temperature, smell, salt content, leakage, objectionable or foreign material, and randomly sampled for bacterial growth. Barrels below set quality standards should immediately be rejected and returned to the producer. Accepted barrels are topped up with brine and securely closed, and not opened again until they are taken into the production line.

### Assessment prior to production

Prior to production, the quality of each barrel is assessed organoleptically. At this point it is not common to find spoiled barrels if good manufacturing practices have been employed and the raw material stored at the correct temperature. Spoilage can be detected by making a deep hole in the centre of the barrel and smelling, noting if any odour is released. Suspicious barrels are set aside for further investigation, pH and microbiological assessment. A rancid top layer, if any, can be removed by a flat

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*Chilled storage of salted lumpfish eggs* scraper and thrown away. The content of a spoiled barrel cannot be allowed to enter the production process as it will destroy the whole batch, with consequent loss of several barrels.

## Equipment

The size and output potential of the de-salting equipment depends on production volume. When the eggs are de-salted it is necessary to be aware of the intended final salt content of the product, and roughly calculate the mass of water required for the mass of eggs to be processed. It is not recommended to de-salt the eggs totally and then add the desired amount of salt. That will result in broken eggs and reduced yield due to osmotic changes (Benson *et al.,* 1988).

A container is needed to de-salt the eggs. It can be open or closed and agitation is needed to speed up the de-salting process. Often a dairy churn is used for this purpose which can also be used for the final mixing of the product. If an open container is used, floating debris can be skimmed off the surface, but that cannot be done in a closed container. Acidification and colouring can be performed at this stage but can also be done later.

Two procedures are possible at this stage. One is to drain the eggs before de-salting them (Benson *et al.*, 1988) and the other is to de-salt the contents of the barrel as a whole. To avoid an osmotic shock for the eggs, the water for dewatering is slightly salted at 1.0–2.0 percent (Sternin and Doré, 1993). The amount of water needed to reach the appropriate salt level is found by trial and error. After experimenting for a while, it will become routine to use a particular amount of water for each barrel of eggs in order to get the correct result. Draining time will depend on the equipment and the eggs and has to be estimated by an experienced worker. There are certain difficulties in de-salting as described in de-salting experiments (Benson *et al.,* 1988) where duplicates did not agree well one with the other, as there was up to 2 percent difference between them. Therefore it is better to overdo in de-salting, as salt can be added again, but it is impossible to remove salt from the caviar in the final stage of production. Water and eggs are mixed together for 30 minutes before draining.

## Blending ingredients and water

The use of many ingredients in lumpfish caviar is restricted by governmental regulation. The use of a prohibited additive or an accidental excess of some ingredient can unfortunately occir during the blending of the caviar. To avoid this, it is recommended

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*Open barrels are inspected before their contents are put into the mixer for de-salting* that only those ingredients required be kept in the weighing room and to label them carefully and train the persons involved well. All weighing should be done in a separate, closed room to avoid any disturbances.

A medium- or high-speed blender is used for mixing the ingredients with water. The ingredients can be in either dry or liquid form and should be handled according to the producers' recommendations. Colourings are dissolved in hot water and dry ingredients mixed together before they are run carefully into the water under constant stirring to avoid lumping. The thickness of the mixture is sauce-like if stabilizers or emulsifiers are used. Care should be taken to avoid air bubbles in the blend.

***Colouring***

For colouring lumpfish eggs, a blend of synthetic food colours is used to achieve the desired shade. In the EU, the colours have been assigned numbers between 100 and 180 and an E prefix, but in the United States of America they are given FD&C (Food Drug and Cosmetics) names and numbers. In addition there are accepted common names, such as tartrazin, which is FD&C (Food Drug and Cosmetics) Yellow #5 in the United States of America and E-102 in the EU – three different names for the same colouring agent. The colouring of the eggs can be done either in the de-salting process or during the mixing of other ingredients and the eggs. If the eggs are coloured in the de-salting bath, the time there has to be sufficient for the colour to fasten to the eggs. There is a danger of uneven coloured batches if the duration of the colouring period is not monitored carefully.

***Stabilizers and emulsifiers***

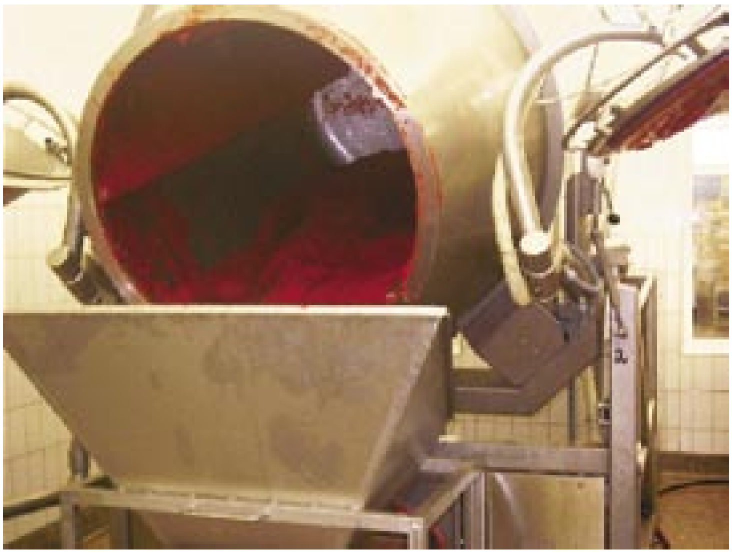
The use of stabilizers and emulsifiers is regulated in most markets in the same way as for the colourants. Food gums, such as agar-agar, tragacanth, xanthan and alginate, are used for caviar production. The stabilizer's function is to maintain the consistency of the product during both further processing and distribution, and also to prevent leakage from the caviar during the entire shelf life, which can be as long as eighteen months or more.

***Flavours and spices***

Flavours in the form of spices, spice extracts and flavour enhancers can be added as the processor wishes and the market demands. There has long been an ongoing dispute about flavours and their use, and some consensus seems to be emerging, but legislation

*Mixers for mixing lumpfish caviar*

*Lumpfish caviar ready for packing is removed from the mixer*



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must be adhered to and the final product must conform current requirements. Further information on this issue can be obtained from an information sheet entitled "Food additives and flavourings" prepared by the European Food Safety Authority (see: .www.efsa.eu.int).

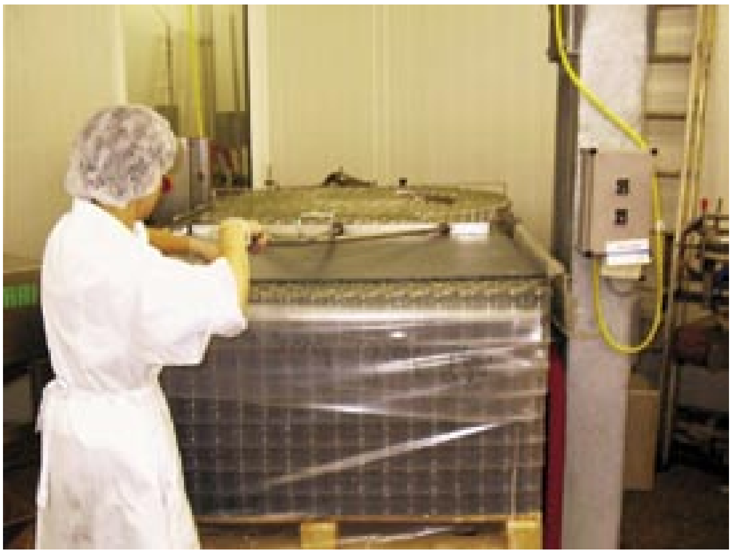
*Preservatives*
Preservatives - often sodium benzoate (benzoate of soda), although potassium sorbate is also used - usually added during the salting of the eggs. During de-salting, the concentration of preservative will diminish because the preservative is soluble in water. In most instances, the preservative is added with the other ingredients to maintain the correct levels and balance in the product. The preservative can be more sodium benzoate, potassium sorbate or a blend of the two. The use of preservatives is regulated by legislation in all markets.

*Other ingredients*
In addition to the main ingredients, others are used for specific effects such as pH reduction, ensuring glossy surface or adding flavour. To obtain a glossy surface, oil or glycerine is used, and the taste is sweetened by using sugar or saccharine.

*Acidifying agents*
Food acids, such as citric, lactic or acetic (vinegar) are used to lower the pH to a desired level. To establish how much acid is needed, a trial-and-error method is used on a small scale, measuring the pH with a pH meter.

*Mixer for mixing ingredients and de-salted eggs*
The de-salting churn can be used for mixing additives with the de-salted eggs although many suitable mixers can be found for this purpose. A vacuum mixer is worth trying because air bubbles formed during mixing in open mixers can be troublesome later in the process of jar closure.

*Measuring salt and pH*
At this stage the product is sampled to measure salt and pH levels, and corrected for deviations if needed. Salt is added if the eggs have been over de-salted. When the mixer is emptied, it is important to weigh the product and calculate the yield.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*Jars entering the filling line*

## Filling

Both manual and mechanical filling are used for filling the product into the jars.

### *Manual filling*

Jars can be filled manually using a spoon and a scale. An empty jar is put on the scale, which is then zeroed and filled to the right weight. There must be some weight limits for the worker to operate within, set by the management, depending on the balance precision and market demand. It is important to have the weight of the product exact and not produce underweight, but it is also bad for business to produce too many overweight units. One gram overweight in a 50-g jar is two percent and equates to considerable financial loss if it is an average overweight. It is possible to fill up to 5 000 jars by hand in eight hours (Benson *et al.*, 1988), presumably meaning by a single worker.

### *Automatic and semi-automatic filling machines (piston filling machines)*

Automatic filling machines use volume measurement not weight. Lumpfish caviar is of uneven density which means that the same volume varies in weight between batches. Therefore the weight has to be monitored regularly and the volume calibrated to ensure the correct weight of product. The monitoring frequency depends on the equipment used and the throughput rate. The need to monitor the weight carefully is even more necessary than during manual filling because of the greater throughput.

Mechanical fillers usually fill from the bottom of the jar up to the rim.

There are many automatic or semi-automatic filling machines of different capacity available on the market. A good filler does not damage the caviar and is accurate in portioning and filling the jars. Perfect synchronization and smooth transfer from filling to closing machines is needed.

### *Check-weight*

Underweight is economic fraud and must be avoided. A control system must be established to ensure accuracy. Knowledge of weighing rules and deviation from net weight is necessary. There are two types of weights and measures legislation in force in different countries, namely the Minimum Weight System and the Average Weight System, described in the following text taken from the FAO Web site.

> *"The aim of this type of legislation is to protect customers from being cheated by unscrupulous manufacturers, for example from being sold underweight packs of food. The laws are to ensure*

*Filling machine*


*that the amount of food that is declared on the label as the net weight (the weight of product in a pack) is the same as the weight of food that is actually in the pack. However, it is recognized that not every pack can be filled with* <u>*exactly*</u> *the specified weight because both machine-filling and hand-filling of containers is subject to some variability. The laws are therefore designed to allow for this variability but to prevent fraud.*

*"There are two types of weights and measures legislation in force in different countries: the older method, which is still used in most developing countries, is known as the Minimum Weight System. This is intended to ensure that every pack of food contains at least the net weight that is written on the label. If any pack is found below this weight, the producer is liable for prosecution. This system works well to protect customers, but is more expensive for producers because they have to routinely fill packs to just above the declared weight to avoid prosecution and they therefore give a small amount of product away in every pack.*

*"A second type of legislation was introduced in Europe to take account of the automated filling and packaging that is used by most producers there. This is known as the Average Weight System and uses a statistical probability of a defined proportion of packages being above the declared weight as a basis for enforcement. As most small-scale producers in developing countries do not use automatic fillers and programmable check-weights, this system is difficult to operate and unnecessarily complex. If however, a producer is considering export to an industrialized country, advice and information on this legislation should be obtained from a local Export Promotion Board or equivalent institution so that an 'e' mark can be obtained to indicate that the process conforms to this system."*

**(FAO, 1997)**

Statistical control charts are of great value in establishing working limits. Detailed guidance of how to make an average and range chart (XR Chart), which is very useful for this purpose, is given in Ishikawa's *Guide to quality control* (Ishikawa, 1991).

*Closing*

Metal lids are used for closing the jars and there are several different styles. The twist-off style is quite common in the lumpfish industry. Other types are s**ide seal closures, pry-off closures** and **other varieties.**

*Vacuum*

The vacuum prevents growth of moulds and helps to keep the lid on. To make vacuum possible, some headspace is needed in the jar. Machines that use mechanical vacuum

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*Steam closing machine*

suck the air out of the jar and screw the lid on before the jars are released. The correct amount of vacuum is applied. There are divided opinions of how much vacuum is needed, ranging from 100–150 mm of mercury (Benson *et al.,* 1988), through 125 mm of mercury (Sternin, 1992) to 250–375 mm of mercury (Dewar, Lipton and Mack, 1971). The lid producer can also be consulted on this matter. The US Food and Drug Administration's Centre for Food Safety and Applied Nutrition have placed their Bacteriological Analytical Manual online and it can be consulted for further information, especially Chapter 22B on *Examination of containers for integrity* (FDA, 2001a).

If the product contains air bubbles, it is possible that some of the content will be lifted over the rim of the jar and become trapped between the rim of the lid and the jar. When the jar is opened, these dried and unappetizing roes will be spread over the surface of the jar. In the worst cases, moulds will grow on it.

***Steam closing machines***

Steam closing machines replace the air in the headspace of the jar with steam in a chamber and close the jar. When the steam condenses upon chilling, a reduced pressure is formed within the jar. Some water will be seen on the surface of the content but it will merge with the caviar and disappear in a few days.

After closure the jars go through a vacuum check before pasteurization.

***Methods of pasteurization***

When lumpfish caviar is pasteurized it loses some characteristics and the colour will fade if overheated. Therefore the producer has to develop a pasteurization process that does what is required, i.e. reduce the number of bacteria to an acceptable level, but no more, as that will result in an inferior product due to cooking, i.e. the coagulation of proteins.

The target bacterial species for pasteurization is usually *Clostridium botulinum,* but the surviving spores are prevented from germinating into vegetative cells by factors such as pH, salt and storage temperature. The effectiveness of the process has to be verified (see discussion of Hazard Analysis Critical Control Point in Chapter 6) and the pasteurization constantly monitored and recorded during the operation. Automatic temperature monitoring is used for monitoring the process.

The pasteurization process can be divided into three phases:

1. Warming phase: the time it takes to warm up the centre of the jar to a certain temperature.

TABLE 11
**Some time–temperature relations used in lumpfish caviar pasteurization**

| Jar Size | | Time | Chamber Temperature | | Jar Internal Temperature | |
|---|---|---|---|---|---|---|
| oz | g | minutes | °F | °C | °F | °C |
| 2 | 56.7 | 23 | 165 | 73.9 | 150 | 65.6 |
| 3.5 | 99.2 | 41 | 165 | 73.9 | 150 | 65.6 |
| 7 | 198.5 | 53 | 165 | 73.9 | 150 | 65.6 |
| 14 | 396.9 | 91 | 165 | 73.9 | 150 | 65.6 |
| 50 | 1 417.5 | 120 | 134.6 | 57.0 | n.a. | n.a. |
| 100 | 2 835.0 | 36 | 167–176 | 75–80 | 167 | 75.0 |
| 50 | 1 417.5 | 60 | 159.8 | 71.0 | n.a. | n.a. |

*Notes:* n.a. = information not available.
*Source:* Benson *et al.,* 1988.

2. Pasteurization phase: the time the centre of the jar is kept at a constant temperature.
3. Cooling phase: the time it takes to cool the centre of the jar down to a certain temperature.

To develop the process parameters, several factors need to be considered:

- The size and shape of the jars – the bigger the jars, the longer the warming and cooling phases.
- The initial temperature of the jars at the time of entering the pasteurizer - the colder the jars, the longer the warming phase, and the pasteurization phase will be curtailed by that duration if the total process time is unchanged.
- The temperature distribution in the pasteurizer- the process has to be designed to work for the coldest part of the equipment, but a jar in the hottest part could then be overheated. If the temperature distribution is very uneven, a pasteurizer could be unusable for this product.

Examples of pasteurization time and temperatures can be found in literature, but it should be emphasized that each producer has to verify the process used in their production line. Some examples are given in Table 11.

### *Pasteurizers*

There are two types of pasteurizers in use for lumpfish caviar: batch pasteurizers and continuous pasteurizers.

Batch pasteurizers are used to process a defined batch size at one time. They are closed containers, heated by steam or water. Autoclaves used for sterilizing can be used

*Pasteurizer seen lengthwise*

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*Pasteurized jars exiting the pasteurizer. By dividing the pasteurizer, it is possible to pasteurize two products simultaneously*

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*A complicated system of automatic conveyor belts move the jars around the plant*

for this work. Jars are put in baskets and immersed in water for the total processing time. Time and temperatures are monitored and recorded.

Continuous pasteurizers consist of a conveyor belt that is heated by water in a tunnel. The temperature of the water and the speed of the belt can be changed to achieve different pasteurization effects. The moving belt carries the jars through the tunnel, where they are heated, pasteurized and chilled. The temperatures and the speed of the belt are monitored and recorded.

### *Drying*

The jars are wet when they exit the pasteurizer and are dried by using hot air blowers. Wet jars are difficult to label, because the labels will not stick to a wet surface.

### *Labelling*

Labels are put on lids, bottoms and sides of the jars, not necessarily everywhere, but one or two labels are common. A labelling machine is needed for each type of label if mechanical labelling is used. Manual labelling can be used under certain circumstances.

There are two kinds of labels common in lumpfish caviar production. Firstly, there are fancy labels placed on the lid and the side of the jar. Often the printing is done on


*Sophisticated technology is needed to apply labels and tamper indicators, including in-line real-time ink-jet printing of batch information, etc.*


*Product packed as a double-pack of red and black jars together*

the lid itself when it is manufactured. These labels are best done by specialized printing companies. Secondly there are black-and-white labels often put on the bottom of the jar. They carry information such as lists of ingredients, lot number, best-before date and a bar code. Such labels can be printed at the plant or elsewhere, whatever suits the circumstances. Ink-jet printers can also be used to print some of the information, such as product shelf life.

To increase consumer safety, some kind of tamper indicator is needed. It can be heat-shrunk sleeves or labels glued over the lid and onto the side of the jar. Sometimes pop-up lids are used, where the centre of the lid pops up when the jar is opened for the first time.

## Final packaging

Cardboard boxes are used for 6, 12, 24 or 36-jar units, depending on the size of the jar and the customer's requirements. The boxes are labelled with information on the size of the jars, colour, quantity, brand, storage conditions, etc.

Information about the size and weight of packaging material should be recorded and kept for environmental reasons. Pallets – usually wooden – of standard size are used for each market. The boxes are put on pallets and the pallets wrapped when fully loaded, and then kept in a refrigerated store until being shipped. The pallets are labelled with information on the producer, quantity, size of jars, colour, brand name and the required storage conditions.

## Yield calculations

At the end of the production line the yield should be calculated and compared with previous yields and the starting quantity. Any discrepancies should be discussed immediately and explanation sought to allow correction. Low yields result, for example, from overweight in the jars, losses in pasteurization caused by improper closure or loss from accidents, and need to be corrected in the future. If yields appear higher than expected it is possibly that they are caused by underweight in the jars, which is potentially a disaster for the producer. It can not be corrected without rework, hence the vital importance of monitoring during the filling phase.

# 6. Hygiene and handling methods from catch to end product

It is of great importance for every food producer to analyse their processes in order to be able to eliminate or minimize possible hazards to human health. Currently the most used method is that of Hazard Analysis and Critical Control Point (HACCP) planning, which was initially developed for the United States of America space programme and later adapted worldwide by governmental authorities and the food industry.

## HACCP CONSIDERATIONS

It is outside the scope of this publication to provide a precise design for a HACCP system. Information concerning HACCP can be found in the literature and through the Internet. See, for example, the FDA Web site and the FAO Web site (for FDA, see www.cfsan.fda.gov/~dms/haccp-2a.html or for FAO, see www.fao.org/DOCREP/003/T1768E/T1768E05.htm.

Designing a HACCP plan requires teamwork, as it needs the contribution of individuals with expert knowledge of the various elements of the food production process that is to be analysed, including areas such as microbiology, chemistry, mechanical engineering and economics. It is also possible to hire a consultant for this work, but the cost should be considered before a contract is signed. The aim of the HACCP plan should be to prevent or eliminate any possible hazard to human health that can affect the consumer. Discussion is still continuing regarding whether other factors of consumer interest, such as underweight, should be included in the HACCP system. In this publication, those factors have already been addressed and are not included in the HACCP plan as they do not affect human health, even though they can have serious economic consequences for the producer.

The final HACCP-plan is a written document, dated and signed by a person with the authority to confirm that the plan is accepted by the firm.

The HACCP analysis procedure includes seven steps:

1. List the food safety hazards that are reasonably likely to occur.
2. List the critical control points for each of the identified food safety hazards.
3. List the critical limits that must be met at each of the critical control points.
4. List the procedures, and frequency thereof, that will be used to monitor each of the critical control points.
5. Include any corrective action plans.
6. List the verification procedures and the frequency thereof.
7. Provide for a recordkeeping system that documents the monitoring of the critical control points.

To start HACCP analysis for lumpfish caviar production, a flow diagram of the processes and information about the machines and housing is needed. The composition of the caviar, salt percentage, pH and use of preservatives is also of great importance. Possible health hazards in the lumpfish industry are identified as microbiological, chemical and physical.

### Microbiological hazards

Microbiological hazards are divided into bacterial, viral and parasitical hazards. General information about microbiological hazards, for example, can be found in what is known as *The Bad Bug Book* (FDA, 2003), which is available on the Internet.

The main hazard in lumpfish caviar production is the danger of botulism and a critical element in the design of the process is to prevent possible spores from germinating and growing.

***Bacterial hazards in lumpfish caviar***

Several hurdles are in used to avoid bacterial growth, including salt, preservatives, pH regulation, vacuum or lowered air pressure, pasteurization and chilling of the lumpfish caviar. A combination of these factors is necessary to keep the product safe during its shelf life.

In lumpfish caviar, salt is used to hinder bacterial growth. There are limits to its use, because very salty products become inedible. It is not uncommon to use 4 percent WPS (water phase salt) for chilled products, but more than 9 percent WPS is needed for other products. To determine WPS, the percentages of salt and moisture should be measured using approved methods, such as those of AOAC, and WPS calculated as percentage salt (%S) divided by percentage salt (%S) + percentage moisture (%M), multiplied by 100.

$$WPS = \frac{\%S}{\%M + \%S} \times 100$$

Chemical preservatives are used to help to keep the bacterial flora under control. Sodium benzoate or potassium sorbate are used in quantities of up to 2 g/kg, depending on the market.

A preserving effect is obtained by lowering the pH of the product. The pH of lumpfish eggs salted in barrels is around pH 6, but lumpfish caviar has a pH usually between pH 4 and pH 6. An acid taste becomes apparent if pH falls below pH 5. Partial vacuum is used for preventing growth of moulds. In lumpfish caviar jars, the pressure is reduced usually by about 30–40 percent. Chilled storage below 4°C is a necessity unless the product is very salty, with a WPS level exceeding 9 percent.

Pasteurization is a process where heat treatment in the range of 60–80°C is applied for up to a few minutes to kill micro-organisms. In general, pasteurization can be defined as a heat treatment intended to kill all the pathogens and most of potential spoilage organisms in order to extend shelf life (Adams and Moss, 2000). The combination of temperature and time can be varied in many ways to achieve the requisite results. The producer needs to verify the process to be used, taking into account the types of bacteria to be reduced or eliminated. Lumpfish caviar is pasteurized after the jars have been closed and the minimum time+temperature treatment has to be measured in the centre of the jar, where the effect of pasteurization is least.

Some information about lumpfish caviar pasteurization was found in the literature. Sternin and Doré (1993) recommend heating for 60–120 minutes at 65–69°C, and Sternin (1992) describes 55–70°C as the best temperature. Dewar, Lipton and Mack (1971) recommend a temperature of 158–160°F (70–71°C) for 60 minutes at the centre of the jar, or a total time of 100 minutes to ensure heating to the correct temperature and effective pasteurization.

Lumpfish is caught in the cold waters of the North Atlantic Ocean and psychrotrophic pathogens are a possible concern. An experimental product called "lightly salted lumpfish roes" (LSLR) produced from heavily salted lumpfish eggs is described by Basby (1997). This product had a pH of 5.4, with a salt percentage of 4 percent WPS. It was not pasteurized, no preservatives were used and it was stored at 5°C for three months. Pasteurized lumpfish caviar with a preservative (PLCP) is better protected than this product. Therefore it is plausible to draw the conclusion that if a certain type of bacteria is of no hazard in LSLR, it is also harmless in PLCP at the same pH or lower.

In the United States of America, lumpfish caviar is defined as a low-acid canned food (LACF) by FDA and stored at ambient temperature. All commercial processors of LACF are required to register their establishments and file processing information for all products with the FDA, using appropriate forms, before they can start to export lumpfish caviar to the United States of America. The processing information must describe the manufacture method used to prevent growth of *Clostridium botulinum* in the caviar.

*C. botulinum* causes botulism, which is a fatal disease in many cases. Combinations of salt and pH found to inhibit growth of *C. botulinum* in lumpfish caviar under various refrigeration regimes were salt 5.6 percent + pH 5.6; salt 4.7 percent + pH 5.4; and salt 4.0 percent + pH 5.0 (Hauschild, 1989). No growth of *C. botulinum* (types E, B and F) was observed at 0–4°C, WPS >4 percent and pH <6 (Graham *et al.*, 1997). *C. botulinum* is not considered a hazard in LSLR stored at 0–5°C (Basby, 1997).

*Listeria monocytogenes*, causing listeriosis, is found in sediments and seawater where the lumpfish spawns. It can also be introduced into the product later in the process. If present, it can not be prevented from growing in unpasteurized LSLR stored at 0–5°C, making it a potential hazard (Basby, 1997). The *L. monocytogenes* hazard can be eliminated by pasteurizing the lumpfish caviar. A study on the influence of mild heat treatment on *L. monocytogenes* was done by Bréand and co-workers (1998). An unpasteurized product has to be protected with chemical preservatives.

*L. monocytogenes* was found in cured seafood, including caviar (type not specified), but did not grow at 5°C, most probably inhibited by preserving parameters of salt, reduced pH and the use of chemical preservatives (Jörgensen and Huss, 1998). Growth of *Listeria* spp. as affected by various factors has been predicted by Razavilar and Genigeorgis (1998). Sodium benzoate at 2000 mg/kg has a retarding effect on growth of Listeria in herring (Næringsmiddeltilsynet i Midt-Rogaland, 1998). The tolerance limits for Listeria is discussed by Teufel (1999), but more information is needed on the use of pasteurization and preservatives to hinder growth of *L. monocytogenes* in lumpfish caviar. The possibilities for Listeria to grow in lumpfish caviar between production and consumption are unknown, but the long shelf life of up to 18–24 months should be considered, especially for unpasteurized products.

Other possible hazards known in seafood, such as *Vibrio* spp., *Aeromonas* spp. and *Plesiomonas* spp., are not considered to be a hazard in LSLR stored at 0–5°C (Basby, 1997), so they are not considered to be hazards in pasteurized lumpfish caviar.

During the long process between catch and caviar production, some contamination with non-indigenous organisms can occur. Enterobacteriacea and *Staphylococcus aureus* are considered to be a low-level hazard in unpasteurized LSLR stored at 0–5°C (Basby, 1997), but both should be eliminated in the pasteurization process and therefore are not considered a hazard in pasteurized lumpfish caviar.

Salmonella was found in one sample out of 213 "prepared items", which included caviar but not specifically mentioning lumpfish caviar (Heinitz *et al.*, 1998). Salmonella is eliminated by pasteurization.

Spoilage bacteria, which are found everywhere in the environment, should be kept at minimum levels by employing good manufacturing practices throughout the industry.

The roe sacs of fish in general contain very few bacteria while still in the fish, and in most cases can be considered sterile (Ingolfsdottir, 1987). The fishing grounds for lumpfish are always close to the shore, and therefore the possibility of pollution from agriculture or other human activities has to be considered. However, during the long storage of salted eggs before processing into caviar, the original microbiological flora will disappear and be replaced by a halophilic flora, mainly yeasts (Martinsdottir and Magnusson, 1983).

The pasteurization process is designed to eliminate bacteriological hazards by heating closed jars and thus avoiding recontamination. Unpasteurized caviar can only be protected by good manufacturing practice because no part of that process will replace pasteurization.

The bacterial flora found in the lumpfish caviar end product is mostly caused by contamination from the processes and does not originate from the fish itself. It has survived the pasteurization process even though greatly reduced in number. Some of the bacteria are able to grow in the jars and spoil the caviar and discolour it if the lumpfish caviar is stored at temperatures higher than recommended. This contamination is in most cases caused by lactic acid bacteria (LAB), and is not a health risk for the consumer because the bacteria are not pathogens, although they cause economic losses for the industry (Peturson, 1976, 1977; Magnusson, 2002, pers. comm.).

*Viral hazards*

Viruses are a possible hazard, but nothing was found in the published literature regarding their existence in lumpfish or lumpfish products. Viruses affecting humans cannot grow in food, but if they exist in the environment, contamination could occur during the handling and processing of the product. Viral infections are usually transmitted by the faecal-oral route, so general procedures of personal hygiene and cleanliness intended to eliminate the hazard of faecal contamination of food will also help eliminate viral contamination.

*Parasitical hazards*

Parasites in lumpfish, considered possibly to be a health hazard to humans, are the nematodes *Anisakis simplex* and *Pseudoterranova dicipiens*, both found in the entrails of lumpfish in Norwegian waters (Karlsbakk and Nilsen, 1993). Theoretically, the larvae can be transferred into the roes if gutting is not done carefully. This can be a hazard in lightly salted lumpfish caviar produced in a one-step process. The hazard of these species in lumpfish caviar made from heavily salted eggs is discussed by Basby (1997) and considered to be minimal, but more data is needed on this issue, especially concerning salt tolerance of the larvae. Both species are killed by heat treatment above 55°C (Hauksson, 1997) and therefore eliminated by proper pasteutrization.

## Chemical hazards

Chemical hazards derive from three sources: naturally from the environment, from pollution in the environment, or from mistakes during processing. The first two can be avoided by monitoring the environment, and the third avoided by good manufacturing practice and proceeding with care.

The most common environmentally occurring chemical hazards are algal poisons indirectly originating from dinoflagellata. These have been reported on seafood, but mainly shellfish, and no known incidences have been reported in lumpfish roe products or in connection with the lumpfish industry (FDA, 2003). Pesticide residues and industrial pollution, such as heavy metals, can have their origin far from the fishing grounds but are distributed worldwide by sea currents. Measurements of heavy metals in miscellaneous caviar, including lumpfish caviar, showed that lead, mercury and cadmium were below the official maximum residue limits (Brunner, Marx and Stoller, 1995), but more data are needed to evaluate the risks of heavy metal contamination and other industrial pollution.

Contamination introduced during processing includes fuel or hydraulic oil leakages in the fishing boats, which can contaminate the catch and render it unfit for human consumption. In the event of such accidents, the catch should be discarded in an appropriate way. Detergents used onboard the fishing vessels and in production facilities should be intended for food industry use, and be used according to the manufacturer's directions. Misuse can lead to contamination of the product. Detergents should be stored in closed cabins or lockers when not in use, and during the cleaning process jars, lids and other packing material should be removed from the area.

## Physical hazards

Physical hazards include dangers from foreign matter such as small stones, broken glass or metal objects, which can physically hurt the consumer such as broken teeth or cuts in the mouth.

### *Environmentally occurring sand and stones*

There is a small but still possible danger that sand and stones can enter the roes aboard the fishing boats, for example if the nets are laid close to the bottom and some bottom material is transmitted with the fish and the net. It is the fisherss' responsibility to avoid this by taking great care aboard the fishing vessel, when the fish is gutted and the roes removed. There is no opportunity later in the process to remove sand, but its presence in the product could have serious consequences for the producer.

### *Foreign matter (pieces of glass or metal, etc.)*

Foreign matter found in food is often of great danger to the consumer. Glass splinters and metal pieces can cut the mouth, break teeth and result in loss of contract and large sums of money in compensation to the victim. A small industry can finish bankrupt after an incident of glass splinters found in the product.

Glass jars are transported on pallets and frequently have accidents *en route*. It is of utmost importance to remove all broken jars and glass splinters and clean the unbroken jars thoroughly before filling. Enclosing or covering the transport line where glass jars are moved open before filling and between filler and closure machines can prevent flying splinters from entering the jars before they are securely closed. Now and then a jar will accidentally fall off the line and the broken glass splinters can be found several meters from the spot where it hits the floor. A glass policy should be established and monitored at the lumpfish caviar plant.

Metal parts of the machinery can loosen and fall off and end in the product if care is not taken to avoid this by regular preventive inspection of machines, checking regularly if nuts and other metallic parts are loose and liable to detach, and securing them again. A possible means to monitor for metal pieces in the product is to install a metal detector between the filling equipment and the closure machine (FDA, 2001b). A device that uses X-rays to monitor jars in the production line is available. It is capable of detecting small particles – down to a grain of sand – inside a jar (Helgi Helgason, pers. comm., 2005).

## CATCHING, GUTTING AND COLLECTING ROES ONBOARD

The fishing grounds should be clean and unpolluted. Because the fish is caught very close to the shore, in many cases just 20–30 m, there is always the hazard of pollution due to human activities such as farming or the humans themselves. Limits must be established between the fishing grounds and possible sources of pollution. When gutting. cutting through the roe sacs or opening the internal organs must be avoided.

## FLOWCHARTS

A flowchart of each stage of the process should be drawn up to be better able to analyse the hazards. Examples of three hypothetical flowcharts are given.

FLOWCHART A

**Catching, gutting and collecting roes onboard and delivery to the salting facility**

Gut
⇓
Remove roes
⇓
Put into containers
⇓
Chill
⇓
Transport to salting facility
⇓
Receive (assessment)

FLOWCHART B
**Separating, salting and curing lumpfish eggs**

Receive (assessment)
⇓
Separate
⇓
Drain
⇓
Salt
⇓
Fill into barrels
⇓
Top up with brine
⇓
Cure
⇓
Add final brine
⇓
Move to chilled storage

## SANITATION

It is essential for a food processing industry to establish a cleaning schedule and a sanitation inspection schedule. It should be part of the HACCP plan. Much information is to be found in the literature or on the Internet, so this is not discussed further here.

## PERSONAL HYGIENE

All employees and other persons who enter the manufacturing plant should follow the requirements for personal hygiene concerning protective clothing, hand washing, ornaments, watches and toilet use.

All employees should receive documented training in personal hygiene, GMP, cleaning and sanitation procedures and personal safety, and their role in the HACCP programme.

FLOWCHART C
**Processing into caviar**

Open barrels; assess
⇓
De -water
⇓
Drain
⇓
Prepare solution
⇓
Blend eggs and solution
⇓
Allow to mature; drain
⇓
Prepare glass and lids
⇓
Fill; check weight
⇓
Screen (metal detector)
⇓
Vacuum close
⇓
Vacuum detect
⇓
Pasteurize
⇓
Vacuum check
⇓
Clean; dry
⇓
Label
⇓
Apply tamper indicator
⇓
Pack into cartons; onto pallets
⇓
Move to chilled storage

# 7. Test procedures

To ensure that production is in accordance with the scheduled process, a number of tests are required, including chemical, physical and microbiological tests. In addition, sensory evaluation is carried out by trained persons. Some of the tests are best carried out in the producer's own laboratory, which should be conveniently located near the site of operations. Other, more complicated tests and those not frequently undertaken are best sent to qualified outside laboratories.

## OWN LABORATORY

A caviar plant requires a small laboratory to perform basic tests (Benson *et al.*, 1988). This laboratory used during production to ensure that the product is in accordance with recipes and end product specifications. The results are needed in a hurry, so that production can proceed smoothly. The laboratory technician must be able to perform the tests required, to interpret the results and make adjustments to the processing when work in progress is outside specifications.

The basic tests are:

Salt content measurements
Moisture content measurements
pH measurements
Basic microbiological tests, including
– total plate counts
– coliform counts, and
– lactic acid bacteria (LAB) counts
Colour evaluation
Vacuum measurements
Visual inspection
Organoleptic (sensory) assessment
Weight checking

### Salt measurement

The salt content is an important factor in caviar processing – salt helps to preserve the product but most markets demand a salt content within stated limits. The United States of America market demands that the product can be stored at room temperature with salt content high enough to hinder growth of *C. botulinum*. Salt measurements during processing help to ensure a uniform end product and can prevent exceeding the upper limit, which could result in refusal by the buyer.

The equipment for salt measurements can be a measuring electrode, which is a fast method. Titration equipment using the Volhard method can also be used (AOAC, 1975). Whatever method is used, a calibration procedure is needed to validate it. Salt measurement is used, first, after the de-watering step to be able to calculate the amount of salt that needs to be added, and, second, after mixing and draining of the product and while it is still in the mixer and it is still possible to adjust the salt content.

### Moisture determination

There are several methods to measure moisture content. One is to dry the sample in an oven and calculate the moisture as the weight reduction (AOAC, 1975). Other methods are based on drying, using automatic or semi-automatic techniques.

### pH measurements
pH measurements are made with a pH-meter on each batch. The pH meter should be standardized daily against known buffers.

### Basic microbiological testing
Microbiological tests take several days to complete and therefore the results can not be used for immediate corrections of the process. A producer could choose to buy this service from a convenient laboratory. The most common microbiological tests are total plate counts and most probable number (for coliforms). Other possible tests are for Staphylococci, *Listeria* and LAB.

### Colour comparisons
Training is needed to compare colours of samples visually, but a colour comparator can also be used.

### Vacuum measurement
Vacuum in the jars is a critical factor affecting the growth of microbes and should be monitored both after jar closure and after pasteurization. This is done by automatic vacuum detectors, located above the conveyor belt, which detect if the lids are concave because of reduced pressure inside the jars. Vacuum testing can also be effected using a handheld instrument beside the closure machine, and the results recorded. A vacuum meter is also needed in the laboratory.

### Visual inspection of the jars
Visual inspection is carried out to check if the jars are clean, and if jar closure is effective. Visual inspection is also needed to ensure that the jars are correctly labelled and that the tamper indicator is correctly applied.

### Organoleptic (sensory) assessment
The product is assessed for taste, smell and texture to ascertain its eating quality. Taste can be described as salty, bitter, spicy or characteristic of the product. The odour can be used as an indicator of whether the product is defective. Off-odour is described as rancid or sour, or both. A product of the correct quality has a characteristic odour. Texture is described as dry, watery, hard, chewy, soft or melting.

### Weight check
Weight checks are performed at the process line to develop a statistical control chart (X-R chart), but the laboratory must have a sensitive weighing balance to check the weight of the product.

## USE OF LABORATORIES OUTSIDE THE PROCESSING PLANT
Bought-in services are used for various tests that are not done often and for those where specialized expertise or equipment is needed.

In development and evaluation of processes, small- and medium-sized companies might not have the expertise needed to evaluate complicated processes such as pasteurization and Low Acid Canned Food (LACF) production, and such service can be bought from external laboratories and consulting firms.

Measuring factors that require sophisticated and expensive equipment, such as measuring colouring agent content, preservatives or environmental pollutants, and that are not done often, are ideally done by external specialist laboratories.

Complicated microbiological testing that buyers are sure to ask for occasionally and which is outside routine work of the processing plants' own laboratories is best done by qualified external laboratories.

## A POSITIVE RELEASE SYSTEM WITH CERTIFICATES OF CONFORMANCE AVAILABLE

The producer can establish a positive release system, with all tests completed before the product leaves the premises, and have the results sent to the customer. That will ensure that the product will not be refused due to it being outside specifications (i.e. non-conforming product). It should be the duty of the laboratory technician to collect the results of tests for each shipment and keep the information easily accessible.

## CORRECTIVE PROCESSES

The lab technician has the duty of working out corrective processes that have to be established for non-conforming products, and that should be a part of the HACCP plan.

# 8. End-product specifications

Specifications are of two kinds: those set by governmental authorities and those stated in contracts between buyers and producers (sellers).

## OFFICIAL SPECIFICATIONS

Governments – individually, or in concert as regional bodies, such as the European Union – set rules concerning food production and distribution. Those rules state what ingredients are allowed and in what quantity, how to store and transport the food, and how to label the product. In each and every case, the producer must know the rules and comply with them.

The label on the product should contain the following information:

- brand name
- name and number of the manufacturer, packer or seller on the market
- generic name
- list of ingredients in descending order by quantity
- net quantity
- information about shelf life before and after opening, storage conditions and conditions of use
- place of origin or provenance
- consumer advice, and how to use the product (optional)
- lot marking (L-code);
- nutritional facts (optional), and
- a bar code.

The small area usually available on a label makes this a difficult task. If jars are placed in boxes, an L-code and plant identification must be on the jar itself.

Official microbiological demands are that the food be wholesome, without pathogens and any potential microbiological growth should be unable to spoil the food during shelf life. Standards differ from one country to another, even in Europe, and should be checked in each case.

### Storage requirements in the United States of America market

Lumpfish caviar sold in the United States of America does not need refrigeration as it has high salt content and pH is below 5.2 (Benson *et al*., 1988) to hinder growth of the botulism bacterium. Use of preservatives and colours are limited. FDA demands a Low Acid Canned Food (LACF) certificate, for which producers need to complete a registration form supplied by FDA. A sample of the form can be found on the FDA Web site (see www.cfsan.fda.gov/~acrobat/frm2541a.pdf). For further information and reference, see also: www.cfsan.fda.gov/~comm/lacf-toc.html.

### Storage requirements in the European market

In most European countries, lumpfish caviar is sold as a chilled product. If not, it is the manufacturer's duty to ensure that the product remains safe to eat. The use of preservatives is limited to 2 000 mg/kg of sodium benzoate (E211) and potassium sorbate (E202), separately or in combination, and the use of food colours is limited to 300 mg/kg in total. In legal terms, the market in the EU is united. A non-European company has to be entitled to export to the EU and be listed there. The EU's Web site (forum.europa.eu.int/irc/sanco/vets/info/data/listes/ffp.html) provides a list of non-EU producers of fish and fishery products.

## BUYER SPECIFICATIONS

Buyer specifications usually concern the water content, the taste and the appearance of the product.

### Texture and water content

The texture of the product depends on the water content and can be described as dry, watery, hard, chewy, soft or melting. A product of good quality has a texture that feels neither dry nor watery. If the product is not drained sufficiently during processing, it will have a watery texture. A dry product is overdrained, and the result is punctured eggs and a chewy texture, especially if the product has low pH.

There is constant dispute between sellers and buyers concerning moisture content of the product. The salting and dewatering processes give the producer the possibility to produce caviar of varying moisture content and to add profit by an extra percentile of water. The buyer in contrast is trying to get a dry product and does not wish to buy water at high prices. Lumpfish caviar is not a standardized product and has therefore no agreed "correct" moisture content. It can vary from 70 percent to 85 percent. The natural water content of roes in newly caught fish was measured during the 1972 fishing season and found to be between 79 percent and 81 percent, increasing over the four-month season (Gudmundsson and Bjarnason, 1973), and it is quite common for lumpfish caviar to have a moisture content in that range.

Consumers usually prefer a rather dry product. If a product is too wet it can be an indicator of adulteration by the producer trying to increase the profit margin by adding extra water. A wet product will leak water when used as decoration and colour the food that surrounds it, rendering it unappetising. A very dry product will become chewy because water will evaporate in the interval between preparation and consumption.

### Taste and odour

Because lumpfish caviar is spiced in many ways and the salt content and acidity vary, the taste is difficult to describe, but salty, acid, bitter, spicy and characteristic of the product are typical terms used when the product is assessed by sensory evaluation. When pH is reduced to below pH 5, an acid taste is noticed. Old and oxidized eggs make a rancid or sour tasting product of bad quality. Lumpfish caviar has a weak odour and it is characteristic of the spices used. If sparsely spiced, a product of good quality has an odour described as sea-like. Rancid odour can be noticed in lumpfish caviar of bad quality made from old eggs.

### Visual quality and colour

Lumpfish caviar of good quality looks bright and shiny. The surfaces of the eggs are transparent and evenly coloured. In an over-pasteurized product, the surface of the eggs is opaque as a result of cooking. Oil or glycerine is used to protect the surface from dehydration and to make it shine.

### Buyer specifications

*Inter alia*, buyers specify:

- Product colour. There are certain possibilities for differences in product colour by using different blends and quantities of colouring agents.
- Taste. This is a reflection of the kinds and quantities of spice used and their intensity. An acid taste comes from the use of organic acids to lower the pH.
- Salt content. This must be within an acceptable range for the consumer tastes typical of the market involved.
- Moisture content. The limits for this are a matter for agreement between buyer and seller.
- Shelf life. For lumpfish caviar, this is usually between 12 and 24 months.

# 9. Official rules and regulations on safety

Every country has some legislation governing food safety that must be respected by food producers, brokers and importers. Disobeying the rules will lead to loss of market share and in extreme cases exclusion from the market and the imposition of penalties.

## FOOD SAFETY REGULATIONS

Before the production of lumpfish caviar starts, information should be obtained on rules and regulations concerning food safety, usually obtainable from the regulatory authorities in the marketing country. There are different safety regulations in different markets and a producer who wants to enter a market has to know how to proceed for each and every one of them. The regulations change from time to time and therefore the producer has to be sure of always having the latest information. There are rules about labelling, packaging material, environmental concerns, ingredients, shelf life and weight. To get the information needed it is possible to contact the authorities direct by writing or by personal contact, and asking business partners, i.e. buyers, for assistance. Another option is to use the Internet or to buy help from private-sector organizations.

The main markets for lumpfish caviar are Europe and the United States of America. A short introduction to their rules and regulations is therefore appropriate.

### Food safety in the United States of America

Imports to the United States of America are under the surveillance of the FDA. The FDA requires Thermal Process Filing (TPF) and Good Manufacturing Practices (GMP) for Low Acid Canned Foods (LACF) from a producer who wants to establish registration and become a certified importer. Producers should contact FDA for further information. Lumpfish caviar is a LACF item in the United States of America.

### Food safety in the European Union

To import seafood to the EU, a producer must be registered to do so by an official body in their own country and have a certification number.  The manufacturer must have an active HACCP plan verified by a governmentally accredited inspection body.

A European Food Safety Authority (EFSA) is currently being established. The primary responsibility of the Authority will be to provide independent scientific advice on all matters with a direct or indirect impact on food safety. EFSA's homepage is www.efsa.eu.int.

### Food safety in other markets

Rules for each market have to be sought on a case-by-case basis.

## LABELLING AND PRESENTATION

Labelling and presentation of products for consumer markets can become a cumbersome issue and governmental authorities in the importing country should always be contacted in the preparation phase, either direct or through the buyer. Otherwise the consignments may be delayed at the border and possibly returned to the place of origin. There are many details to observe concerning the labelling, such as nutritional facts, list of ingredients, weight and volume, storage condition and shelf live, so care is needed.

# 10. Future trends and possibilities for the lumpfish industry

The question has arisen as to whether the lumpfish stock is being overfished during the spawning season. The situation seems to vary among the main fishing countries. Lumpfish has been, and still is, considered as an underutilized species by Icelandic marine biologists and the catch is not restricted (Hafrannsoknastofnun, 2004)). In Norway, in contrast, the catch is restricted based on complicated rules that are issued annually after calculations are made based on the catch of the previous year (Albert, 2001). Canada uses what is termed a "controlled effort" to restrict the catch, and Greenland has not yet restricted the catch. Fishing for lumpfish in Greenland is a fast-growing industry and the potential and resilience of the lumpfish resource is not known.

The future of the lumpfish industry will depend on fisheries of the wild stock. If the stocks diminish there will not be enough supply of salted eggs. The world production of salted barrels peaked in 1998, and has since diminished. In general, the stocks seem to be in equilibrium and the industry should not face any shortage in the immediate future even if there has been a contracting trend over the last ten years. Some quantity of lumpfish is caught in Russia, but no salted lumpfish eggs are produced, and there could be some potential for salted egg production.

Two methods have been discussed to increase the production of salted lumpfish eggs. One is to use a non-lethal extraction method for obtaining the lumpfish eggs, and experiments have been conducted in Canada at the Fish Harvesters' Resource Centre in St. John's. According to Dr Grant, who conducted the research, there are many biological obstacles to overcome before it can be carried out economically (pers. comm.). The other method is to use marine culture to ensure the future supply for the lumpfish caviar industry and some experiments have been carried out in Scotland, planning to produce eggs from lumpfish by raising the female and using the meat from the male for human consumption. Lumpfish marine culture in Scotland has been described optimistically by Holmyard (1997). Some experiments were also done successfully in Canada where the aim was to enhance wild stocks by producing juvenile lumpfish in land-based tanks at The Ocean Science Centre and The Wesleyville Hatchery (Department of Fisheries and Aquaculture, no date).

Some studies have been carried out to find if there is a possibility to produce lumpfish caviar with lower salt content, or even without preservatives and unpasteurized. Market demands are increasingly for fresher products with less salt and a minimum of preservatives. A one-step process in lumpfish caviar making is described as promising by Magnusson *et al.* (1984), with the caviar produced directly from fresh eggs with no salting and curing stage. Some experiments using frozen storage before the final processing were done by Jonsdottir, Thorarinsson and Jonsson (1997). A product called "lightly salted" from heavily salted eggs is described in great detail by Basby (1997). Even though some of those trials have been described as promising, lumpfish caviar is still mostly produced in the classical manner.

There are some actual and potential obstacles to lumpfish fisheries. Bycatch can be a problem when gillnets are used for fishing lumpfish as many different species can be possible bycatch, including seabirds, seals, crabs and seaweed. Little is known of the quantity of the bycatch or what species are involved because it is not reported. This lack of knowledge could become a threat in the future. A typical bit of information about this matter can look like this one from a Norwegian report in 2002:

> *"Lumpfish are caught almost exclusively by gillnets. This fishery is most widespread off the coast of northern Norway. Relatively small quantities of this species are taken, with a total catch in 2000 of 2374 tonnes. Nets are set in shallow water, often within the seaweed zone, and by-catch of other fishes are not reported. King crabs are, however, taken as by-catch in the northeastern parts of Norway."*
>
> **(Husel** *et al.*, **2002)**

Another possible obstacle is the custom of throwing the carcasses overboard after the roes have been removed, as there is very limited use for the carcasses. There is only a very small market for dried and salted female lumpfish in Iceland and that is the only active market identified. The meat of the fish is of low quality, very loose in consistency and with high moisture content during the spawning season. Hence most of the carcasses are thrown overboard after the roe removal.

The roes are around one-third of the fish's weight when the fish is gutted, but some of it is liquid, which is drained during screening. The eggs ready for salting represent about 22 percent of the fish (Martinsdottir, 1980). The chemical composition of the carcasses was analysed by Gudmundsson and Bjarnason (1973) with the results shown in Table 12.

The meat is only about one-fifth of the fish's weight and it is high in moisture and fat, but low in protein and thus has little nutritional value. The taste of the fish fresh is acceptable, but marketing trials in Iceland have not been successful. However, a dried product is considered a delicacy by a part of the population in Iceland, mainly the elderly, who learnt to appreciate it when they were young.

The head and the skin is not suited for reduction to fishmeal, as the high salt content and low protein level produce meals with poor nutritional quality. When the amino acid composition of the protein fraction, which is high in collagen, is taken into account, the result is very unfavourable (Gudmundsson and Bjarnason, 1973). Some research has been done on gelatine extraction from the lumpfish skin (Martinsdottir, 1978). Gelatine from aquatic sources is not as good as animal gelatin. It is, however, seeing more demand as a reaction to the bovine spongiform encephalopathy (BSE) situation (Sea Fish Industry Authority, 2001). Other possibilities of using the carcasses as a raw material for fine chemicals such as fish serum for use in the pharmaceutical industry and antifreeze protein have been considered. A company in Canada is said to be experimenting in this field (see www.nlbusiness.ca/directories/biotechnology.pdf).

Parasites in the lumpfish can hinder the use of the meat for human consumption (Hauksson, 1997), but it is possible to use the carcasses as bar whelks, as reported by the Marine Institute of Memorial University of Newfoundland, Canada (2001). Using the carcass as bait was tried in Canada and found that it could be used for crabs but not for fish (Blackwood, 1982).

Economics also come into play inasmuch as the value of roes to the fishers is so high that the value added by selling the carcasses is negligible compared with the work involved in collecting them and bringing them unspoilt ashore.

Competition from other species on the market could be a threat to the lumpfish caviar industry, and already capelin caviar is sold in supermarkets in many European

TABLE 12
**Chemical composition of the carcasses of female lumpfish**

| | As percentage of total weight | Moisture % | Protein % | Fat % | Salt % | Ash % |
|---|---|---|---|---|---|---|
| Meat and bones | 21.8 | 85.4 | 6.3 | 7.6 | 0.5 | 0.7 |
| Head, skin, tail | 42.4 | 89.6 | 8.0 | 0.9 | 0.8 | 0.7 |
| Entrails | 6.1 | 87.8 | 8.5 | 1.8 | 0.8 | 0.8 |
| Liver | 3.3 | 68.9 | 10.9 | 19.1 | 0.4 | 1.2 |
| Average | – | 87.3 | 7.6 | 3.7 | 0.7 | 0.8 |
| Roes | 26.4 | 79.5 | 13.6 | 3.6 | 0.7 | 0.9 |

countries. Capelin caviar is made from heavily-salted capelin eggs in much the same way as lumpfish caviar. The natural colour of capelin eggs is yellow and sometimes it is sold uncoloured alongside the red and black coloured versions. Masago, a Japanese-style product spiced with soy, is often made of capelin eggs. A mixture of capelin and lumpfish eggs is found on the market, and recently a mixture of lumpfish eggs and imitation eggs made from algae entered supermarket shelves.

Caviar substitutes are produced from the eggs of many salmonoid species, such as keta salmon. Tobiko, a Japanese-style product, is made from flying-fish eggs, and a reconstituted product made from herring eggs can be found on the market. In New Zealand, eggs from orange roughy have been used to produce imitation caviar for export (Anon., 1992). Imitation caviar for vegetarians has also been seen, produced not from fish eggs but from soy meal or algae.

Trade hindrances can be of cultural or economic origin. Fish roes are consumed in all countries but some cultural barriers exist on religious grounds. Lumpfish roes can not be kosher food because the lumpfish is a fish without scales. In Islamic culture, lumpfish caviar can be eaten by most people (L. Ababouch, pers. comm.), and there could be hindrances in other cultures not as widespread as these two.

Trade treaties between nations and economic blocs decide what tariffs are paid in the import-export trade. The lumpfish industry is divided into two parts: trade with the raw material (salted lumpfish roes) and trade with lumpfish caviar (the consumer item). Trade treaty rules can be complicated and sometimes change when a new treaty is signed. It is important to have the latest information available on current and potential requirements. This is the main reason for moving processing plants from Iceland to the European mainland, because no duty is paid when Canadian raw material is imported into the EU, but if the product is produced in Iceland or Norway from the same raw material, there is 10 percent duty to be paid when entering the EU market.

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Fish roe products have historically been seen as expensive and highly-desirable luxury food items. The best and most expensive is true caviar, which uses eggs from sturgeons caught in the Caspian Sea. In recent years, eggs from many other fish species have been used to develop products imitating original caviar. By utilizing processes appropriate for each kind of fish, it is now possible to make a similar – but nevertheless imitation – product. This publication presents a comprehensive overview of the production of lumpfish caviar as a model for developing fish caviar. The source, lumpfish (*Cyclopterus lumpus*), is from the North Atlantic and can be used as a case study to develop similar products from other fish species. The document describes fishing methods, preservation and storage of the eggs as well as details on the caviar production process itself to obtain the final product, lumpfish caviar. Product safety and packaging are considered, and the rules and regulations that apply to the main markets are discussed. Production and marketing statistics demonstrate the extent of the global lumpfish caviar business. The publication draws heavily on source material from Iceland, a major producer and processor, and includes many illustrations.

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