EMERGING TECHNOLOGIES FOR DETECTION OF FOREIGN BODIES

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Abstract – Despite the recent advances in technologies and algorithms challenges still persist with respect to detection of cartilage, sinews, skin, polymer sheets and paper in fresh meat and meat products. Commercial systems based on attenuation of X-rays have demonstrated versatility in detection of hard materials like cortical bone fragments, most metals, glass, stones, and some polymer remains. The challenges in detection of light, fibrous materials and thin sheets are met in this work by evoking new X-ray modalities and hyper spectral vision. We demonstrate that darkfield X-ray radiology has good detection potential for fibrous materials like insects, paper and wood using an interferometry detector design and a conventional X-ray source with highly spatial coherent radiation. Furthermore we demonstrate its potential for detection of intrinsic tissues like cartilage and skin and thin sheets of polymers in meat products using a six-wavelength vision system for online applications in the meat industry.

Key words: Darkfield radiology, foreign body detection, hyper spectral vision.

I. INTRODUCTION

A recent survey of Japanese customer complains on contaminants in food [1] showed that the most challenging foreign materials, which still cannot be adequately detected are paper, wood chips and insects. The major difficulty arises when these foreign bodies are within bulk produce, which will require the application of penetrating radiation - typically x-rays - for their detection. However, the materials listed above have a low x-ray absorption cross-section and are therefore difficult to distinguish in foodstuff using conventional radiology. An alternative approach is therefore needed. A common feature with these extrinsic materials is their fibrous composition. Fibrous materials frequently have the property that they efficiently diffract x-rays [2 - 4]. It is therefore an objective of this study to investigate methodology utilizing this property and assessing its potential for foreign body detection in food. Diffraction of electromagnetic waves requires some degree of coherence. Previously coherent x-ray radiation required advanced and expensive facilities such as synchrotron or storage rings. However, for a technology to be relevant for the food industry is must have the potential of being accessible and affordable. With the advent of techniques for the generation of spatially coherent x-rays using conventional sources [2] a detection method based on x-ray diffraction is within the scope of the food industry.

When the foreign bodies of interest are located on the surface of the foodstuff, e.g. as would be the case when looking for bone fragments after a sawing process, optical radiation in the near infra red visible range can be used. The main challenge is identifying the materials (intrinsic and extrinsic) and determining whether an intrinsic material component is acceptable at the observed location. Conventional RGB (red-green-blue) vision techniques frequently are insufficient to distinguish between materials with similar color properties, e.g. white polymer and fat. On the other hand spectroscopic methods using more wavelengths and with better resolution can be efficient in distinguishing and identifying materials and tissues. This study investigated the potential of combining spectroscopy and vision - hyper spectral vision – for the detection of foreign bodies on foodstuff surfaces.

II. MATERIALS AND METHODS

The main detector parts of the experimental setup is shown in Fig 1 illustrating the position of the two detector gratings necessary to select the diffraction effect with a 0.172mm pixel CMOS Si detector (PILATUS 100k, Dectris Ltd.). A detailed description of the grating interferometer may be found in [2 - 4].

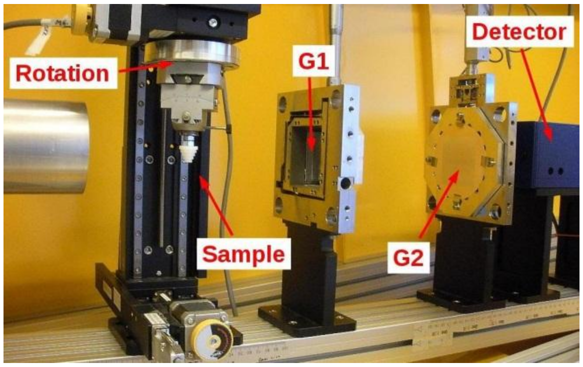

Figure 1 Experimental dark field setup. The source grating and the x-ray source is not showed in the photo.

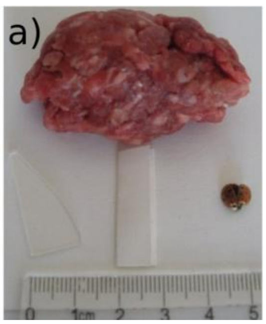

Figure 2a Photo of the minced meat sample and three contaminants: Glass, paper and insect

We demonstrated the potential of the darkfield modality in a simple experiment including a minced meat sample obtained from a local retail store. We inserted three different foreign materials in the meat sample: glass sheet of 1mm thickness, 4 layers of printing paper and a dead Harlequin ladybug (Harmonia Axyridis) Figs.

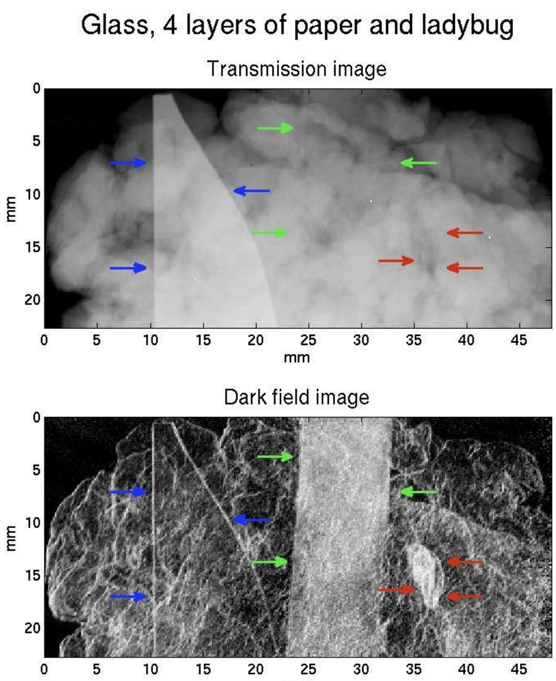

Figure 2b Transmission and dark field radiograms of the meat sample including three contaminants of Fig. 2a

2a. and 2.b show the conventional transmission image compared to the corresponding darkfield image, illustrating the pros and cons of the two modalities: The glass sheet is visible in the transmission image which shows no traces of paper or insect; whereas in the darkfield image the latter two items are seen with good contrast. The contrast is estimated by comparing the standard deviation in the areas indicated by blue (glass), green (paper) and red (insect) arrows.

Our hyperspectral approach to surface contaminant detection is based on initial measurements with the VideometerLab (Videometer AS, Denmark). The main goal is to use an existing online hyperspectral sensor, the DMRI 6-pack [5], to be applied as a surface contaminant detector. The calibration is made on three different meat products: porcine belly slices, porcine neck slices and 25mm beef cubes. (Fig 3) A range of thin polymer sheets were imposed on the meat samples and presented to the VideometerLab.

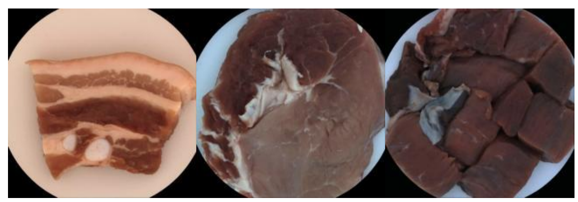

Figure 3 Three fresh meat samples

The polymers were obtained from Danish meat companies as representative wrapping materials. The extrinsic materials were consecutively positioned on the meat samples and placed in the vision system.

Each polymer sheet was placed on the three different meat products in five different positions on the surface. All positions were imaged with the 20 individual wavelength of the VideometerLAB, thus generating 100 images of each contaminant. An operator selects by 15 mouse clicks in each image, 15 different pixels all belonging to the contaminant, indicating the position of the foreign material. The repeated mouse clicks define the spectral appearance of the contaminant on each of the three meat products. As some of the contaminating materials are translucent the contaminant/meat product combination influenced the spectral appearance. As reference the operator also indicates the meat product in each image by selecting 15 different pixels belonging to the meat product.

The intensity of each wavelength reflection from the 15 “contaminant pixels” and the 15 “meat pixels” are registered using proprietary software, transferred to a spreadsheet for analysis. All reflection values are analyzed in SAS® [6] to find the six wavelengths to be used in the DMRI 6-pack, using canonical discriminant analysis and stepwise regression [6].

III. RESULTS AND DISCUSSION

The dark field experiment is to be considered as proof of concept and the full potential of the technology is still to be revealed. Here we restrict the analysis to a simple contrast assessment of conventional transmission and emerging dark field modality.

Table 1 Contrast performance of conventional transmission radiology and dark field radiology.

Food product	Foreign body	Transmission contrast	Dark field contrast
Minced meat	Glass	0.13	0.05
	Paper	0.05	0.22
	Ladybug	0.01	0.28

The glass contaminant generates approx. 40% lower contrast in dark field compared to the transmission image, so for glass contaminants the conventional x-ray systems outperform the new modality. For the fibrous contaminants, paper and insect the situation is quite different. The contrast is 4.4 and 28 times higher comparing the dark field to the conventional transmission contrast. This indicates a high potential for improved detectability with new detection systems based on dark field radiology for fibrous contaminants.

The calibration performance of the hyperspectral VideometerLAB is made to define the best combination of 6 wavelengths to be included in the DMRI 6-pack to give the best detection performance of surface contaminants on three different meat products.

The regression result of the canonical variables for the best three models, evaluated on the belly products, is given in the table below:

Table 2 Canonical modelling with porcine belly as input matrix with various contaminants.

Model	**Wavelengths [nm]**	**Model R^2**
Can 1	430, 660, 700, 850, 890,970	0.9872
Can 2	450, 590, 630, 700, 850, 870	0.9958
Can 3	470, 565, 590, 660, 700, 870	0.9159

The detection versatility of the calibration model is now evaluated, in Table 3, for each of the contaminants on all three meat products.

In table 3, contaminant No.6 is recognized in 66.18% of the presentations, whereas it is taken as contaminant No. 5 in 10.18% cases. Only in

Table 3. Detection performance of the Can2 model developed on belly products and evaluated on all three meat products. The contaminants represent plastic materials present in a typical Danish meat production.

Calibration results for Can 2 [470, 565, 590, 660, 700 and 870nm]										
Contaminant	No. 10 	No. 3 	No. 4 	No. 5 	No. 6 	No. 7 	No. 8 	No. 9 	Intrinsic	False negative
No. 10	99.64%	0.00%	0.36%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
No. 3	0.00%	91.64%	0.00%	2.55%	2.55%	1.09%	0.00%	2.18%	0.00%	0.00%
No. 4	0.36%	0.00%	77.82%	3.64%	0.73%	1.45%	0.36%	0.00%	2.55%	13.09%
No. 5	0.00%	8.73%	4.73%	45.82%	11.64%	7.27%	13.09%	0.73%	1.45%	6.55%
No. 6	0.00%	2.18%	4.73%	10.18%	66.18%	7.27%	2.91%	6.18%	0.00%	0.36%
No. 7	14.55%	9.45%	0.00%	2.55%	0.00%	70.91%	1.09%	1.45%	0.00%	0.00%
No. 8	1.45%	7.27%	6.55%	25.82%	16.73%	4.73%	19.64%	9.82%	7.27%	0.73%
No. 9	0.00%	1.82%	3.27%	9.82%	3.64%	4.73%	20.36%	56.36%	0.00%	0.00%
Intrinsic	0.00%	0.00%	2.46%	0.00%	0.00%	0.14%	0.00%	0.00%	92.32%	5.07%
False positive	0.00%	0.00%	0.11%	0.50%	0.00%	0.00%	0.00%	0.00%	1.15%	NR

0.36% incidents is the contaminant interpreted as meat, i.e. missed detection, and so a false negative. The experiment also indicates that the most transparent contaminants (No. 4 and No. 5) give the highest level of false negatives.

IV. CONCLUSION

The potential of dark field radiology for detection of light but fibrous contaminants as insects and paper represent a dramatic improvement compared to conventional transmission radiology. In our pilot study we achieve 4 times and more than 20 times better contrast of fibrous materials in the minced meat product compared to the conventional modalities.

The wavelengths selected for the DMRI 6-pack in a calibration trial demonstrated, a promising detection performance on surface contaminants in fresh meat products. However, the calibration performance however still needs to be validated on a larger selection of meat samples.

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