Detecting bone fragments in meat products

Josh Cowling, Adam Hirst and Tamzin Lafford

IBEX Innovations Ltd., Discovery2, William Armstrong Way, NETPark, Sedgefield, TS21 3FH, U. K.

Abstract

Detecting bone fragments in meat products is just one aspect of food safety which is important to both consumers and food producers. Fresh meat products pose particular challenges: the sample shape is not regular and there is variation from one sample to the next; the thickness of the product varies; the bone fragments are probably not visible on the outside of the sample; and the bone fragments are small compared to the surrounding flesh. X-ray absorption contrast and image recognition techniques have limited application in this field – there is little or no absorption contrast, and edges and shapes cannot necessarily be clearly identified. IBEX technology, by restoring energy information to X-ray images, overcomes the limitations in order detect bone fragments in meat products through a difference in material-related signals, regardless of absorption contrast. Two case studies are presented: bone fragments in diced chicken and in a whole, large chicken breast sample.

Introduction

Food safety is important for the consumer, for both health reasons and a positive eating experience. For the producer, not only for those reasons but also since below-standard product affects production efficiency and brand image.

X-ray imaging is in routine use in food product inspection lines, but hits limitations where the absorption contrast of the foreign object compared to good product is poor or non-existent, and/or where shape or edge recognition cannot identify the contaminants.

IBEX technology overcomes these constraints by restoring energy-dependent information to X-ray images, giving contrast between the signals from different materials, regardless of the absorption contrast. In this way, foreign matter is identified by its material difference from normal product.

Raw meat products such as chicken breast pieces or diced chicken are a particular example. Sample shapes and thicknesses vary considerably over a single sample and between samples. By teaching the system the “signature” of normal chicken flesh, anomalies in material signal caused by unwanted material, such as bone fragments, can be detected.

IBEX technology

The absorption of X-rays by a material depends on the material type, its thickness, and the energy of the X-rays (Eq. 1):

$$I(E) = I_0(E)\exp(-\mu(E)t) \qquad \text{Eq. 1}$$

where $I(E)$ is the intensity incident on the detector after the sample, as a function of energy; $I_0(E)$ is the incident intensity, as function of energy, in the absence of a sample; $\mu(E)$ is the linear attenuation coefficient of the material as a function of energy, and t is the material thickness.

The X-ray imaging detectors in most widespread use are based on silicon with a scintillator screen in front. These are rapid, relatively inexpensive, reliable and available in large areas, but integrate all energies in each pixel – and therefore do not record spectral information. Without spectral information, there is no direct way to determine both material and thickness from the signals obtained. Spectroscopic detectors are available; they are generally slower than silicon detectors, more expensive and are not usually available in large areas.

IBEX overcomes the limitations of standard integrating detectors by placing a patented Multi-Absorption Plate (MAP) in front. The MAP is a 3D periodic structure which modulates the image, repeating the pattern across the area of the detector. Sophisticated software algorithms use the resultant data to recover the energy-dependent information and construct an image based on the difference in materials across the sample (materials contrast), rather than absorption contrast. Material thickness information is then also available. The results can be presented in a variety of ways, depending on the requirements of the application. A high resolution conventional absorption contrast image is delivered as part of the process.

Figure 1 schematically shows a conventional X-ray imaging system: the source delivers a spectrum of energies which are attenuated by the sample according to the material thicknesses and densities in the beam path. The resulting absorption contrast image is collected using a flat-panel detector or a line scanner. Each pixel integrates over all the energies incident on it, returning a single value of intensity.

In this example, the human eye is able to pick out the bone in the chicken drumstick quite readily by the shape of the edges of the bone, which are more absorbing than the adjacent flesh. However, absorption contrast alone is not a reliable method for automated detection, as there are grey-levels within the bone regions which are the same as in some areas of the chicken flesh.

Introduction of the IBEX MAP (Figure 2) enables energy-dependent information to be recovered, which allows a materials image to be constructed. Here, at the thickest part of the drumstick, the bone is less dense than elsewhere and the flesh is thick, so the material is classified as mostly flesh. With suitable training of the system, it is possible to generate scales showing the relative amounts of flesh and bone in a given location.

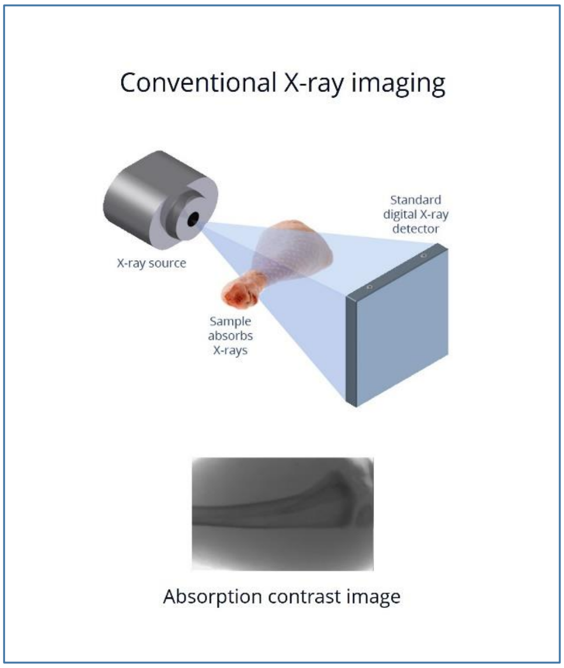

Figure 1: Traditional X-ray absorption contrast imaging. The X-ray source delivers a spectrum of energies. The X-rays are attenuated by the sample according to the materials and their thicknesses in the path of the beam.

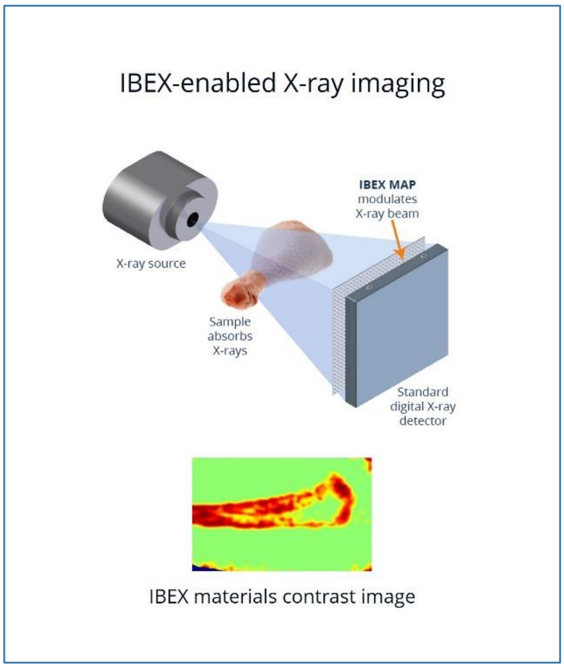

Figure 2: An IBEX MAP-enabled system. The MAP modulates the image in a predictable manner, allowing reconstruction of a materials image.

Experiment

Two studies are presented:

(1) Fresh chicken breast was diced and set in a clear plastic tray 12 cm × 12 cm (Figure 3). Small pieces of bone around 1 mm thick were hidden in the mass, which was about 3.5 cm thick at the thickest point.

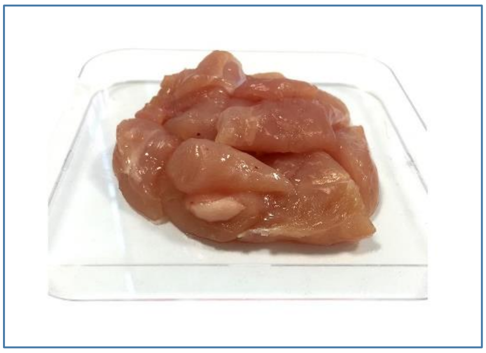

Figure 3: Diced chicken sample containing fragments of bone deliberately introduced.

(2) Two rib bones and a fan bone were inserted in a large, whole, fresh chicken breast at positions where they might appear in a production line. Fan bones have low levels of calcification and are therefore normally more difficult to detect than other bones.

Images were collected using a commercially-available micro-focus tungsten X-ray tube running at 90 kV, 3.9 W. The detector was a Dexela 1512 CL CMOS flat-panel detector (74.8 µm pixel size) fitted with an IBEX MAP. Total image acquisition time in these particular tests was 12.8 s for each of the sample, brightfield and darkfield images. An image was also collected of a wedge-shape of chicken flesh. This was used to train the analysis system to recognise the material signature of chicken tissue.

The sample images were then analysed to provide an image showing *materials* contrast, irrespective of the absorption contrast.

Results and Discussion

The absorption contrast image of the diced chicken sample is shown in Figure 4. The positions of the bone fragments cannot be reliably determined from this image, either by changes in absorption or by shape or edge recognition. Grey-levels in regions of thick flesh are similar to those in areas of flesh containing bone fragments. In addition, there are areas with abrupt changes in contrast, indicating edges, which are not necessarily related to bone; and some bone fragments may have tapered thickness, leading to less clear definition of the edge.

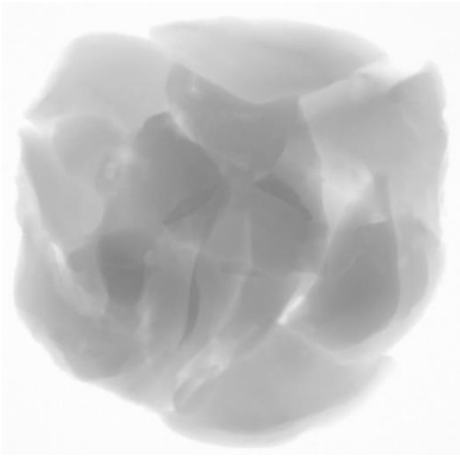

Figure 4: Absorption contrast image of the diced chicken sample, with the effect of the IBEX MAP stripped out. The locations of the bone fragments are not evident from this image, as there are different grey-levels in different areas, and shapes and edges do not give reliable clues.

The IBEX materials contrast image is shown in Figure 5, where chicken flesh is displayed at a similar grey-level in all regions, regardless of its thickness, while anomalous regions (bone fragments) have higher contrast. The locations of the bone fragments are clearly revealed.

Figure 5: IBEX materials image showing chicken flesh mid-grey, and revealing the bone fragments in black.

Having obtained the materials image, image processing techniques can be used to present the information in different ways, e.g. to produce an image showing the locations of the bone fragments only (Figure 6) or an absorption contrast image with the positions of the bone fragments overlaid (Figure 7).

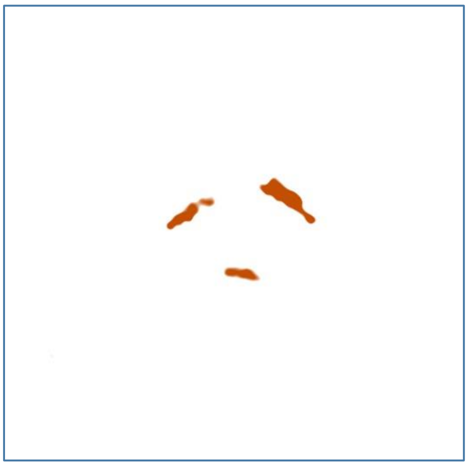

Figure 6: Classified materials image, showing the locations of the bone fragments only.

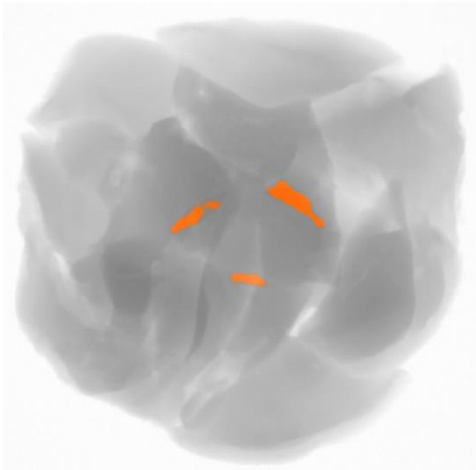

Figure 7: The positions of the bone fragments overlaid on the absorption image of the contaminated diced chicken sample.

Applying IBEX technology to the whole, large chicken breast sample, materials contrast again proved essential for identifying the positions of the bone fragments. While one or two of the rib bones might be located in the absorption contrast image by eye, the fan bone is not discernible. The IBEX materials contrast image brings them all to light.

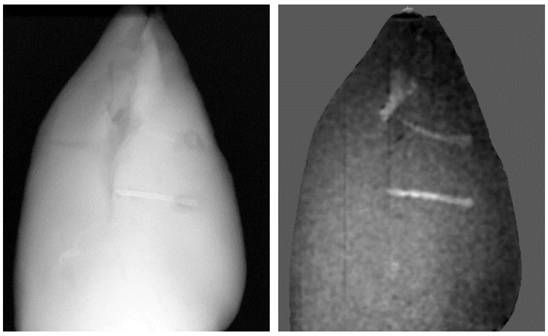

Figure 8: Absorption contrast image (left) of a whole large chicken breast containing three bone fragments. The bones are hard to see, although the eye picks out one of the ribs quite readily. Right: IBEX materials contrast image, revealing the locations of all three bone fragments (light contrast). From top to bottom: Fan bone, rib, rib.

Conclusions

IBEX technology has successfully identified bone fragment contamination in a mass of diced chicken and in a large whole chicken breast via contrast in the materials signal, irrespective of the absorption contrast afforded by different regions of the sample. This overcomes limitations of methods based X-ray absorption contrast and has potential benefits in the food industry.

Acknowledgments

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References

IBEX technology is protected by a number of patent applications worldwide. See www.ibexinnovations.co.uk for the latest information.

