

NON-DESTRUCTIVE DETECTION FOR FOREIGN MATERIALS IN FOOD AND AGRICULTURAL PRODUCTS USING X-RAY SYSTEM

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ABSTRACT

Quality evaluation for food and agricultural products have always been one of the most elusive problems associated with the handling, processing and marketing in a food plant production. In order to detect physical foreign materials in food and agricultural products, non-destructive techniques have been developed for many years. Application of X-ray system to detect physical foreign materials in food and agricultural products could be considered to be a high potential method. Especially, it is impossible to detect internal physical foreign materials by visual inspections. In this study, it was tried to be applied for two different X-ray devices. Soft X-ray system with CdTe sensor and X-ray CT scanner were evaluated for advantage of the detection of non-metallic foreign materials in food and agricultural products. Though the soft X-ray is not a high energy radiation, it is possible to detect small different density in a material. The CdTe sensor has a high resolution for the soft X-ray energy region. The density characteristics of foods and foreign materials were expressed as a soft X-ray energy spectrum. The energy spectrum was analyzed by a personal computer with a multi-channel analyzer. X-ray CT scanner can provide visual image and analyze by three dimensional information inside food and agricultural products. The X-ray CT scanner using as a medical equipment was used to detect a foreign material. The density characteristics of food and foreign materials in food were tried to be detected by the threshold value on the basis of the CT numbers.

The soft X-ray absorption characteristics for acrylic plates and distilled water were obtained and could be found the possibility for detecting a small physical foreign materials such as a plastic wrapping film, a stone and grasshopper in food and agricultural products.

KEY WORDS: SOFT X-RAY, X-RAY CT, FOREIGN MATERIAL, NON-DESTRUCTIVE DETECTION

INTRODUCTION

Recently, safety of food and agricultural products is most important problem and concept of safety is going to become severe. Safety inspections for quality control consist of biological, chemical and physical tests. The biological inspection is to detect contamination by microorganisms. The chemical inspection is to detect harmful substances like agricultural chemical residues.

The physical inspection is to detect physical foreign materials in the products. In case of biological and chemical inspections, most of the sampling and analysis methods are established by government standards for known hazards (Muramatsu. 1989). However, as the type of foreign materials and their locations in the food product are usually unknown, there are no fixed physical inspection methods except for the detection of metallic foreign materials (Schatzki and Wong. 1989, Takeuchi. 1992). It is especially difficult to detect foreign materials mixed in processed foods with a rapid non-destructive method as the amounts and/or locations of foreign materials are known (Sakou. 1989, Ishikawa and Shikiya. 1989).

Therefore, it is important to develop a physical inspection system and establish the non-destructive inspection technique for physical foreign materials in food. When investigating the internal condition of different materials, application X-rays are most effective. Although there are some studies in X-ray used for non-destructive inspection, there are few fundamental studies and hardly any for practical use (Fujii and Uyama. 1994, Morita et al., 1996, Morita et al., 1996) In this study, a soft X-ray system with CdTe sensor and X-ray Computed Tomography(CT) were applied for the detection of foreign materials in food and agricultural products. The aim of this study is to obtain basic absorption characteristics of the soft X-ray and X-ray CT for the detection of foreign materials in foods and agricultural products, and also to discuss a possibility of detection for physical foreign materials.

MATERIALS AND METHODS

1. Soft X-ray source and detector

A specially modified soft X-ray device of SOFTEX M-80WE type (SOFTEX CO.,LTD) was used as a soft X-ray generator in this experiment. The X-ray tube (SOFTEX I-1310 type) with a tungsten cathode and a Beryllium radiation window were used (see Fig.1). Though the X-ray through glass radiation window absorbs soft X-ray radiation, the Beryllium radiation window does not nearly absorb soft X-ray radiation. Under the operating conditions of less than 80kV and 5mA, a continuous wave X-ray beam with energy levels up to 100keV was obtained. The peak of the energy spectrum was approximately at 10keV and the spectrum curve was shown in Fig.1. A Cadmium Telluride (CdTe) sensor was selected in this experiment to be used as a Soft X-ray detector. The CdTe detector has higher sensitivity compared to Si and Ge radiation detectors and is operational at room temperature (Iwase et al., 1992). The CdTe radiation detector can count photons at each selected level of the energy. The detector sensitive range was from 5keV to 100keV and its sensitivity was highest in the soft X-ray region. The detecting area of the CdTe sensor was 6mm in diameter and the sensitivity was adjustable by using a filter. The photon detected by the CdTe sensor was transformed into an electrical signal, amplified by a CT571 type amplifier (TOYO MEDIC CO.,LTD) , digitized into 1024 energy levels by a

multi-channel analyzer, APTEC S3000 MCARD (Aptec Engineering Ltd.) and analyzed by a personal computer AT1500 (Epson Direct Co. Ltd.). The energy spectrum resolution was approximately 0.1keV and the energy spectrum was calibrated using a radioactive element Cobalt 60 in this experiment.

2. Measuring of soft X-ray

The transmitted intensities of soft X-ray spectrum were measured about distilled water with different depth, acrylic plates with various thickness and Irish potato with a small stone. The schematic diagram of experimental apparatus was shown in Fig.2. The distance between the X-ray source and the detector was fixed at 800mm. As the soft X-ray beam was not collimated, the soft X-ray radiation from X-ray tube was scattered in the lead chamber. In order to eliminate reflected X-ray from the chamber wall, the CdTe sensor was exactly positioned just under the X-ray tube using a laser beam.

At the same time, in order to analyze a soft X-ray picture, X-ray film (Fuji X-ray film FR) was used. The X-ray film measurement was carried out at same situation in case of CdTe sensor (Fig.2). The Irish potato with a small stone and cabbage leaves with a grasshopper were measured and the pictures were analyzed by a computer with an image processor.

3. Measurement of X-ray CT

An X-ray CT scanner (SCT-4500TC, Shimadzu Co. Ltd.) developed for the medical field was used in this experiment. The adopted scanning method was the rotating type and the full scanning time was 4.5 seconds. A continuous X-ray tube with a rotating anode was used and the electric voltage of the X-ray tube was fixed at 120kV, while its electric current was changeable from 50mA to 130mA. A sensor array using xenon gas was used as the X-ray detector and this array can have a maximum of 512 sensing elements in use. The reconstructed image has a size of 340 x 340 pixels. The following experimental conditions were used; 120kV, 50mA, 2mm collimation, and full scanning method were adopted in this experiment. A fish meat sausage as a food material and a plastic wrapping film is mainly made from a vinyl chloride resin and added a calcium compound. The film was made spherical shape with approximately 1, 2 and 4mm in diameter. They were put into the fish meat sausage and their CT numbers were measured.

RESULTS AND DISCUSSION

1. Soft X-ray spectral curves for acrylic plates

In order to investigate soft X-ray absorption characteristic of acrylic material, spectral curves for acrylic plates with various thicknesses were measured (Fig.3). The soft X-ray power was 40kV, 3mA and the measuring time was 60 seconds. In the soft X-ray picture, the black part of the picture increased with increasing amount of the transmitted intensity of soft X-ray. In the spectral curves, a relationships between photon numbers detected by CdTe sensor and its energy (keV) was shown. Though the quality of acrylic plate has

an uniform density, the transmitted intensity greatly changed with its thicknesses (3, 6 and 9mm). Especially, the spectral curve greatly decreased in the low photon energy region. There was a same result in the soft X-ray picture.

2. Soft X-ray spectral curves for distilled water

In order to investigate soft X-ray absorption characteristic of water, spectral curves for distilled water with different depth were measured. The depth of water in a glass container with 1mm thickness was changed in 3, 6 and 9mm. The soft X-ray power was 30kV, 3mA and measuring time was 60 seconds. Though the transmitted intensity of soft X-ray decreased with increasing the depth of distilled water, the shapes of spectral curves were different. As the soft X-ray in the region of low photon energy was absorbed better than that in the region of high photon energy by distilled water, the peaks of spectral curves were shifted towards to the region of high photon energy with increasing the depth of distilled water. The phenomenon was remarkably happened in the region of soft X-ray.

3. Soft X-ray spectral curves for an Irish potato with a small stone

A hole with 10mm in diameter and 50mm in depth was made in the potato and a small stone (approximately 10mm x 10mm x 10mm) was put into the hole. Fig.5 showed the energy spectral curves and soft X-ray power was 50kV, 4mA and measuring time was 30 seconds. The transmitted intensity in a normal part of Irish potato. The different spectral curves were caused by different densities of the stone, potato and air in hole. When there are a big different of density between foreign material and food and agricultural products, possible to find the foreign material by measurement of the spectral curve without the soft X-ray picture.

4. Image analysis for soft X-ray picture

An image analysis for soft X-ray pictures was carried out by a computer with an image processor. Fig.6 showed the picture of the small stone in the potato extracted by the image analysis. The characteristic of small stone was emphasized by a brightness level slice method.

Fig.7 showed a soft X-ray picture for a grasshopper under a cabbage leaves. It was hard to find the grasshopper under the cabbage leaves in the original picture. Fig.8 showed the analyzed image by a sobel filter. The characteristics of the cabbage and grasshopper were emphasized in the picture, but there was no different between them. Fig.9 showed the analyzed image by a unsharp masking. It was more clear than Fig.8 and the outline of grasshopper was emphasized. Fig.10 showed the analyzed image by high pass filter. Most part of cabbage leaves disappeared on the picture and the outline of grasshopper appeared with the pretty clear condition. Consequently, though the grasshopper under the leaves was not confirmed from the original picture, it was considered to be possible to find the grasshopper by the computer image analysis with various filtering.

5. Detection of foreign material by X-ray CT

Fig.11 showed an image picture of X-ray CT for a fish meat sausage. Three black spots were plastic wrapping films with 1, 2 and 4mm in diameter. Though all of the foreign materials were detected by CT numbers, the image picture was not clear in order to have a system error in the X-ray CT scanner. Fig.12 was a three-dimensional surface distribution of CT number for a scanning area in the X-Y plane and with the CT numbers plotted on Z axis. It was much easier to judge visually the region corresponding to the foreign material with this type of plot. In order to have different CT numbers between plastic wrapping films and the sausage, it was clear to find foreign material in the sausage in this figure. It was considered to be possible to detect foreign materials by a threshold value using CT numbers.

CONCLUSIONS

In order to detect internal physical foreign materials in food and agricultural products, soft X-ray system with CdTe sensor and X-ray CT scanner were applied in this experiment. Though the soft X-ray was not a high energy radiation, the density characteristics of foods and foreign materials were expressed as a soft X-ray energy spectrum. The spectral curves for acrylic plates with various thicknesses, distilled water with different depth and Irish potato with a small stone were measured, and their density characteristics were expressed by their spectral curves. To detect a grasshopper under a cabbage leaves, the image analysis of the soft X-ray picture was carried out. It was possible to find it using various filtering in the computer image analysis. The X-ray CT scanner was used to detect plastic wrapping film in fish meat sausage. The density characteristics of food and foreign materials were expressed as a three dimensional distribution using X-ray CT numbers. These methods was evaluated for advantage of the detection of non-metallic foreign materials in food and agricultural products.

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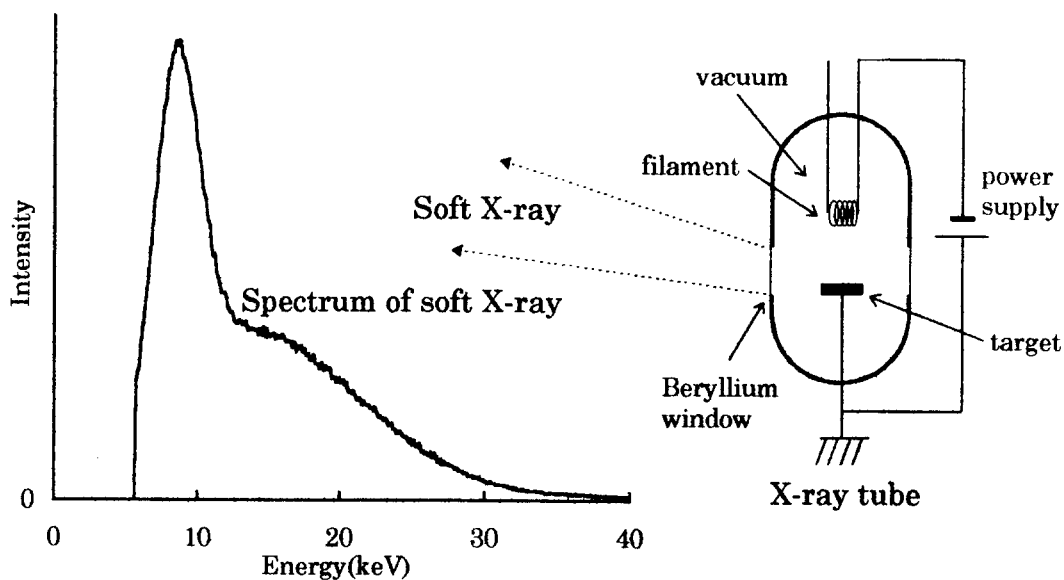


Fig.1 Generating soft X-ray and its spectrum.

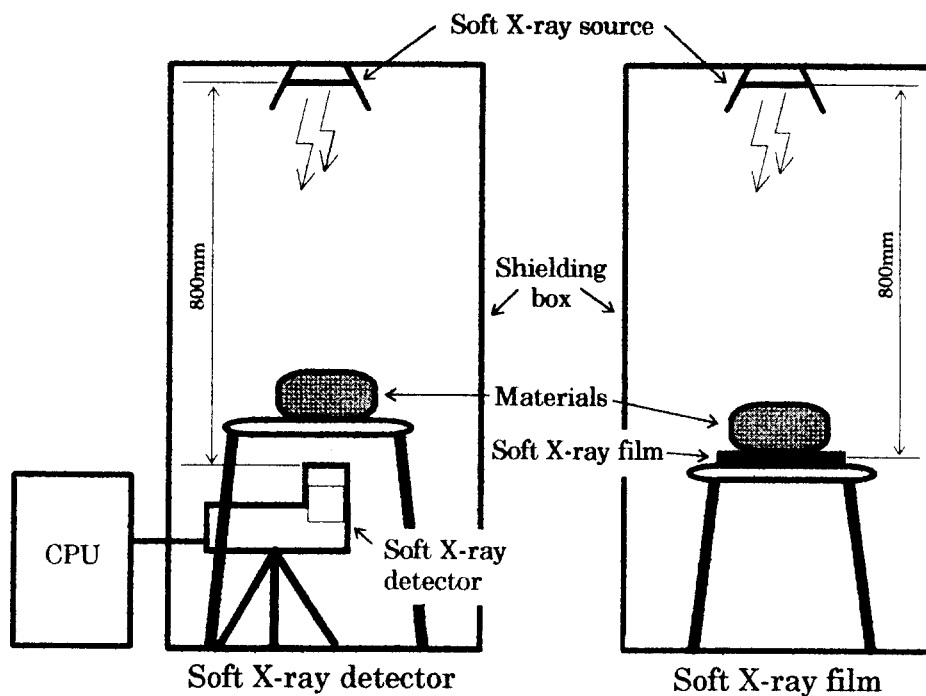


Fig.2 Schematic diagram of experimental apparatus.

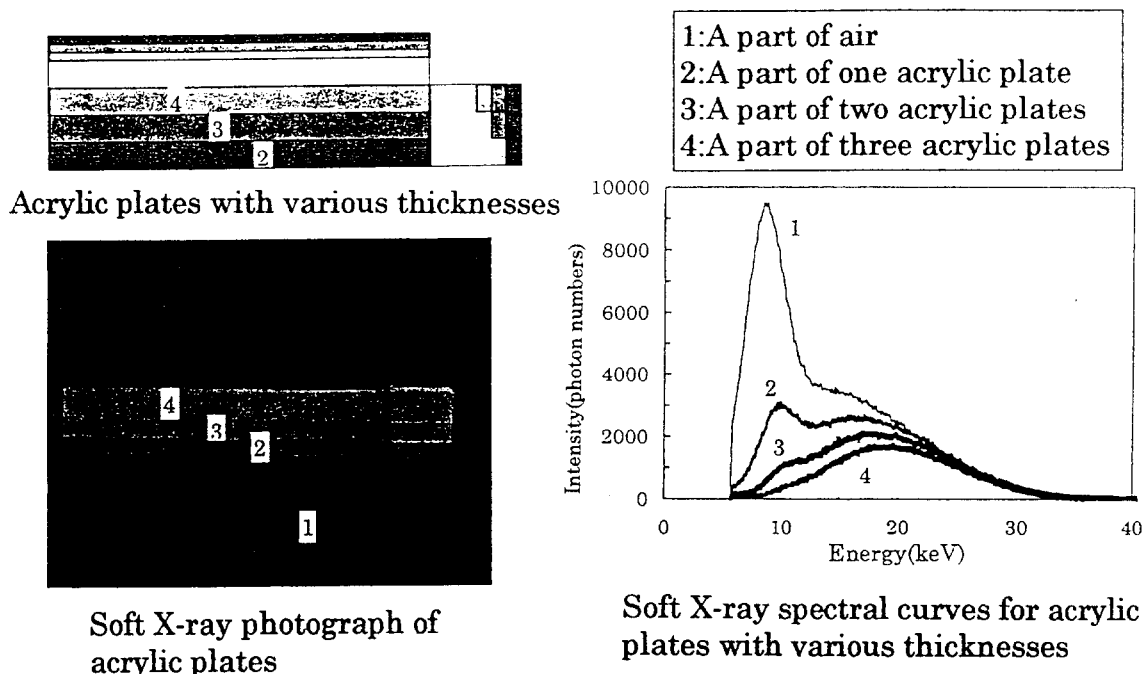


Fig.3 Measurement of Soft X-ray for acrylic plates.

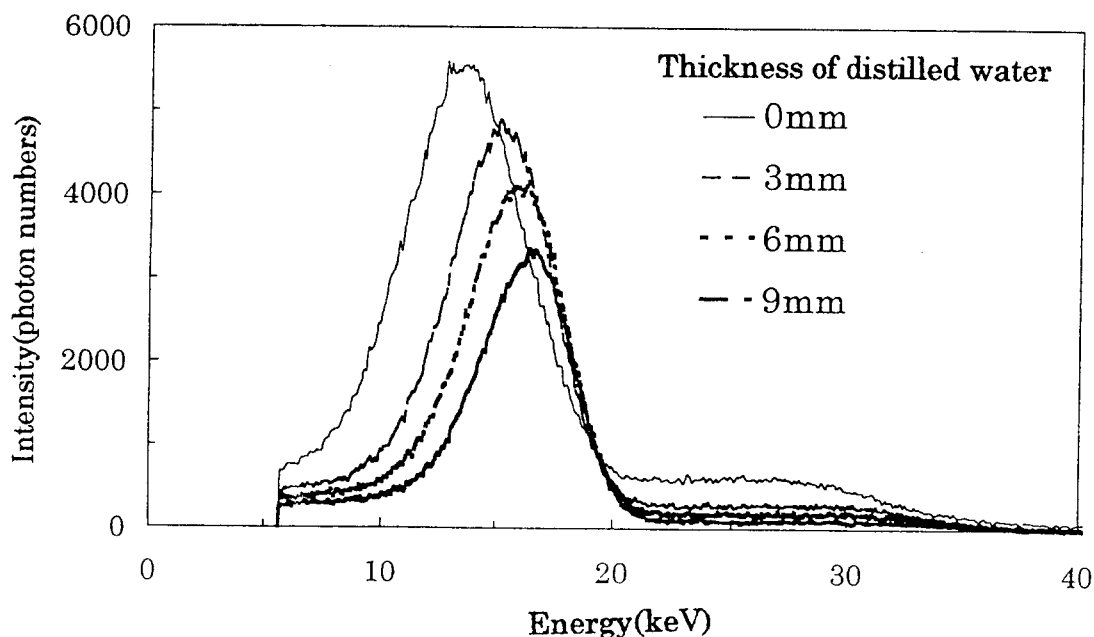


Fig.4 Soft X-ray spectral curves of distilled water.

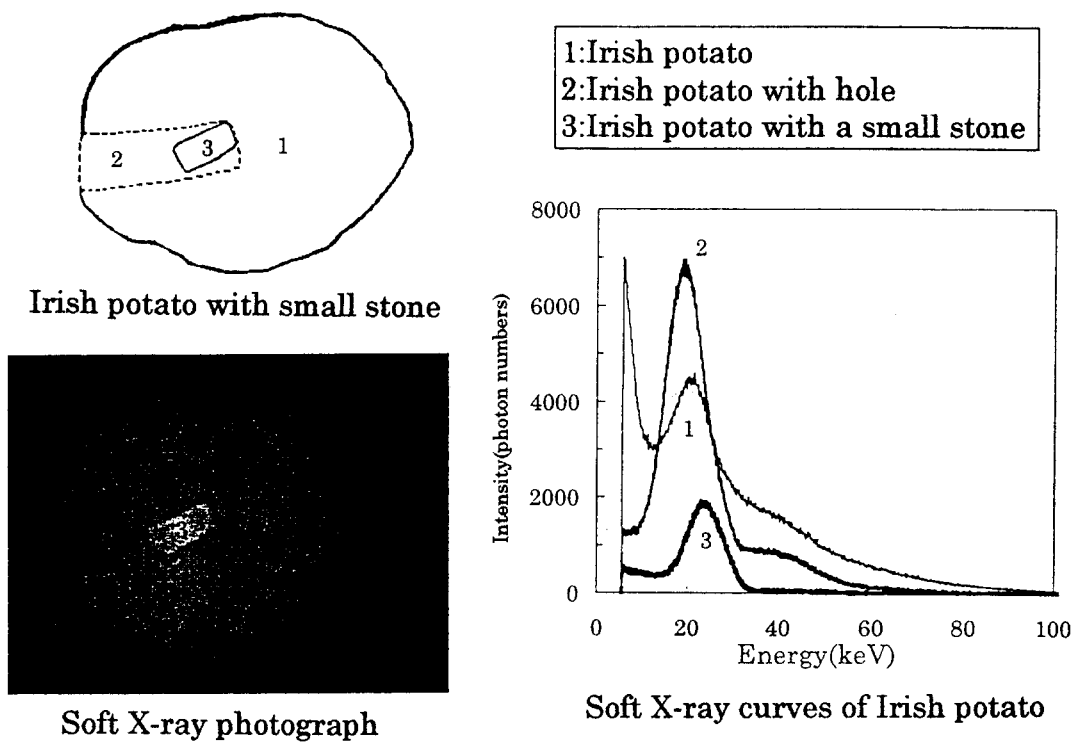


Fig.5 Measurement of Soft X-ray for Irish potato.

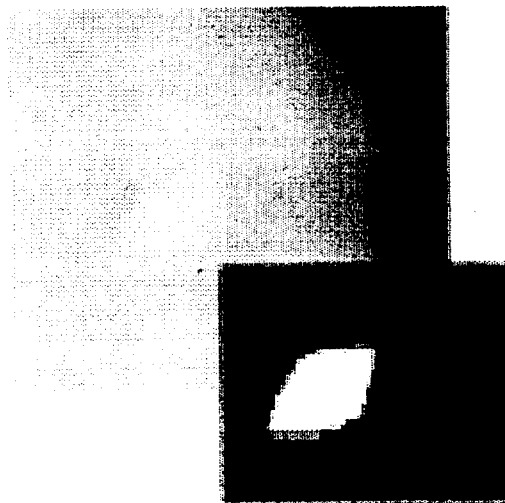


Fig.6 Image picture of a small stone in Irish potato.

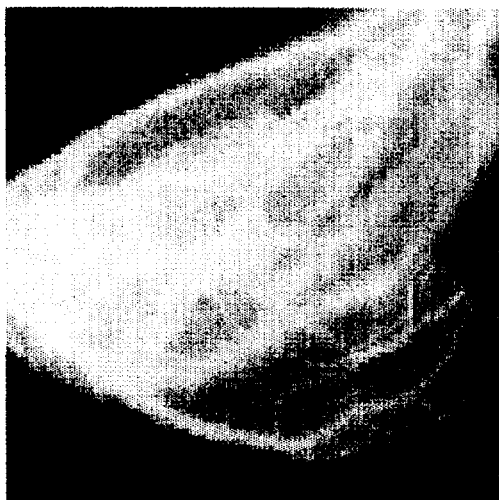


Fig.7 Image picture of
a grasshopper in
cabbage leaves.
(Raw)



Fig.8 Image picture of
a grasshopper in
cabbage leaves.
(Sobel filter)



Fig.9 Image picture of
a grasshopper in
cabbage leaves.
(Unsharp masking)



Fig.10 Image picture of
a grasshopper in
cabbage leaves.
(High pass filter)

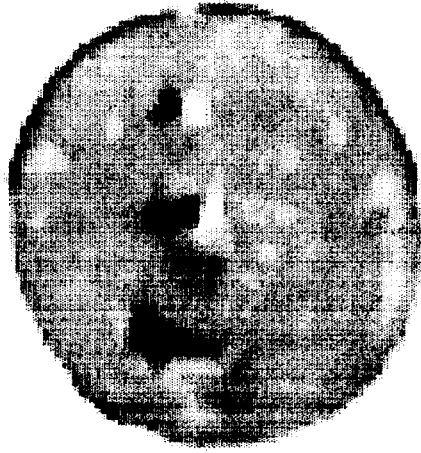


Fig.11 CT image of foreign materials
in fish meat sausage.

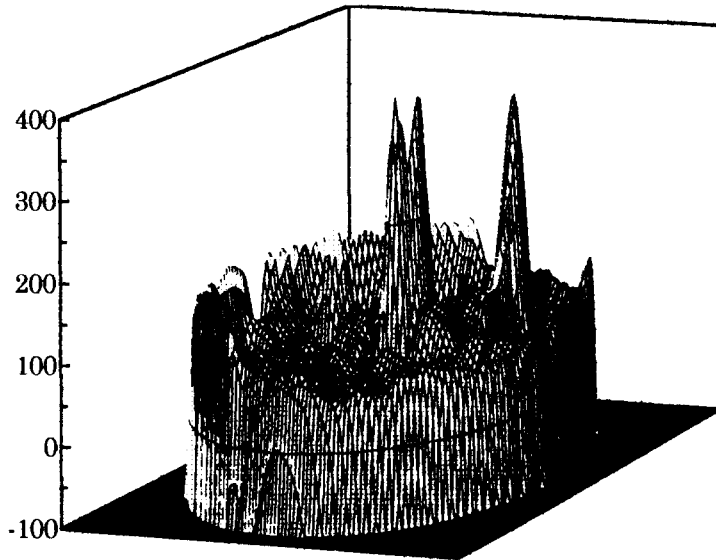


Fig.12 Three dimensional CT numbers of foreign
materials in fish meat sausage.