ISHIDA

10 factors to consider in selecting an X-ray inspection system for your food production requirements

Introduction

There is an increasing interest in applying X-ray technology into food production facilities for foreign body detection. The primary drivers in considering the application of X-ray are;

- Retailers demanding higher quality inspection regimes that cannot be provided by metal detection technology alone.
- A desire for improved product quality which can open up new customer bases or maintain margins with existing customers by providing high quality products.

Irrespective of the drivers behind the decision to apply X-ray systems within a facility, there will typically be a consistency in the fact that a group or one individual will be faced with making a capital equipment purchase decision around a technology that they have limited experience with.

As with most purchases there is nothing to fear, provided you have a clear understanding of what you want from the system and you have undertaken a reasonable amount of background research.

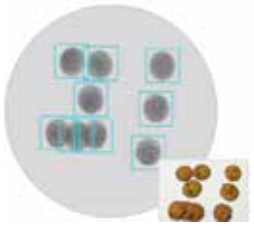
The starting point would be to have a clear understanding of the products that you want to use the technology on, of particular importance would be:

- Whether the products are packaged or in bulk (free flow) form
- The dimensions of the product and if there is any preferred and/or desired orientation to their flow on the conveyor
- The density (mass/volume) of the product as this can influence the ability of the X-ray system to pick up the desired foreign bodies

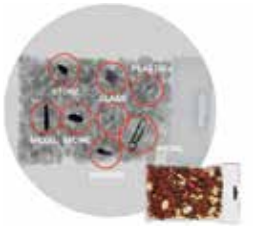
The next consideration would be what you want to use the system for as there is a wide range of functionality available apart from foreign body detection including:

- Counting
- Weight estimation
- Packaging integrity
- Detecting fill levels
- Product flaws

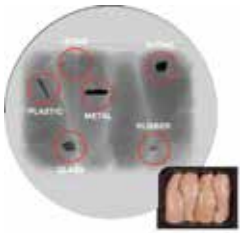
Fig.1 Examples of products with X-ray images



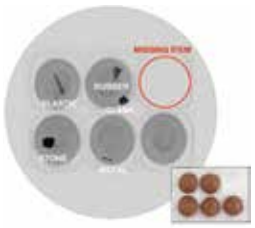
Counting the number of cookies



Contaminant detection in mixed nuts

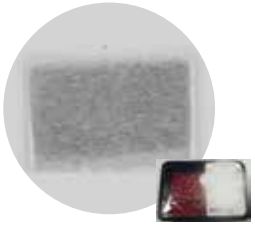


Contaminant detection in chicken



Missing item detection in tea cakes

Defect inspection in sausages



Trapped product in the seal of the minced meat pack

However, the majority of X-ray applications are in foreign body detection and particularly in detecting materials that cannot be picked up by metal detectors, for example glass, stones and bone.

In general X-ray systems work on the principle of providing images of products and foreign bodies, the contrast of which is determined by the density difference between the two. As such the greater the density difference between the two the easier it is to detect and see the foreign body.

Once you have a clear view on your requirements then there are typically a number of factors that should come into play in your decision making process. To assist, a list of the top 10 factors is indicated below along with some initial considerations on what should influence your selection.

1. Generator type

At the heart of every X-ray machine is a generator which produces the X-rays that are transmitted through the product and foreign bodies. The generator selection is critical and will largely dictate the performance you can expect from your system, broad consideration of potential applications needs to be undertaken to “future proof” your investment.

The first criteria to consider might be the material that the X-ray tube and in particular emissions aperture is made from. Two classic materials are glass and Beryllium.

While the former is more cost effective, some glass tubes can attenuate (reduce) X-ray emissions by up to 50% which can be quite limiting when trying to pick up low density foreign bodies (See Fig. 2a and 2b).

Beryllium although more expensive attenuates at around the 10% level and as such 90% of the X-ray emissions make their way through to the product. This means that at the same power settings the Beryllium tube provides much better images and contrasts than their glass tube counterparts.

The next consideration for generator selection is their maximum power and the flexibility of selecting the correct power for a particular application.

Generator power consists of the potential voltage (kV) and current (mA). The potential voltage which can range from around 25kV to 100kV largely dictates the depth of product that you can work with. Low voltages allow for relatively shallow products, while high voltages can allow for deeper products. Some X-ray systems have large potential voltage ranges (high to low), this is to facilitate the fact that while high voltages are good for deep products and dense foreign bodies, they are less useful than low voltages on low density foreign bodies (see Fig.3).

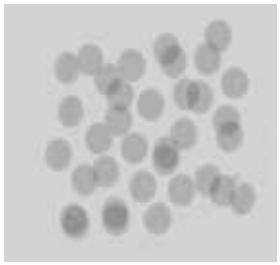


Fig. 2a. Image created by Glass X-ray tube

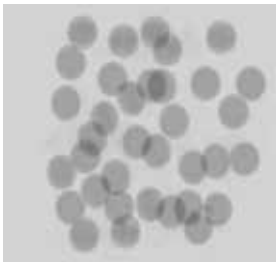


Fig. 2b. Image created by Beryllium X-ray tube

However high voltage (power) can assist with penetrating deep products, while low voltage can assist with low density foreign bodies. The range and flexibility in the current (mA) settings - which in effect dictate the number of electrons – can assist in foreign body detection as well.

A simple analogy might be to consider a hay field within which you are searching for a missing object. A high voltage and low current setting might be the equivalent of a single powerful individual moving across the field very quickly. They achieve a good penetration but their time searching in the field is limited. At the opposite extreme would be a low voltage and high current setting which would be the equivalent of a large slow moving search party going through the field. They may not penetrate as far but the search is probably more comprehensive on what they cover.

In units that offer the capability to select both voltage (kV) and current (mA), an ideal combination can be determined for a particular product and foreign body contaminant.

Fig.3 X-ray emission absorption within different materials.

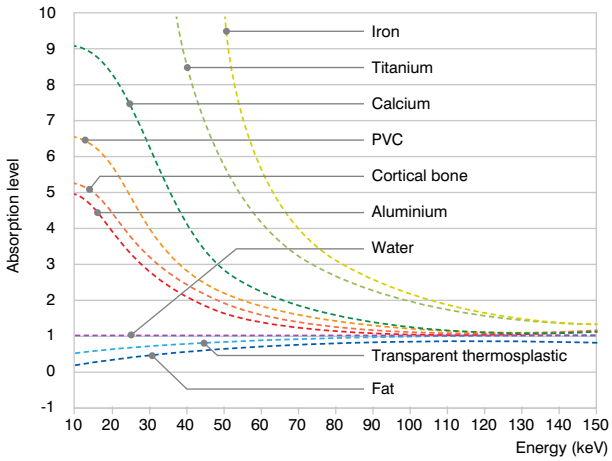
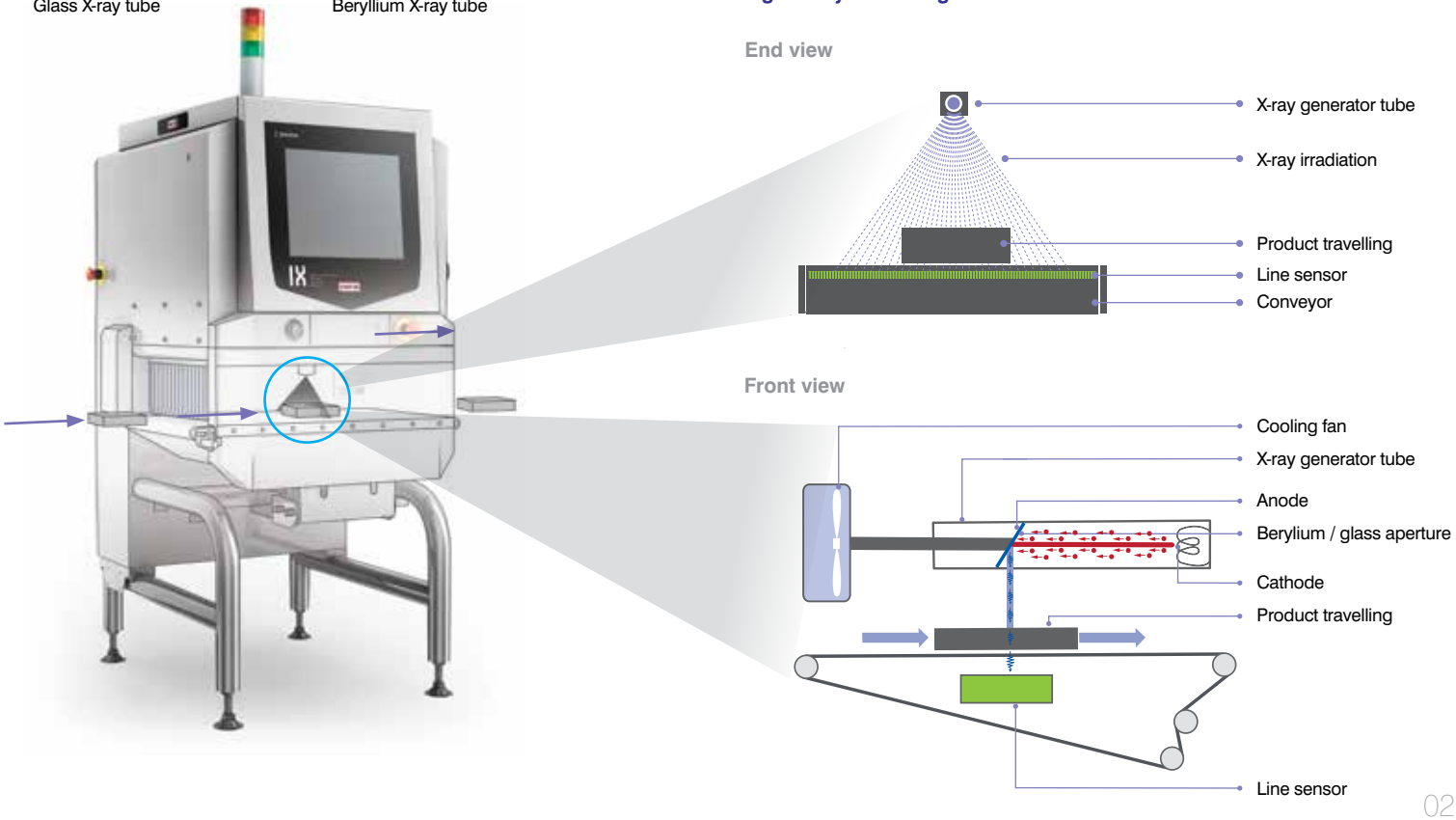


Fig.4 X-ray unit with generator structure indicated.

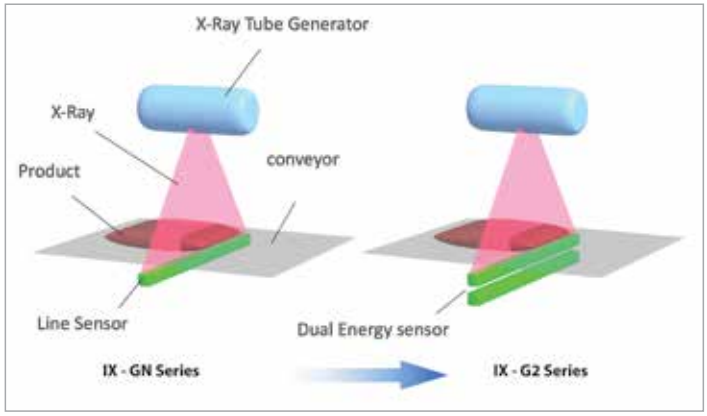


2. Number of line sensors

All X-ray systems work on the basic principle of X-ray photon emissions going through a product and foreign body and hitting a line sensor which provides contrasting shades of grey depending on the attenuation of the X-ray emissions. The majority of X-ray systems come with just one-line sensor.

However, some units come with two line sensors which take images at different energy settings. i.e. one low and the other high (see Fig.5). Comparing the images collected by these sensors can provide a better contrast in products which have relatively low differences in density with the foreign bodies that are trying to be detected. A classic application for two-line sensor units is in the poultry market where individuals want to detect bones in chicken pieces.

Fig.5 One and two line sensors



Comparison between X-ray systems with one and two line sensors.

3. Pixel size

Each line sensor is made up of small pixels which are similar to the pixel arrays that you might get in a digital camera. As with a digital camera the more and smaller the pixels you have then the better the resolution of your image. In a similar fashion with X-ray machines the smaller the pixel size then the better the image and possibly even more important the smaller the foreign body that you can detect.

The size of foreign body that you can detect is dependent on a wide range of factors within a particular application. However, from a pixel perspective a reasonable “rule of thumb” might be a 1.5:1 ratio. In that ratio a pixel size of 0.4mm would allow for a foreign body of 0.6mm to be detected.

4. X-ray certification

All X-ray units sold in the UK need to adhere to certain guidelines which limits their X-ray emissions to less than 1 micro sievert per hour.

All installations and work with X-ray machines in the UK is covered by the IRR99 (Ionising Radiations Regulations 1999) which indicates requirements on manufacturers and users of the machine.

While there is a lot of expectations and criteria on manufacturers around X-ray machine production and installation there is less on producers. The main activities for the latter are:

- To notify the HSE (Health and Safety Executive) of a planned X-ray machine installation 28 days in advance.
- To obtain advice from an RPA (Radiation Protection Advisor) on the safe use of the machine in their facility.
- To appoint an RPS (Radiation Protection Supervisor) for their site that can ensure safe guidelines and practices are maintained at all times.

5. Reject mechanisms

There are a wide range of reject mechanisms that are available with X-ray products and as with your application, they can be split into those suitable for packaged products and those suitable for bulk (see Fig.6).

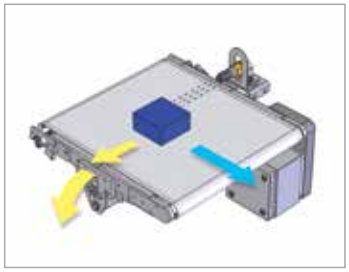
Some of the more common for packaged products would include:

- Arm
- Pusher
- Air

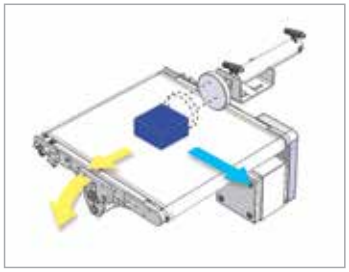
The final selection will depend largely on the size and weight of your products along with the speed at which you want to operate.

Another consideration around reject mechanisms is that typically any food producers providing for the large retailers need to adhere to RCOP (Retail Code of Practice) which includes both machine sensitivity and reject confirmation criteria. The latter typically entails fitting a number of sensors to the unit to ensure that bad products are rejected, a confirmation that they have been rejected and also that no bad product makes it down the line.

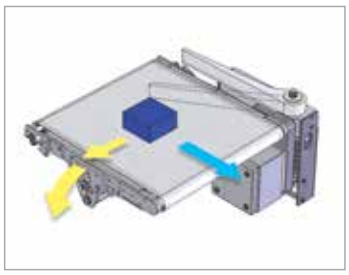
Fig.6 Example of reject offerings



1. Air Reject



2. Pusher Reject



3. Slap Arm Reject

6. Software capability

While machine performance can dictate whether you achieve your desired foreign body detection, the software usability plays a large part in the technology adoption.

The critical software elements that should be considered when selecting an X-ray machine would include:

- General user friendliness and how easy to go from one section to the next.
- The flexibility of the software in setting up foreign body detection and the other quality control features available.
- The number of production (product) presets that can be set up on the machine to simplify the product testing environment
- How easy it is to set up production presets.
- The access levels that are available in the software and ability to restrict access to configuration and preset selection only to approved personnel.

7. Imaging software

As indicated X-ray units largely provide (shades of) grey contrast images which allow for foreign body detection.

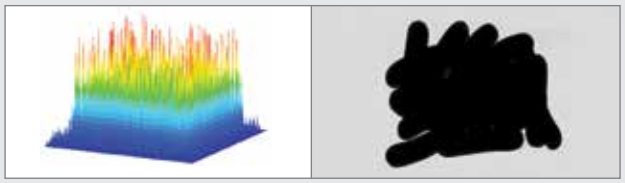
However often the density of the product and foreign body are very close and the machine hardware struggles to provide a contrasting image.

In difficult applications, there is often a requirement to use clever image analysis software to provide better contrasts between products and foreign bodies. This entails using a number of software algorithms which can apply filters to the image to provide the desired improvements. The ability to have this functionality and the ease with which it can be applied can be a critical factor in system selection.

Fig.7 Advanced imaging software evolution

Example of imaging software: detecting foreign matter in a pack of sausages

X-ray image with no algorithms applied



X-ray image with initial applied imaging software

X-ray image with final imaging software

8. Training provision

Despite any concerns that you may have X-ray machines are not “rocket science”, however they do require a certain amount of knowledge and skills – particularly around regulations and HSE compliance.

As such it is critical when selecting a provider that you ensure that they are willing to offer a suitable level of training prior to installation and also that they have the skills, resources and commitment to work with you on your journey to maximise the potential of the technology within your organisation.

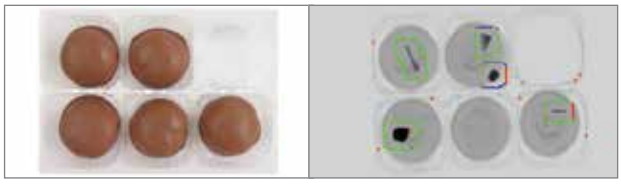
9. Applications support

The results that you can obtain from an X-ray unit are very much product and foreign body dependent. As such when selecting a provider, it is important to be working with an organisation that has extensive experience in your sector and your application in particular.

If you are a poultry producer one of the initial questions that you need to consider in selecting a provider is, what is their experience of the meat industry and specifically poultry applications?

Fig.8 Focused food sector applications

Bone detection in chicken fillet.



Contamination and missed item detection in chocolate cakes.

Contamination detection in yogurt pots.

10. Cost of ownership

There are number of potential X-ray providers in the market that offer a variety of performance and pricing options. However as with other industries and capital equipment purchases, you get what you pay for. The premium providers with high quality products are typically more expensive than the lower quality units. As with any capital equipment purchase the total cost of ownership should be factored in and elements to include would be:

- Success of the system in meeting your application needs and ability to consistently meet them.
- Confidence in the quality of products that you provide to your customers.
- Training and support provision for your staff during installation and throughout their learning process.
- Ongoing service maintenance and support provided

Hopefully this white paper has assisted in highlighting some of the key issues in X-ray machine selection and raised your interest in exploring more about how it might be used to assist your quality control needs.

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