



X-ray based automatic detection of bones in fish fillets, and bits & pieces – including Salmon pin bones



FISH BONE DETECTION REQUIRES SPECIAL X-RAY TECHNOLOGY

Seeing the invisible

During the last years, InnospeXion has developed a unique real-time X-ray imaging technology, based on using a part of the X-ray spectrum not used in other imaging applications.

Along with a very high image resolution of 0.1 mm, this innovation has unveiled a substantial improvement of the bone detection capability, compared to traditional X-ray systems used for fish bone detection.

The technology is used in fish factories for automatic detection of pin bones (e.g. Salmon), for detection of bones in trimmed fillets, and for bone detection in bits and pieces used for e.g. fish blocks.

When a bone is detected, a signal is sent from a PLC to a reject arrangement. Different settings can be applied to obtain a sorting of products into different categories of product. The accurate location of bones can be transferred to a monitor in front of an operator who may withdraw the bone at the specified location.



Alternatively, a bone location map can be transferred to e.g. a water cutting system that automatically cuts the bones from the fillets (see <u>www.valka.is</u>).



The InnospeXion fish bone detection system is based on the newest and most effective X-ray technology. The technology has been proven in numerous applications during many years, and has been further developed to satisfy the requirements of the fishing industry. This e.g. concernings hygiene, reductors, cleaning and detection performance.

robustness, cleaning and detection performance.

Tailoring towards the customer's need is an essential necessity for the integration of the technology in the different production lines.

InnospeXion supplies auxiliary equipment for in-feed, out-feed, sorting, reject arrangements, timing control and overall system integration.



Comparison to standard technology

The low X-ray energy gives a very high contrast for fish bones. At the same time, a high resolution implies that a fish bone is represented by many pixels. This highly improves the software recognition of a bone. The examples below represents fish product imaged using a standard X-ray technology, as compared with the InnospeXion technology.



Cod fillet imaged using standard X-ray technology at 40 kV, 1 mA, 0.4 mm pixel size, 20 m/min.



Bone detection software used on the above X-ray image. No bones can be identified.





Same fillet using InnospeXion low E HYMCIS technology. The image is acquired using the InnospeXion technology at 25 kV, 10 mA, 0.1 mm pixel size, 21 m/min.

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Bone detection software used on the above X-ray image. All bones are identified.





X-ray image of fish fillet with abundant bones in two rows. Acquired using InnospeXion technology at 21 m/min



X-ray image of the same fish fillet as shown above, with abundant bones, in two rows. Acquired using standard X-ray technology at 25 m/min. Note the marked lower contrast and poor definition of bones, especially for bones in the lower row.





Bones detected by automatic software in the X-ray image from the standard system shown above. Note that all bones in the lower row are undetected.



Table of Measurements

Given below is a table that gives the probability of detection relative to different scanning speeds. It also shows the percentage of bones represented in the binary image.

Bone Diameter	Bone Length	Speed of Conveyer – POD – % Bone in Binary Image		
0,11-0,14	7-12 mm	3 m/min	▶ 70%	▶ 60%
		9 m/min	≻ 60%	> 55%
		15 m/min	≻ 50%	≻ 50%
		26 m/min	▶ 30%	> 30%
0,15-0,16	14-16 mm	3 m/min	▶ 80%	▶ 70%
		9 m/min	➢ 70%	▶ 65%
		15 m/min	▶ 60%	▶ 60%
		26 m/min	▶ 40%	▶ 40%
0,17-0,19	17-18 mm	3 m/min	> 99%	> 85%
		9 m/min	▶ 85%	≻ 80%
		15 m/min	≻ 80%	▶ 75%
		26 m/min	▶ 70%	≻ 65%
► 0,20 mm	≻ 21 mm	3 m/min	> 99%	▶ 99%
		9 m/min	▶ 99%	▶ 95%
		15 m/min	≻ 96%	▶ 90%
		26 m/min	▶ 95%	▶ 85%

Table 1: POD of bone dimensions in salmon fillets



The sequence below shows the binary bone image of the same fillet, scanned at different conveyor speed.



3 m/min



9 m/min



18 m/min



26-27m/min





Pink Salmon Fillet in InnospeXion Low Energy X-Ray Machine





Pictures showing the dimensions of the bones.

Bones found in the pink salmon





Bits & Pieces

Bones larger than approximately 0.4 mm and longer than about 10 mm, are generally tolerated only to a certain low content in fish blocks. The cost effective solution is the detection of the bones before they are formed to blocks, and automatic reject of bits containing bones, in as small batches as possible.



X-ray system for off-line and automatic detection of bones in bits & pieces. Here the sorting is possible in three pre-defined classes.





Typical X-ray image of bits and pieces – showing tiny 0.2-0.3 mm 8 mm long bone . The sorting can be set up towards different bone dimension categories.

Pin bone detection



InnospeXion X-ray technology image of a 60 cm long Salmon.

The pin bone detection is very important, not least in the Salmon case, where the ability to remove the bones in the pre-rigor condition (i.e., shortly after slaughtering) may represent a large value since the fillet can be sold e.g. for Sushi, etc.



The challenge is, that bone removal in the pre-rigor condition is very difficult due to attachment of the bones. Therefore, there is an important need of determining if some bones were not (completely) removed in the process.

The Norwegian organization Nofima conducted by the end of 2011, a consumers study on the consumers sensitivity towards the dimension of bones in Salmon and Cod (Nofima report 7/2012, FHF-prosjekt #900340). The result is as shown below for Cod and Salmon.



The results of the Nofima investigation of 2011. Red marks denotes bones that were perceived as "unpleasant" by the consumer. The green line is for Cod, red for Salmon, and these lines limits the bone diameter and length relative to whether they are perceived or not. Xaxis show the bone diameter, Y axis the bone length. Note that 0.3 to 0.4 mm is the lower limit of detection required for the Salmon industry



InnospeXion has collaborated with SINTEF and Norwegian Salmon producers, and a system is residing in Norway, used for the pin bone detection.



Avbildning av laksefilet med pinnebein

Avbildning av post-rigor laksefilet med pinnebein



SINTEF SINTEF Sikeri og havbruk AS

The images are taken from a SINTEF presentation used to explain the need for the X-ray technology for an internal forum. As can be seen the InnospeXion X-ray technology detects consistently all pin bones – here



27 of 27, with the smallest measuring 0.34 mm in diameter and a length of 22 mm.



Detail X-ray image of Salmon fillet clearly showing the pin bones. Acquired using InnospeXion X-ray system.

Safety, Cleaning and Hygiene

The InnospeXion X-ray systems for fish products are manufactured to sustain the harsh environment and the cleaning needs in the fishing industry. All materials that may get in contact to food products are certified food grade, and/or FDA approved.

Cleaning operations in the system interior do not allow the use of acids or bases.

X-ray safety is well integrated into the system, and the system is as safe as any other machine in the fishing industry. InnospeXion has a long record of providing X-ray systems world-wide. Individual and/or specific requests are considered and integrated wqhere needed or practical.





The system has internal steel curtains for ensuring that scattered radiation does not leak. The steel curtains are accessible after opening the front hatch using a special tool. The curtains are retracted and can be washed as required. The curtains are interlocked so the system cannot be started unless the curtains are in their locked position. The conveyor is easily removed for cleaning.





The fish bone detection system provides full access to the system interior for cleaning and maintenance. The system is protected up to IP65.



The X-ray system is controlled by a PLC, and the extremely sensitive X-ray detector has a resolution of 0.1 mm, at up to 300 frames per second.

This enables running speed up to 30 m/min.

The system is simple, robust, compact ,and easy to service. It features a hygienic design, has a long lifetime, and is fully automatic.

We are take pride in integrating the Fish Bone Detection System into existing production lines, along with required automation and auxiliary equipment.

> Jørgen Rheinländer Managing Director InnospeXion ApS



InnospeXion

InnospeXion is a dynamic Danish company, specialised in the development and manufacturing of X-ray based inspection systems. We apply the newest X-ray technology to enable the implementation of the most adequate and cost effective solution for a specific inspection and measurement task.



What makes our systems special, is the low-energy X-ray technology that enables detection of very small objects and defects, which are not visible using conventional X-ray technology.

InnospeXion uses the knowledge on X-ray interaction with matter to develop innovative techniques for inspection and characterisation, by X-ray imaging or by measurement of the spectrum of transmitted or scattered X-radiation. We apply these principles for numerous industrial systems, e.g. manufacturing control, core analysis for petroleum research, can quality control, on-line conveyor inspection of food, castings and many others. We develop and manufacture special controllers, complete tailored shielding solutions, software and perform installation as well as continuous monitoring services.



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