

What food processors should know: metal detection vs. X-ray inspection

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Consumer safety has always been a primary concern for food processors. However, the recent enactment of the Food Safety Modernization Act (FSMA) has turned the intensity up even higher. (FSMA shifts federal regulator focus from responding to food contamination issues to preventing them.)

With significant costs and penalties for non-compliance, processors will be relying, more than ever before, on the latest quality control methodologies and equipment to keep the food supply safe.

Although recalls due to Listeria, E. coli and Salmonella, may be grabbing headlines, foreign object contamination is an equally important food safety issue—and an all too common occurrence.

Most raw foods and ingredients originate in a natural environment—a field, an orchard, a farm, etc. As the food is picked or harvested, foreign objects such as stones or glass can end up comingled and transported into the processing plant. Additionally, objects found in manufacturing facilities—such as metal and plastic—can also find their way into the processing stream.

Lastly, fragments of bones, pits or shells that are removed during processing can end up hidden in the final products.

In addition to more stringent regulations, retailers have also started to make product inspection demands on food processors—even refusing to do business with those not employing the latest technologies.

With these drivers currently in place, the objective of this white paper is to review the attributes of both metal detectors and X-ray systems and for which each is best suited. (The technologies are frequently deployed at different points in the production process which means it is not uncommon to find both on the same production line.) The goal is to provide food quality professionals with comparative information which can then be used to make the right decision for individual product and processing requirements.

The challenge

Metal detection and X-ray inspection traditionally have been the first line of defense to identify the presence of foreign contaminants in food products before they have the chance to leave the processing plant.

For food quality professionals, process engineers and corporate food safety executives who decide which technology will best protect them from contaminants, choosing a detection system is typically based on three things: the optimum detection point, overall application capability and total cost/benefit.

However, even though detection technologies have been employed by food processors for decades, engineering and software improvements continue to set new standards. This has led to some confusion regarding which technology to employ and why.

The basics

In security applications, such as airport screening, metal detectors use radio frequency signals to react to moving metal (e.g., coins in your pocket). X-ray systems produce density images that are analyzed for irregularities.

Deploying these technologies for food applications is more complex. The size and type of anomaly being detected is more challenging and the rapid speed in which the detection needs to take place makes the process more complex. In fact, in many cases, the real challenge isn't finding the contaminant; it is ignoring the product, packaging or environment. False detections add up to big costs and high frustrations.

Metal detectors and X-ray systems for food applications must be very sensitive, easy-to-use, fully automatic, fast, extremely robust, reliable and cost effective. This is a tall order for any automated system that must run for many years in a hot, wet factory and make reliable pass/fail decisions on literally millions of products.

Foreign object detection performance is determined in three ways: detectable contaminant types, minimum contaminant size and probability of detection.

Below is a basic summary of detectable contaminant types by technology. Please note these are general guidelines. Situations can occur when contaminants can be missed, or conversely, find foreign objects you thought weren't possible. The best practice prior to deployment is always to test many samples with different contaminants. This helps you understand how the product and contaminant react when in the detection system. *See Table 1 below.*

Table 1 — Detectable contaminant types by technology.

Detectable Contaminant Type	Metal Detectors (MD)	X-Ray Systems (XR)	Comments
Ferrous metal	● ● ●	● ● ●	
Non-ferrous metal (e.g., brass or bronze)	● ●	● ● ●	Ferrous, non-ferrous and stainless steel different for MD, the same for XR
Stainless steel	●	● ● ●	
Aluminum	●		Not dense enough for XR
Wires	● ●	●	Depends on orientation for MD and diameter/length for XR
Glass		● ●	Depends on composition
Rock		● ●	Depends on type and density
Bone		●	Calcified bone only
Plastic		●	Depends on type and size
Wood, pits, shells, insects, etc.			Not conductive for MD or typically not dense enough for XR

Minimum contaminant size depends on the system design/technology and the product effect (how much the food itself "looks like" a contaminant to the system). Probability of detection means "what is the chance of missing a contaminant in real production with real products running at real speeds?" Typically, the larger the contaminant the higher the probability of detection.

This fundamental trade-off is addressed by building in margin for error, setting periodic mandatory audits and performing preventative maintenance. Policies, procedures, training and discipline are the order of the day.

Selecting the detection point

Companies typically use Hazard Analysis Critical Control Point (HACCP) methodology to manage their food safety. The first part of the process, (HA) identifies which contaminants are most likely to occur. Next, is the determination of the (CCP)—or in the case of contaminants, the best detection point. CCPs can occur in multiple places: at the beginning of the process; after cutting, sifting or mixing; immediately after a bag or box is filled; or at the end of the line.

Ideally, the goal is to find problems early in the process to reduce the cost of rework or scrap while still ensuring the final product is safe. Inspecting large cases immediately prior to shipment is not always the right decision.

The optimum detection point can influence which technology should be employed. Metal detectors can be installed almost anywhere, but their performance depends on the size of the aperture (hole) the product passes through. In general, they work best for bulk conveyed or piped product or products in small packages.

X-ray systems are dependent on product size, too, but have greater sensitivity with large products than metal detectors. Due to the basic detector sensor scanning rate, X-ray systems are limited by speed. They are typically found closer to the end of the line. Because X-ray systems need a constant, known speed to construct images, they cannot be used in gravity flow applications. Metal detectors are ideal for these types of products.

Decision-making check list

Before making a decision, answer these fundamental questions: What contaminants do you want to find and where do they come from? See *Table 2 below*.

Table 2 — Capability comparison between metal detection and X-ray inspection.

Metal Detection	X-Ray Inspection
Detects metal including aluminum and wires.	Detects most metals and many other solid contaminants. Can also inspect a product by measuring shape, counting objects or estimating weight from the density image.
Can be used almost anywhere in a process; conveyors, drop through and pipelines.	Conveyor, bulk and pipeline; not for gravity applications.
Operates over a wide range of speeds.	Speed must be constant and range may be limited.
Conductive (wet/salty) products are the most difficult to ignore.	Dense products with a lot of texture are the most difficult to achieve good performance.
Performance dependent on aperture size, coil configuration and software.	Performance dependent on X-ray source, receiver, power and software.
Long life in even the most harsh environments.	Moderate life in harsh environments. Controlled environments are best.
Metal only usually > 1 mm in size.	Typically can find smaller contaminants than metal detectors and also nonmetallic contaminants.
Dry products, small products, piped or bulk products have best sensitivity.	Large packaged products and cases can be inspected; cans and bottles too.
Sensitive to metallic packaging so detection performance is poor.	Ideal for metalized structures.

Given all the factors that affect application performance, the best way to select a technology and specific system is to run a test. Try everything to make the system fail. Strive for near 100% probability of detection with no false readings. Make sure you have enough detection margin so the system can run trouble free for hours without false rejects or the need for calibration.

X-ray inspection guidelines

X-ray systems create grayscale images corresponding to density. To detect a contaminant in those images the contaminant must have significant contrast compared to the product the contaminant is inside.

Shown here are some typical contaminant material densities compared to water (i.e., water density = 1.0). General X-ray system capability regarding the detection of these materials is shown at right in Table 3. The only way to definitively determine what can and cannot be detected (material and contaminant size) is to have an application specialist run a test.

Table 3 — Typical contaminant material densities compared to water.

Detectable		Possibly Detectable		Not Detectable	
Iron	7.15	Nylon	1.15	Hair	0.32
Steel	7.86	PVC	1.38	Fruit	0.56
Stainless steel	7.93	Teflon	2.19	Insects	0.59
		Calcified bone	2.20	Fish bones	0.60
		Stone	2.5 (avg.)	Wood	0.65
		Glass	2.50	HDPE	0.92
		Aluminum	2.71	UHMW	0.94
		Dense rubber	1.52	Ice	0.92

Table 4 — Metal detection capability for dry, non-conductive product.

Contaminant Type	Aperture Height		
	2-6 in	6-12 in	12-20 in
Ferrous	0.9 mm	1.4 mm	1.9 mm
Non-Ferrous	1.0 mm	1.6 mm	2.2 mm
Non-Magnetic Stainless Steel	1.4 mm	1.9 mm	2.5 mm

Typical metal detection capability

Sensitivity decreases for wet/variable products. (X-ray systems also can detect metals—typically in the 0.5 mm to 2 mm range. The capability is dependent on the density and texture of the product, not the aperture size.) Table 4 (at right) is for dry products that are not conductive.

Package material trends

The need to market products in packaging materials which cost-effectively enhance shelf life has led many brand owners to convert to metallized film or foil-based structures. These materials not only provide better oxygen, moisture and UV-light barriers, but they also improve shelf presence.

However, metal-based structures are not compatible with metal detectors. On the other hand, X-ray systems have no problem seeing right through these packages and are able to detect very small contaminants inside.

Packaging material trends will continue to be a critical factor in contamination detection choices.

Missing product detection

While the focal point of this white paper is foreign object contamination, it is important to point out another benefit of X-ray detection. The technology is ideal for the detection of missing products. A good example is a tray filled with individual chocolates. With many higher-end brands garnering upwards of \$20 per pound, it is critical that all pieces are in place and not broken. The ability of an X-ray system to “see” inside a container enables it to detect not only when a contaminant is present, but also when a specific food item is not. This is not possible with metal detectors.

Equipment costs vs. failure costs

Small incidents can cost millions of dollars and lead to total business disruption. How much are you willing to risk? Weigh this against the total cost of ownership for the metal detection or X-ray system including installation, training, maintenance, repairs and the cost of downtime.

In general, metal detection systems are less expensive than X-ray units and last two-to-five times longer. If your main concern is metal contamination in small, dry products, choose a metal detector. If you want to find glass, rocks, bones, plastic, or have metallic packaging, an X-ray system can be the best return on investment.

Conclusion

Metal detector and X-ray systems have been deployed for decades. Deciding which to use can be difficult. Find vendors with both technologies and long, successful track records. They can easily provide you with the confidence you need.

Finally, make sure you fully educate your staff on use and operation. Audit the system regularly to assure your policies and procedures are being followed.

About Thermo Scientific Product Inspection

If you would like to get more information on how we can assist you with your product inspection requirements, please contact at +1 (800) 227-8891 or sales.packaging.us@thermofisher.com.

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