X-Ray Inspection:
More Than Just Foreign Body Detection

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Since the early 1990s, the food and pharmaceutical industries have relied on x-ray technology to detect potentially harmful foreign bodies, such as glass and metal, to protect consumers and maintain brand reputations.

But can x-ray inspection do more? Could x-ray technology be a multi-tasking defender of product safety and brand quality?

This white paper looks at the potential of x-ray inspection to solve a wide range of product safety and quality control issues typically found within food and pharmaceutical manufacturing. It explores how x-ray inspection can detect faulty products before they leave the factory, avoiding product recalls and customer disappointment. It describes how in a single pass – and at high line speeds – x-ray systems can perform several inspection tasks simultaneously.
1. Why use X-ray to Inspect Food?

Food and pharmaceutical manufacturers use x-ray inspection technology to ensure product safety and quality. X-ray inspection gives them exceptional levels of detection for stainless steel, ferrous and non-ferrous metals. The technology is also extremely good at detecting other foreign bodies such as glass, stone, bone, high density plastics, and rubber compounds. X-ray systems can, however, simultaneously perform a wide range of other in-line quality checks, such as measuring mass, counting components, identifying missing or broken products, monitoring fill levels, inspecting seal integrity, and checking for damaged product and packaging.

Increasing line speeds and consumer expectations have put pressure on manufacturers to adopt more reliable methods of product inspection. Although there are no legal requirements to use x-ray inspection, guidelines such as Hazard Analysis Critical Control Points (HACCP), the Global Food Safety Initiative, Good Manufacturing Practice, and ad hoc standards set by individual retailers put the onus on manufacturers to establish reliable product inspection programmes.

Incorporating x-ray inspection systems into a company-wide product inspection programme, to ensure product safety and quality, helps manufacturers comply with national and international regulations, local legislation and standards set by retailers.

2. How Does X-ray Inspection Work?

X-rays are invisible. Like light or radio waves, they’re a form of electromagnetic radiation. Because their wavelength is short, x-rays can pass through materials that are opaque to visible light. But they don’t pass through all materials with the same ease. The transparency of a material to x-rays is broadly related to its density, which is why x-ray inspection is so useful in the food, beverage, and pharmaceutical industries. The denser the material, the fewer x-rays that pass through. Hidden foreign bodies, like glass and metal, show up under x-ray inspection because they absorb more x-rays than the surrounding product.

An x-ray system is essentially a scanning device. When a product passes through the unit, it captures a grey-scale image of it (Figure 1). The software within the x-ray system analyses the grey-scale image and compares it to a predetermined acceptance standard. On the basis of the comparison, it accepts or rejects the image. In the case of a rejection, the software sends a signal to an automatic reject system which removes the product from the production line.

3. X-ray Inspection Sees What You Can’t See

By exploiting simple density differences and analysing the resulting grey-scale x-ray images, x-ray inspection equipment has moved beyond product safety into other areas of quality control.

One X-ray System – Many Quality Control Functions:

In addition to detecting foreign bodies, modern x-ray systems are multi-tasking defenders of product and brand quality. In a single pass at high line speeds, x-ray systems can perform several inspection tasks simultaneously, including:

- Measuring product weight, width, area, and volume
- Identifying missing or broken products
- Monitoring fill levels
- Measuring mass
- Inspecting for compromised seals while still catching contaminants.

3.1 Measurement of Product Length, Width, Area, and Volume

Measuring the length, width, area, and volume of a product, in conjunction with contaminant detection is the simplest form of product inspection. The process is known as ‘object finder’.

As previously explained, an x-ray image is a grey-scale image. The darker the grey, the more product is in the path of the x-ray beam. By converting those grey tones into a 3D image, the software can calculate, for example, the area of the product.

This type of image analysis takes quality control to a new level of sophistication. It identifies products that don’t look right, even if they’re the correct weight, in the correct position, and free of foreign bodies. It’s hugely useful for manufacturers of products that depend on visual appeal. For example, one of the
three meat patties shown in figure 2 has a hole in it. It shows up as a light patch amid the uniform grey.

One of the three patties shown in figure 3 is misshapen. The two flow-wrapped garlic baguettes (Figure 4) take the process further still.

The quality control issue here is the potential underfilling of garlic butter in each slot because the butter injection machine could block up or run out of butter. Since the x-ray system can see the individual blobs of butter, it can analyze each zone separately. It checks that the surface area or volume in each zone meets a preset standard. If it doesn’t the product will be rejected from the line.

3.2 Identification of Missing or Broken Items

X-ray inspection will also detect faulty and missing products.

Examples are:

1. Detection of damaged products
   - Crushed, missing, and partial tables in a blister pack
   - Dented, squashed, or deformed packaging
   - Checking that box contents are intact an unbroken

2. Detection of missing products
   - Counting components to check they’re all there
   - Checking that the locking level of an asthma inhaler is in place

3. Insert inspection
   - Identification of missing components such as lids and instructional leaflets
   - Checking for the presence of promotional giveaways

These inspection routines are just as effective when a product is packed in multiple layers, such as a blister pack.

#### 3.2.1 Detection of Damaged Products

The detection of damaged products relies on the same principles as length and volume measurement. By setting minimum and maximum sizes for pack width, height, volume or surface area, x-ray analysis software can spot a deformed pack.

In figure 5, a check for surface area was enough to catch deformed cartons and reject them from the production line. The x-ray software assigned a surface area value of 100 for good packs, and rejected any that fell below 90.

#### 3.2.2 Detection of Missing Products

X-ray systems can look inside the final sealed packaging to check that all components are present. It can count products and components that cannot be seen or counted by cameras or human eyesight. For example, it can count needles and syringes in a box.
check for the locking lever in an asthma inhaler, count cheese cubes in a tray, or pralines in a gift box.

Spotting the missing sausage in figure 6 was easy. The software found five dark zones in the grey-scale x-ray image when it was programmed to expect six.

![Figure 6: Detection of missing sausage](image1)

Spotting the presence of caps or lids could be done by the human eye, but the process is far faster and far more reliable with x-ray technology. If the cap area appears brighter, then the product will be rejected from the production line (figure 7).

![Figure 7: Detection of missing cap](image2)

### 3.2.3 Insert Inspection

If x-ray inspection can identify objects that shouldn’t be in a pack, it can also find ones that should be there, such as leaflets and promotional gifts.

Figure 8 shows boxes of contact lenses which, according to industry regulations, must include handling guidelines and product information. By checking that the leaflet is in place, x-ray inspection verifies compliance.

![Figure 8: Leaflet inspection](image3)

Figure 9 is an x-ray image of a cereal carton containing a promotional giveaway – a toy. If the software can find the toy, it’s a good pack. At the same time x-ray inspection can inspect for foreign bodies. By eliminating the toy from the image, the x-ray system can check the rest of the pack. It’s a simultaneous process in which the promotional giveaway doesn’t interfere with foreign body detection.

Another example comes from the meat packing industry. Many meat-based products contain oxidisers (known as ‘scavengers’) to help keep the product fresh. Oxidisers can be quite dense, which could reduce the effectiveness of foreign body detection. Figure 10 shows how, in a packet of cooked ham, the x-ray system not only checks that the oxidiser is present, but also removes it from the x-ray image for optimum foreign body detection.

![Figure 9: Checking for the presence of a giveaway](image4)

![Figure 10: X-rays check if the oxidizer in ham is present](image5)

### 3.3 Measuring Mass and Monitoring Fill Levels

Maintaining the correct mass and fill levels of a product is a constant challenge in food and pharmaceutical manufacturing. Measuring overfills and underfills has an effect on manufacturing costs as well as consumer satisfaction.

X-ray inspection can analyse:

* The overall mass of a product
* The individual masses within various zones or compartments of a product
* The overall fill level of a product
* The individual fill levels within various zones or compartments of a product
3.3.1 Overall Mass Measurement

As explained under point 3.1 an x-ray image shows up as varying tones of grey. By converting those grey tones into a 3D image, the x-ray software can calculate how much product is in the pack. This 3D volumetric check is also used for mass measurement.

The x-ray system has an auto-learn facility whereby an acceptable weight pack (close to the nominal weight) is passed through the x-ray system, typically 10 times. The gross weight of the pack is then entered into the system. (The user must have previously weighed this pack on a set of calibrated static scales offering a suitable weight range and accuracy.) That way the analytical software can calculate the weight of subsequent packs by comparison to the weight of its learned reference pack. The x-ray inspection system can now compare all future products against its ideal reference product. If the calculated mass falls within a programmed tolerance, the package is good. If it deviates, the package will be rejected.

Figure 11 shows a box containing six foil wrapped cereal bars packed in two layers. The middle cereal bar is missing from the upper layer, which is why another cereal bar has moved out of place. It shows as shadows outside the normal range on the grey-scale x-ray image, hence the product will be rejected.

The quantity of jam inside a doughnut is another example of how x-ray inspection can be used to exert better quality control. From the outside, a doughnut with too much or too little jam in the centre looks perfect. No one knows until they take a bite. Too much jam increases production costs. Too little jam leads to disappointment. With x-ray inspection, every doughnut can be checked, even when the line runs at 600 doughnuts a minute. The x-ray inspection software examines each grey-scale x-ray image. From the overall level of blackness, it calculates the mass of jam inside the doughnut. If the mass meets the preset standard, the doughnut passes the test. If it fails, it’s rejected from the line and the manufacturer can adjust filling equipment to maintain the standard (Figure 12).

3.3.2 Zoned Mass Measurements

For products that are in defined compartments, such as a box of chocolates or a two-compartment ready meal, mass measurement can provide results for each individual zone/compartment. It lets manufacturers check the overall mass of a product and the masses within each compartment.
Figure 13 shows a twin compartment ready-meal (TV dinner). The x-ray software is simultaneously checking the overall mass of the pack and that of each compartment. In this case the overall weight is right, but there is low fill in the rice compartment, so the pack is rejected.

### 3.3.3 Overall Fill-Level Inspection

Fill-level inspection is different to mass measurement. It’s a 2D process based on a simple inspection process: you set maximum and minimum fill levels and reject any product that falls outside them. It doesn’t matter what the product is made of, or the mass of it. It simply has to reach a certain height within the pack or container. Fill level becomes a simple 2D image check instead of the 3D volumetric check required for mass measurement.

The tube of crisps in Figure 14 is an example of fill-level check. As you can see, the stack of crisps has collapsed on its side and some crisps are broken. By checking the height of the stack, x-ray analysis can tell that the fill level has dropped below an acceptable standard, and reject the pack.

You could also add an optional feedback to the filling machine to adjust the fill level. This is especially relevant for fluid products like yogurt drinks or loose powder products like milk powder (Figure 15).

### 3.3.4 Zoned Fill-Level Inspection

X-ray inspection is as good at checking zoned fill-levels as it is at checking zoned mass measurements. An underfill in one pot of a yogurt multipack could potentially be compensated by an overfill in another pot. Another example could be the fill level inspection of each pot in a six-pack of yoghurts. X-ray inspection will examine the fill level in each pot. If any one of them is under filled, the entire pack would be rejected (Figure 16).

![Figure 14: Composite tube of crisps stacked](image1)

![Figure 15: Yogurt pot with low fill level](image2)

### 3.4 Product-in-Seal Inspection

The integrity of airtight seals is a vital quality control issue for manufacturers of sealed food and pharmaceutical packs. The safety and sterility of pharmaceutical products and freshness of food products depends on the seals, yet they’re easily compromised by stray particles of product, foreign bodies, or misplaced products. Anything trapped within the seals could mean that the pack is no longer airtight. The seal inspection x-ray tool can identify particles as small as 1mm caught in the seal areas.

On low-density packaging, a special ultra-high contrast detector system can simultaneously check for foreign bodies and seal integrity. Figure 17 shows the x-ray image of a sealed pack of chocolate. The system checks for the presence of dense material between the inner and outer edges of the seal. If it detects material in this area, it rejects the product.

![Figure 16: Twin lane inspection of six pack yogurts with one low fill](image3)

![Figure 17: Pack of chocolates with particles trapped in seal](image4)

An example from the pharmaceutical industry is the inspection of surgical wound dressings (Figure 18).
Here, the analytical software is checking that no wound dressings are trapped within the seal, thereby compromising pack sterility.

Figure 18: Wound dressing trapped within the seal

4. Conclusion: No Shocks or Surprises X-ray Inspection Enforces Brand Values

X-ray inspection equipment gives manufacturers the tools to maintain quality control and product integrity at every stage of production for raw, bulk, pumped, and packaged products.

By setting appropriate parameters and fine-tuning the sensitivity, manufacturers can investigate numerous quality issues from catching foreign bodies to checking that a product looks exactly as a customer expects it to look. The product that successfully passes x-ray inspection contains no shocks, surprises, or disappointments. The manufacturer knows that it fulfils its brand promise.

As the example in this white paper have shown, modern x-ray systems are multi-tasking defenders of product and brand quality as well as detectors of foreign bodies. In a single pass at high line speeds, x-ray systems can perform several inspection tasks simultaneously. They can measure product mass, count components, check fill levels, identify faulty products, inspect seal quality, spot missing giveaways – and still catch foreign bodies. In short, x-ray inspection is a highly effective tool for maintaining production costs and product integrity. Most of all, it’s a tool for keeping customers happy – for checking that a product looks and performs exactly as they expect.
What are the Benefits of Fat Analysis to Meat Processors?

This White Paper focuses on the key benefits DEXA affords meat processors, with real-life examples illustrating how it enables them to:

- Verify purchased meat was accurately priced
- Achieve blending target and eliminate downgrading
- Reduce inconsistencies in recipe operations
- Achieve real-time results
- Access product tracking information quickly

What is DEXA Technology and How Does it Measure Fat Content?

More and more meat processors are relying on Dual Energy X-ray Absorptiometry (DEXA) technology for measuring the chemical lean (CL) or fat content of meat trimmings and ground beef. DEXA is capable of inspecting 100 percent of throughput in real time and has the power to help meat processors save costs.

But what exactly is DEXA technology? How does it actually work? What benefits does it offer the meat industry? This white paper takes an in-depth look at a technology that's fast becoming the global standard for CL measurement.

X-ray More Than Just Foreign Body Detection

X-ray inspection can detect numerous quality shortfalls that lie hidden within product packaging or deep within the product itself. This white paper explains that x-ray inspection is no longer just a technique for catching foreign bodies; it's become a wide-ranging tool defending brand values and keeping customers happy.

How to Select Critical Control Points

X-ray systems can be installed at any point during the production process, but choosing the most effective location/s – the critical control points (CCPs) - can prove a challenge. This white paper discusses the relevance of x-ray inspection to each stage of the production process, from raw ingredients to packaged products. It includes real-life examples to illustrate how cost-effectiveness and the efficiency of foreign body detection help determine the optimal location.

BRC Global Standard for Food Safety

This white paper takes an in-depth look at one of the GFSI's biggest standards - the BRC Global Standard for Food Safety (issue 6) and its latest requirements. Focusing in particular on traceability, quality control, foreign body detection, hygienically-designed equipment and equipment calibration; it explores how the implementation of a product inspection programme that incorporates x-ray inspection equipment helps food manufacturers achieve compliance, which is vital to stay ahead in the highly competitive food industry.

How Safe is X-ray Inspection of Meat?

Some of the most popular misconceptions about x-ray inspection of meat are tackled in this white paper. It is indispensable white paper for slaughterhouses who consider x-ray inspection to comply with meat-safety regulations and legislations.

How Safe is X-ray Inspection of Food?

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Can you Guarantee Your Chemical Lean Values

With a number of recent trends calling for highly accurate and rapidly-obtained Chemical Lean (CL) values, it's more important than ever for meat processors to be able to guarantee their CL values, and Eagle's brand-new white paper is essential reading for anyone involved in the production or processing of meat.
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What are the Benefits of Fat Analysis to Slaughterhouses?

With worldwide meat consumption on the rise and global competition becoming increasingly fierce, slaughterhouses are under constant pressure from many different stakeholders to deliver meat within specification, as well as rapid traceability and consistent profits. Reliable fat analysis is crucial to meet today’s demands and Eagle’s latest white paper shows how more and more plant and quality managers of slaughterhouses are realizing the benefits of Dual Energy X-ray Absorptiometry (DEXA) technology.

By enabling manufacturers of raw meat to manage fat in order to secure the best value and save costs, this white paper shows how DEXA technology is a prerequisite for slaughterhouses keen to define themselves in a cutthroat international marketplace.