SPECIAL X-RAY TECHNOLOGY SAFE-GUARDS **FISH BONE DETECTION**

Results on on-line X-ray based automatic detection of bones in fish fillets, and bits & pieces

This article describes the use of a novel X-ray technology for fish bone detection. The technology uses X-rays of a lower energy, causing fish bones to have a markedly higher contrast compared to the fish fillet. It has thus proven to be superior to any other technology for automatic fish bone detection with automatic reject. The method is suitable for fillets, bits and pieces, and packaged fish.

The technology has been used in the fishing industry for years, but it is only during the latest year that dedicated studies have been conducted at fish processing plants, documenting the cost-benefit in the wet fish processing industry.

X InnospeXion

the invisible made visible

A TECHNOLOGY TO **SEE 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, this innovation has unveiled a substantial improvement of the fish bone detection capability, compared to traditional X-ray systems used for fish bone detection, as well as to other techniques for bone detection in the fish processing industry. Thus, the Micro Fish Bone Detection System of InnospeXion enables the detection of fish bones down to *0.1 mm in diameter.*

The technology is used in fish factories for automatic detection of pin bones (e.g. salmon), for detection of bones in trimmed fillets (Cod, Haddock, Red fish, Tilapia, etc.), and for bone detection in bits and pieces used e.g. for 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 products. This may be based on a classification of bones into sorting by bone dimension. 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.

The benefit for the manufacturer is an automatic, robust, reliable and hygienically designed system that can safeguard bonefree fish products, hence enabling a higher price per kilo and a highly reduced risk of having a shipment returned due to a too high bone content. The novel technology therefore has a very short time of the return on investment.

The InnospeXion fish bone detection system is based on the newest and most effective X-ray technology. The technology has been developed to satisfy the requirements of the fishing industry, notably concerning hygiene, robustness, cleaning and detection performance. Most of all, the detection performance is unique, and leads to a very short return on investment period

WHICH BONES ARE CRITICAL TO DETECT?

The high sensitivity of the X-ray systems makes it possible to detect all bones in the fish product, down to 0.1 mm. However, the challenge is not to detect bones that are too small for a human to perceive the bone as such. A study conducted in Norway [(Nofima report 7/2012, FHF-prosjekt #900340), www.nofima.no/filearchive/Rapport%2007-2012.pdf.], documents the size of bones that the consumer is likely to detect upon eating the product. As a general rule, bones of a thickness lower than 0.3 mm are not likely to be detected by the consumer. This implies, that the X-ray system must be adjusted to reject bones in different size categories, from "unpleasant" bones to actual critical bones.

The observation however, is that most producers wish to detect all bones possible. The problem is, that the system sensitivity leads to very high reject rates. However, if proper sorting is made, the usage of the micro fish bone detection system may be extremely valuable to evaluate the work of the trimming line personnel, on an individual basis (e.g. for training towards optimum performance).
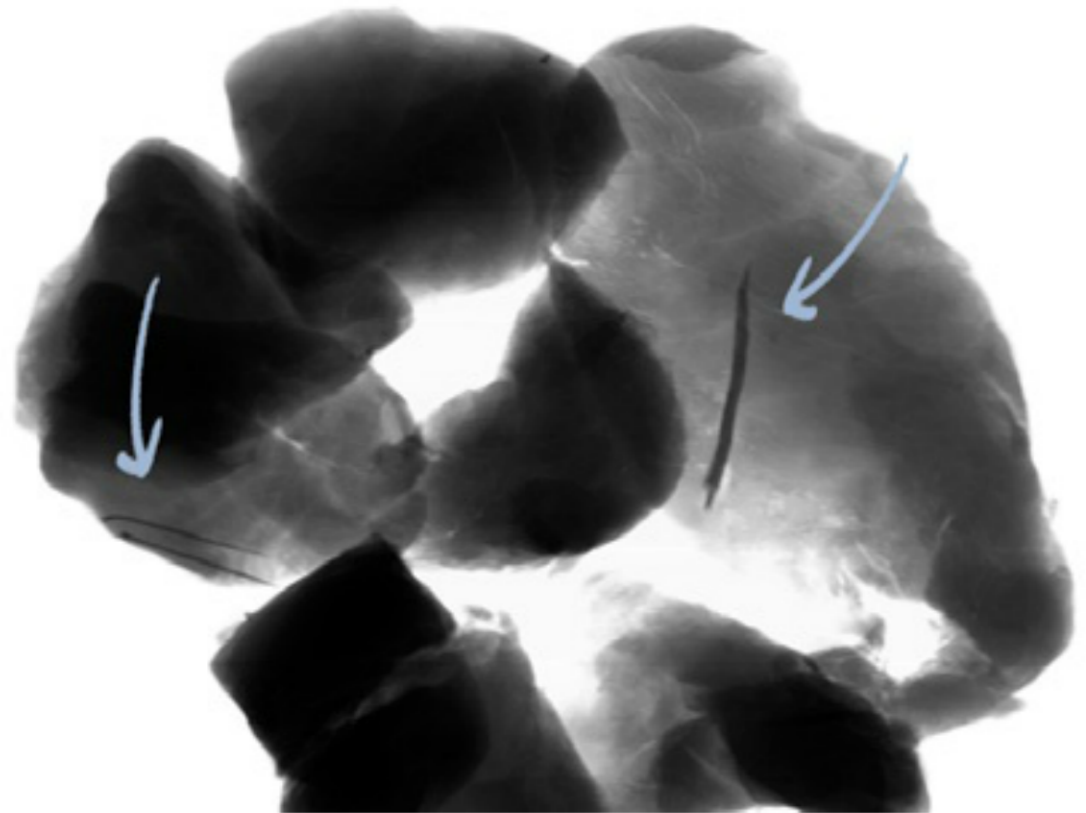
A portion of bits and pieces of Cod at Espersen Polska. The bones (arrowed) are detected by the InnospeXion X-ray system, and correctly rejected. The small bones at the left are just acceptable (i.e., may not be detected by the consumer), whereas the one at the center right is a critical bone.

THE EXPERIENCE FROM ONLINE APPLICATIONS

The implementation of a system that is based on advanced technology into the wet processing conditions for fish is not trivial. Indeed, very strong cleaning agents and high pressure water cleaning denote severe requirements for the materials used. Sticky and slippery surfaces also need to be considered, especially for timing control for rejecting.

At Espersen in Poland, the X-ray technology has been in use for three years. Today, the conclusion is that the X-ray technology has provided a significant improvement, compared to traditional human inspection.

Thus, the X-ray systems have proven to be reliable for repeatedly providing the same result on inspection. This safeguards the production to be marked as bone-free and eliminates costs, hygiene issues and risks associated with human intervention.

The high standards of Espersen Polska and the provision of fish products towards large and important retailers, conforms to the need of having all products X-ray inspected online.

Overview of an application similar to Espersen, but involving different production line set-up. Here, the X-ray system is used for control of the quality of the work performed on the filleting line, as part of a task of improving the overall quality and significantly reducing the bone content by an iterative learning procedure based on the X-ray system bone detection

At Espersen in Poland, the X-ray technology was initially evaluated based on off-line usage. Experience shows that the technology is much more reliable and robust than human inspection. Today, all relevant products are inspected using X-ray systems, in an in-line arrangement.

Generally, the X-ray inspection is not seen as a cost, but as a means of **(a)** improving overall production quality by dedicated training of personnel based on X-ray inspection of the production, and **(b)** significantly reducing the likelihood of bone content in the production, thereby minimizing costs on complaints handling, temporary storage, waste, and returns. Additionally, the technology may safeguard the production relative to foreign objects, such as metals, glass, stones, shell fragments, etc.

However, the introduction of advanced technology has required investments, specifically on qualifying personnel, but also for trials, technology integration and modifications of cleaning and maintenance procedures. Compared to the system investment, running costs have been relatively low, and it has proven that well trained operators may undertake the large part of maintenance and service tasks.

Probability of detection of bones down to < 0.3 mm is considered to be better than 98%, with a false reject of less than 2-3%. Compared to other means of inspection, the low energy X-ray technology is the only option for securing a reliable and robust bone detection in both fillets, bits&pieces, and blocks. The technology works equally well on frozen as on fresh products.

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 images acquired using a standard X-ray technology, as compared to the InnospeXion technology.

The low energy technology however also requires that the system design is oriented towards the fish processing environmental conditions. Hygienic issues are particularly important, and the use of various specific developments have proven needed for the technology to work reliably. Water tightness, resistance to cleaning chemicals, fast and easy cleaning procedures, stainless steel of sufficient anti-corrosion grade, are, among with hygienic design, very important criteria for the robustness in use.
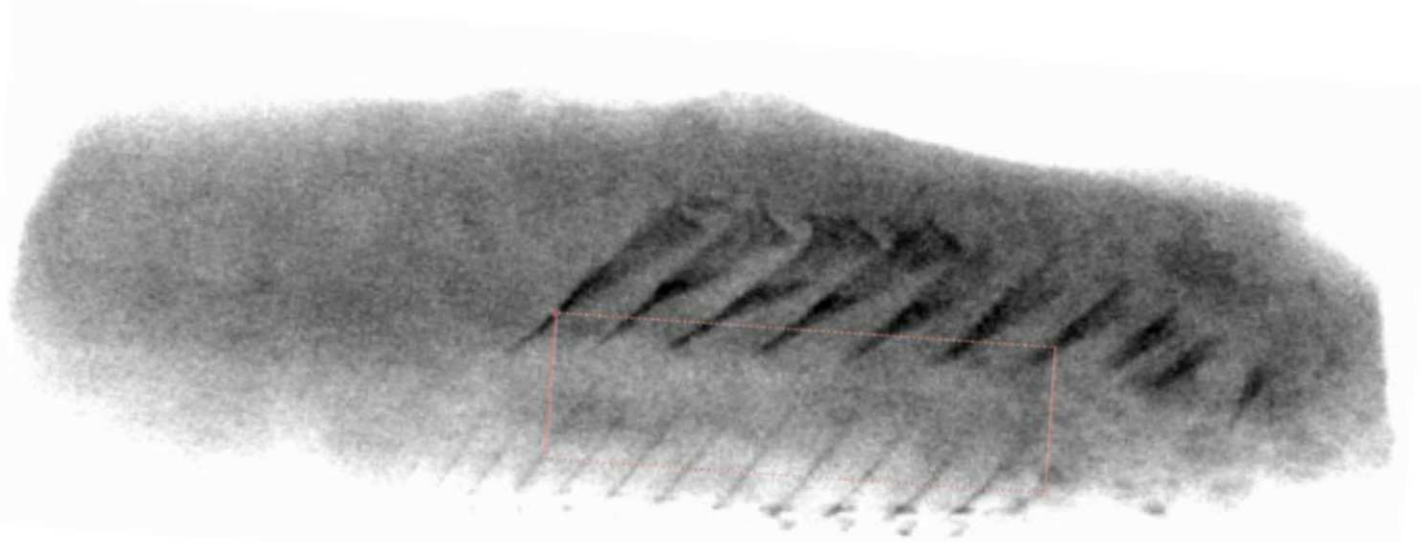
Cod fillet imaged using standard X-ray technology
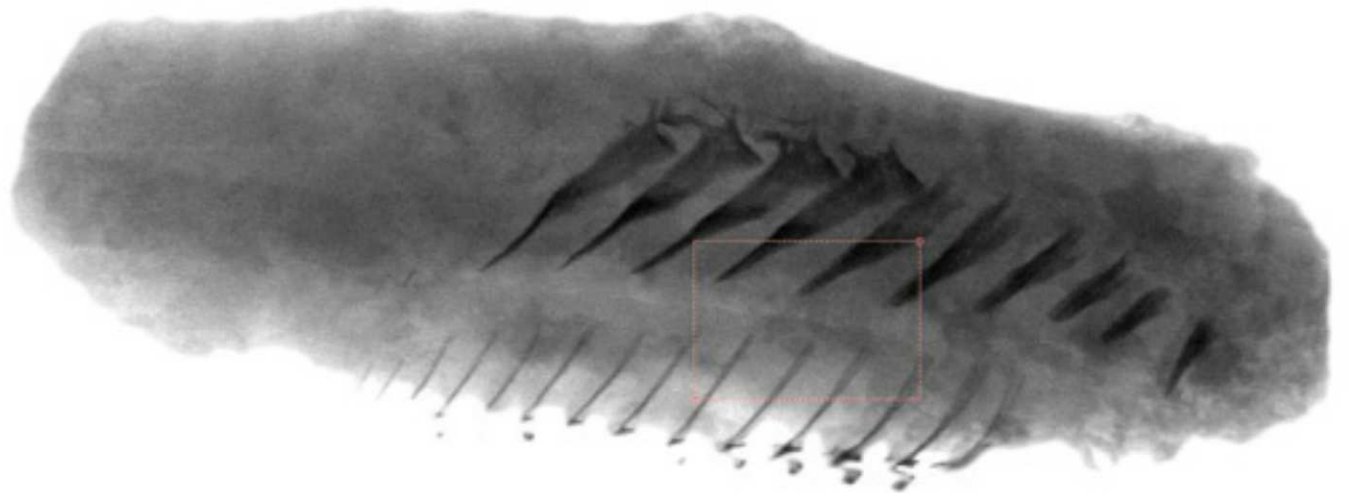
Same fillet using InnospeXion low energy HYMCIS technology

Salmon fillet passing through retractable steel flap curtains inside the X-ray system

CONCLUSIONS

The low energy X-ray technology systems differ significantly from other X-ray systems by using longer wavelength X-rays which are preferentially attenuated by small thickness/density or compositional differences.

Traditional X-ray systems generally are unable to image objects below 25 kV, owing to the poor sensitivity of the detector used to acquire the images. Using low energy X-rays, thickness differences down to a few micrometers can be discerned and quantified. The high contrast makes the technology extremely suitable for detecting fish bones, and together with a high image resolution, it secures a vast improvement in detection where fish bones are represented by many pixels. The extremely sensitive X-ray detector enables detection of fish bones down to 0.1 mm at up to 300 frames per second.

The systems are intended for 24/7 operation and are fully automatic, robust, reliable and hygienically designed safeguarding bonefree fish products, hence enabling a higher price per kilo and highly reduced risk of having a shipment returned due to a too high bone content.

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

Finally, the Fish Bone Detection System system is integrated into existing production lines, along with required automation and auxiliary equipment. X-ray safety is also well integrated into the system, and it is as safe as any other machine in the fishing industry.

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