XSpectra®: the most advanced real time food contaminants detector

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***Abstract*—With the aim to contribute to the persistent effort to enhance quality controls carried out by the food community, Xnext® has developed an innovative technology (XSpectra®) for X-ray real time inspection. The application exploits a semiconductor detector (Cadmium Telluride) and a licensed electronic readout system which has been designed to handle big flux of data. Differently from conventional machines, such application allows to discriminate multi spectral energies, so that it can gather more informations suitable to distinguish different materials. As a matter of fact, X-ray spectra strongly depend on the mediums the radiation crosses along its path, due to the radiation-matter interaction. By means of advanced imaging techniques and deep learning models, the system is able to identify organic and low density contaminants which are currently not detected.**

The great potentiality of such technology is also related to its wide flexibility. Indeed, it can operate in several quality industrial inspection such as ripeness status of the fruit or for instance the homogeneity of the bread loaf.

I. Introduction

Any contamination of food with foreign objects or substances represents a serious threat to any company. In case a product is not compliant with quality, legal and safety standards force the company to recall the product, with serious consequences on reputation. These recalls have different causes which can be generated either at the incoming of raw materials or during the production process.

Outer foreign bodies such as glass, plastic and other materials are frequently found despite the controls effected during procurement of raw materials and during production. The problem is global and so serious that the EU has implemented a specific portal - RASFF (Rapid Alert System for Food and Feed) - whose purpose is to offer the opportunity, as earliest as possible, to report to the local authorities of the European countries involved when an alimentary risk for the public health is detected. In 2015 over 3.000 risks have been reported in Europe, of which more than 800 were real alarms that caused the withdrawal of the involved products.

Starting from 1948, the first industrial metal detector has been registered as a patent. Since then, food community felt the need to carry out increasingly precise inspections to detect foreign bodies within industrial food products.

In the early 1990s, single-energy X-ray detectors based on scintillators turned as a pivotal technology in such field, since it allowed to identify more high density matters besides metals, such as glass and stones even within steel packages.

In order to follow more information from the incoming radiation, dual energy approach has been developed. Such method is accomplished by matching information gathered from two detectors with different mechanical filters, thus sensitive to different ranges of energy.

With the aim to exploit as much as possible the information coming from the radiation, Xnext® developed an innovative real time technology (XSpectra®), based on a pixelated semiconductor detector capable to detect and classify photons with different energies.

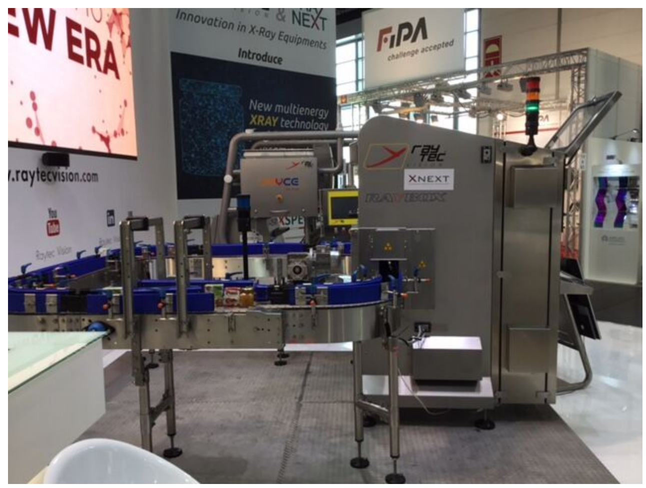

Fig. 1. Picture of Raybox™, a X-ray Raytec® Vision machine where XSpectra® has been embedded, validated and presented at Interpack 2017 in Dusseldorf, Germany

II. Material & Methods

A. Inspection arrangement

1) Set-up: X-ray food safety control machines are commonly placed in a specific spot on the production line so that they are able to eject not compliant products. Each item travels on a conveyor belt through an X-ray machine which analyzes the product by means of a transmission measure: a polychromatic radiation is generated by the X-ray tube and runs over the product before being collected by the detector situated in the detection unit, as depicted in Figure 2.

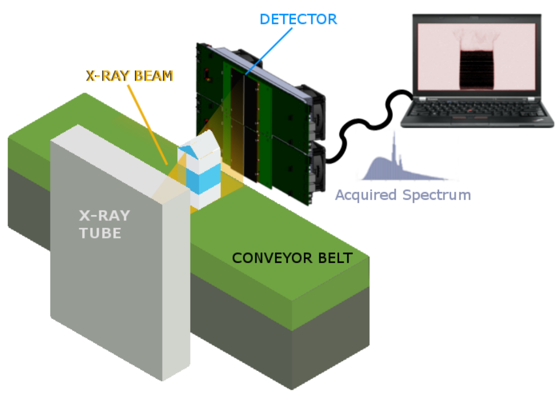

Fig. 2. Scheme representing the set-up arrangement in an industrial line.

2) Conventional vs XSpectra®: whereas a conventional X-ray machine employees scintillators, XSpectra® exploits a detector based on semiconductor material (Cadmium Telluride, CdTe). Indeed, scintillators provide merely an indirect evaluation of the incident x-ray photons number, independently from their energy, while XSpectra® is capable to distinguish multi spectral energies. As consequence, XSpectra® is able to discern the full energy components of the incident radiation.

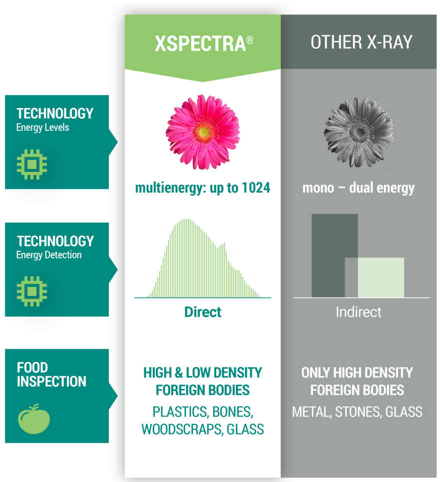

Fig. 3. Schematic comparison between XSpectra® advantages and the convetional machine currently on the market.

B. XSpectra® system

1) Sensor Module: As shown in Figure 4, due to the interplay between the particle and the crystal, when a photon characterized by a certain energy hits one of the detectors pixels induces an amount of charge proportional to its energy. The charge pulse is then processed by an Application Specific Integrated Circuit (ASIC) converting them into voltage pulses and keeping the proportionality. The voltage pulse is then shaped in order to improve signal noise ratio (SNR).

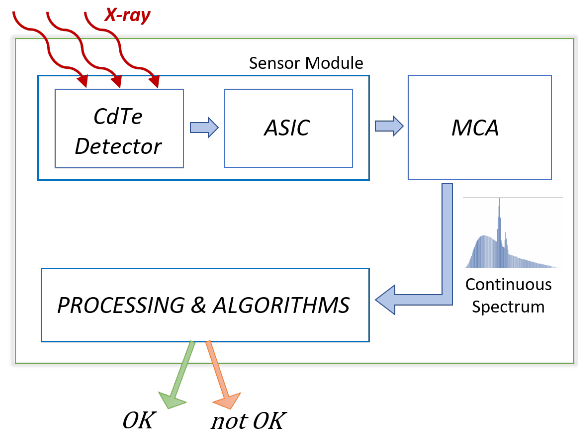

Fig. 4. Block diagram representing XSpectra® electronic chain

2) MCA: the shaped pulse is then analyzed by a Multi Channel Analyzer (MCA), which discretizes the voltage pulse through a 14 bit Analog to Digital Converter (ADC) and sorts it to the corrispective energy bin according to its amplitude by means of a Field Programmable Gate Array (FPGA). Multi-energy events combined by FPGA compose a spectrum, namely the collection of all energy components in transmission (shown in Figure 5). The time taken to build such spectrum is called integration time.
The set of signals so processed depends on the crossed voxel (representative of the volume unit, including the materials on which radiation comes through). The acquisition procedure is applied for all the pixels so that it is possible to characterize the whole object height. In order to acquire a moving object, the integration time is calculated as the travel duration needed for the object to cover the pixel pitch (0.75mm).
The juxtaposition of consecutive acquisitions returns both the image related to the moving object and the data flux to be elaborated.

3) Processing & algorithm: Once the calculator receives raw data from MCA, it is necessary to homogenize all the pixels response. For that reason, a calibration procedure as function of electronics and room temperature has been built up. The calibrated data are then analyzed through advanced imaging techniques and deep learning models so that the machine is able to determine whether the product is compliant or not. A dynamical dual energy algorithm is currently running on the machine, representing already a good enhancement in comparison to the standard one. Moreover, multispectral procedures are being developed achieving considerable improvements in the foreign bodies detection which let us appreciate the huge potential of this technology.

The multispectral images give different informations as function of the energy stripe analyzed, as shown in Figure 5. In fact, the spectrum changes its trend depending on the medium nature: due to the interaction between radiation and matter, spectra strongly depend on the chemical composition of the voxels crossed by the incoming radiation. For example,

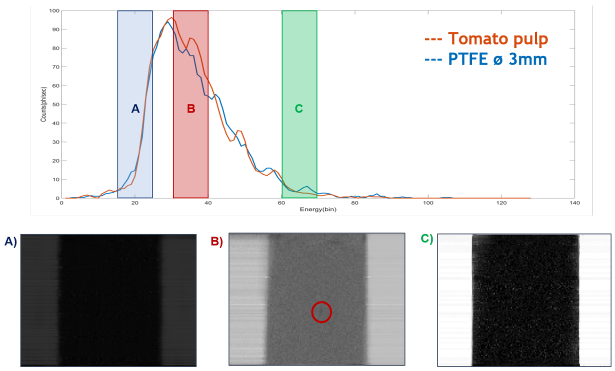

Fig. 5. Spectrum comparison between tomato pulp and PTFE 3mm of diameter in which three energy bands have been employed to obtain the brik accumulated images: A) energy bin 15-25 B) energy bin 30-40, C) energy bin 60-70.

low density matter, as polymers or organing bodies, interacts with low energy photons. On the other hand, high density matter, as metal, stone or glass, interacts with a wider range of energy photons resulting in spectrum changes at higher energies. Relying on such considerations, multispectral algorithms have more sensitivity than the indirect methods based on scintillators.

C. Results

1) Frontiers contaminants detected: as mentioned before the food community seeks a qualitative improvement in food contaminants detection. XSpectra® may grant such need.
In order to achieve this purpose, an on-going field test is taking place in collaboration with the partner Raytec® Vision SpA embedding XSpectra® in a RayBox™ machine (as shown in Figure 1). The goal of such test is to confirm in a real industrial environment what the laboratory results highlight.
As depicted in Figure 6, the attempts carried out so far suggests that XSpectra® is very effective on identifying organic food contaminants. For example, several successful tests have been fulfilled on corn cob in tomato pulp Tetrapak® for minimum diameter size of 8mm.
The same ease has been shown on identifying the polymer

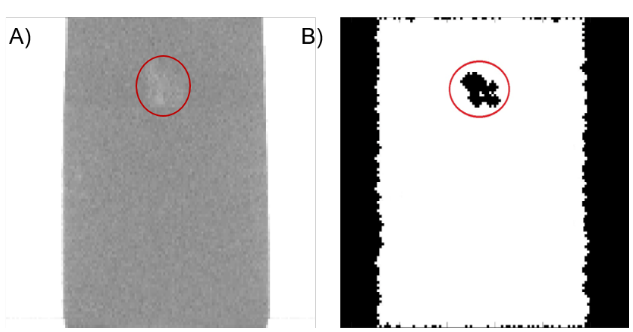

Fig. 6. Figures related to a tomato pulp brik contaminated by corn cob: A) radiographic image acquired by XSpectra®. B) Logical image as algorithm processing result showing the contaminant coordinates

Polytetrafluoroethylene (PTFE) - 3mm diameter size (Figure 5) and the synthetic rubber Viton - 2.5mm diameter size.
The future reduction of the pixel pitch will allow XSpectra® to decrease the minimum detectable size.

2) Other application fields: the great potentiality of the technology has interesting implications not only in food contaminants detection. Promising preliminary tests have been carried out for instance on kiwi fruits.
As depicted in Figure 7, XSpectra® is able to estimate the ripeness of the fruit. Such appraisal would let be aware the manufacturer of the maturation status of the product before being distributed.
Another prospective application is about the bread loaf.

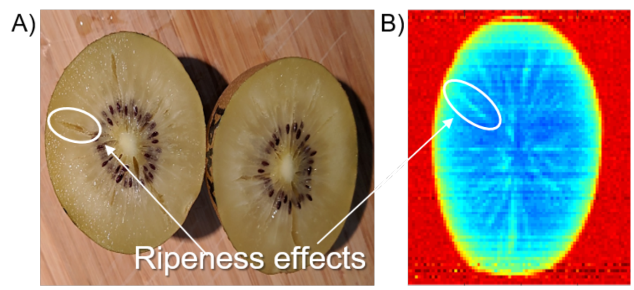

Fig. 7. Comparison between: A) Real image of kiwi fruit B) related radiographic image showing ripeness effects

During the leavening, the irregular rise of the yeast might create air bubbles within the bread.
The same problematic is observed in the fridge manufacturing quality control. Since the fridge aluminium cap is filled with polyurethane lather, some unwished air bubbles take place within the cap due to the solidification process.
Both problematics might be worked out by XSpectra® since it may identify the position and size of such bubbles thus avoiding destructive inspection on the products.

III. Conclusion

XSpectra® exploits a multi-disciplinary approach that combines photonics, nuclear electronics, parallel calculation and Artificial Intelligence algorithms to achieve significative improvements in real time quality controls:

- sharp increase in sensitivity: XSpectra® detects foreign bodies and contaminants which cannot currently be detected as i.e., low density polymers, organic unwanted bodies.
- reduction of false positive alarms: XSpectra® eliminates only the food products from the production line that do not meet the required safety and quality standards, reducing drastically the costs of falsifying waste,
- increase of detection speed: XSpectra® is faster than the actual technologies in use, therefore improves the number of products that can be checked and delivered by the production line,
- capabilities to recognize the characteristics of the contamination: XSpectra® makes available in real time the problem to the management plant by IOT interfaces.

XSpectra® contribution to X-ray quality control in food contaminants inspection might be the crossroad for a new era, introducing a new concept of industrial food quality. A coming-up scenario where low density foreign bodies and contaminants are not anymore invisible to in-line machines inspection.
As mentioned before, XSpectra® has been embedded in the X-ray machine RayBox™ manufactured by Rayetc® Vision S.p.A.. It has been validated in a real operational plan and then officially presented at Interpack 2017 Fair.

Acknowledgment

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