Considerations for detecting needles and wire in food products for better food safety

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Importance of Food Safety

There are many threats to the world food supply—and once adulteration is suspected or known, global exports and the supply chain to end users can come to a halt. This was evident in the recent tampering of fresh strawberries with needles in several regions of the world.

Contaminants can be broadly classified as either physical (foreign material detection) or biological (microbiological, pesticide residue, GMO or nutrition analysis). Growers and processors of fruit and vegetable products must take an active role to ensure that these products are safe to consume—free from both foreign material and biological hazards all the way from the farm to the fork.

The alternative is sobering. The price of a food recall or consumer warning goes well beyond the cost of lost product. These incidents can threaten the safety of consumers directly; can cause alarm among a broader range of consumers globally via news and social media; and can furthermore damage a brand's reputation, in some cases irreparably.

This paper will examine foreign object detection in such adulteration events—including discussion of the particular detection challenges in finding very small contaminants such as needles and wire in a complex and fast-moving, global supply chain of perishable products. Ensuring produce is free from foreign objects requires several considerations: a.) the type of foreign object that could be present, b.) how it may enter the process and c). where it may be present in a packaged food product. All three have implications for ensuring that foreign objects are detected and eliminated in the supply chain before reaching the end user.

Particular challenges with detection of metal slivers, needles and wire

Metal slivers, needles and wires—such as those found in the recent contamination events—are challenging to find with conventional inspection practices because of their variable size, thin shape, material composition, numerous possible orientations in a package and their light density.

It is incumbent upon food processors in this situation to analyze the entire process flow to determine where these materials could be coming from and where inspection may be needed. The biggest challenge is determining at which location(s) in the supply chain—from the field to the checkout conveyor—a needle could be inserted into a product. Ideally, unwanted items would be found early in the process during

incoming inspection. Inspection early can limit additional wear and tear of processing equipment such as dicers, slicers and cutters down the line. It also reduces the risk of further breakage of these items into multiple smaller pieces—so small they wouldn't be detectable. Additional inspection after slicers, dicers and cutters is advisable because of their risk as a source of contamination. Therefore it's possible multiple systems are needed throughout a processing facility to aid in finding the next unknown foreign object that could drastically affect your brand.

With multiple tampering incidents potentially occurring at different times and places in a relatively short period of time, it underscores the need for companies to reevaluate their Hazard Analysis and Critical Control Points (HACCP) and Hazard Analysis and Risk-based Preventive Controls (HARPC) procedures and consider them living documents. No plan can possibly foresee every possible contaminant and every possible point of entry in today's complex global marketplace for food.

We can also anticipate that such tampering could lead to changed or innovative new package types such as the use of tamper-proof seals in an attempt to better control the chain of command. Each new package type will have its own unique inspection considerations and variables, which could necessitate addressing them individually in HACCP and HARPC planning.

How can I best protect against and eliminate foreign materials from my fresh produce?

Quality control personnel work diligently to provide the manufacturing facility with the best food safety programs and processes. National food safety guidelines (such as FSMA, FDA) provide guidance in preparing the most robust solution for a particular environment. It's the quality team's job to then consider the type of inspection system to use, either metal detection or X-ray inspection, based on the types of foreign materials possible to enter the process. There must be a clear understanding of the purpose of each detection system, where to place it in your process and how to set it up to ensure all factors that could impact the detection capabilities are carefully considered and addressed in the configuration and set-up. Even after all of this is done, it's important to understand that it may still be nearly impossible to find every unknown object anywhere in the process at any time.

Metal detection and/or X-ray inspection are the two most common technologies used to find foreign objects in food. Each technology should be considered independently and based upon the specific application. Following are some key considerations.

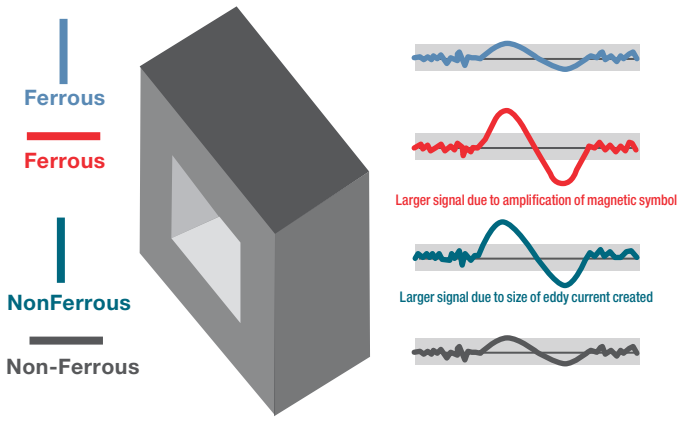
Common strengths and weaknesses of metal detection

Metal detection is based on the response of an electromagnetic field at a specific frequency within a stainless steel case. Any interference or imbalance in the signal is detected as a metal object. Metal detectors only detect metals, not non-metal contaminants. Unfortunately most food products have their own response to this field which must be first ignored during the setup of the machine. Hot, wet, conductive products have more inherent signal than dry non-conductive products which impact the detection capabilities of the machine.

Factors to consider when evaluating metal detectors are that all metals react differently, external noise (from large motors, vibration & RF interference) can negatively impact detection capabilities, the size of the metal detector limits the detection capability, and knowing there is no single best frequency for detection of a specific metal.

All products and metals also have a phase angle (a vector of the magnetic and conductive properties of the material) which also presents challenges. In some cases, these two angles can overlap and conceal the metal from being detected. This means the metal signal isn't large enough or doesn't shift the phase enough to overcome the product signal; the metal goes undetected at that specific frequency. Newer multiscan and simultaneous frequency metal detectors have lessened this impact.

In testing, the industry standard is to use spheres for quantifying performance because they are uniform for consistency. Yet, thin slivers of metal passing through the metal detector head may not have enough metal interfering with the electromagnetic signal at a given time because of their orientation affect. Below are examples of ferrous and non-ferrous wires of the same size passing through a detector in different orientations. Note the difference in signal magnitude.



To address this, food processors could install two detectors at 45° angles from each other or use multiscan detectors with many frequencies running at a time to increase the probability of catching the item. There is still risk of these items getting through to a customer, however.

The detector head size also impacts detection capability since the further the metal gets from the coils, the more difficult it is to detect small metals.

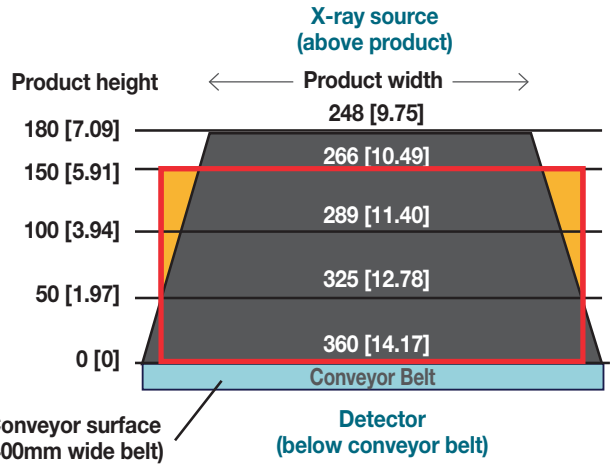
Environmental conditions in the plant can impact results, too. For example, external noise from large motors turning on/off and vibration can affect the background signal of the detector, which necessitates that the detectable size of metal be larger. This noise can also spike occasionally at any time. It may be observed as false rejects and will cause the operator to desensitize the detector. This also leads to detection of larger sizes of metals.

X-ray Considerations

X-ray inspection is a density measurement system, so some nonmetallic contaminants can be detected in certain situations. The X-ray beams are passed through the product and an image is collected on a detector. The average gray level of the product is learned as the standard and any areas that are denser (or darker) would be detected as a foreign material by the system. Here the challenges are: limitation of the photodiode size, homogeneity of the product, density of the foreign material being denser than the product being inspected, robustness of the software used to detect the foreign material, and overall size of the system (larger packages require larger systems).

In general, items that float in water are not detectable by X-ray systems, such as wood, hair, insects, most plastics and rubber. Interestingly, aluminum is often not detected because its density is low; yet it is quite reactive in a metal detector and often detected by such a machine. For an X-ray machine thin, flat metal slivers, needles and wires may not have enough density to be seen through the product when lying flat versus standing upright and vertical to the X-ray beam. In that case the diameter of the metal must be large enough to cover the majority of a diode in order to be detected.

Non-homogeneous products cause problems because the sensitivity must be set for the densest portion of the product, not the thinnest area. This often means larger contaminants are detected in these products. In this case it's important to use as many software filters as possible to find objects based on density, shape and size.



Note the yellow highlighted areas will NOT be inspected on this 150mmH x 325mmW package.

- Packages at 325mm W would have to be at or less than 50mm H in order to fit inside the X-ray beam.
- Packages at 150mm H would have to be at or less than 266mm W in order to fit inside the X-ray beam.

Thermo Scientific™ Xpert™ C400 X-ray Inspection System - Maximum package dimensions (248mmWx180mmH (9.75x7"))

The size of the equipment must be considered, especially when adding to an existing line in order to avoid the need to reconfigure it. The most critical factors here are that the package fits through the opening and the entire package is inspected in the X-ray beam. Since most systems have a trapezoidal X-ray beam, to be fully inspected, it's important to known that all corners of the package are inside the beam. Often the length of the machine is related to the opening of the machine so larger openings require a longer overall system length, which translates into a larger footprint.

Comparing metal detector and X-ray system performance in detecting needles and wire

Thermo Fisher Scientific conducted a comparison test with the Thermo Scientific™ NextGuard™ C330 (340x185mm opening) X-ray inspection system and Thermo Scientific™ Sentinel™ 5000 350x150mm multiscan metal detector on a 16oz clam shell container of fresh strawberries.

Test results- Minimum contaminant size detected 100% on 10 passes each

Foreign material	NextGuard C330 HP/SR	Sentinel 5000 350x150
FE sphere	**1 mm**	1.1 mm
NFE sphere	**1 mm**	1.5 mm
SST sphere	**1 mm**	2.5 mm
SST wire	**0.63x5 mm**	0.71x5mm NOT DETECTED
Nickle plated sewing needle	**0.54x28 mm**	0.54x28 mm
Magnetic metal wire	**0.42x9 mm** (50% - only in vertical orientation)	0.42x9 mm NOT DETECTED

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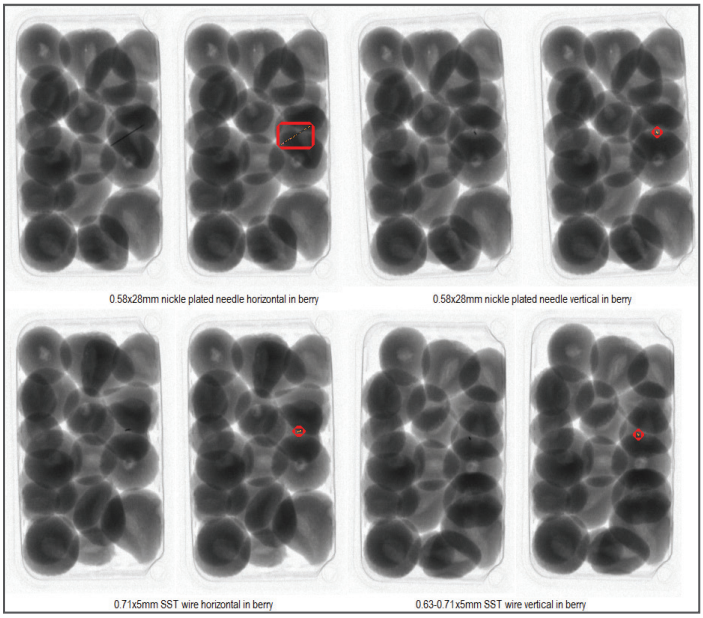
Test Image – Showing detection of wire and needles by a NextGuard C330 X-ray inspection system



Testing proved smaller sizes of standard metal spheres, needles and wires were detected by the X-ray system. All metals were tested in many orientations (vertically, horizontally in direction of flow, horizontally perpendicular to flow and at angles) to ensure successful detection.

The Sentinel metal detector only detected the sewing needle in all orientations because of its large size and the reaction within the electromagnetic field.

Sentinel metal detector

Recommendations

Even with a better understanding of each technology from this discussion, you still may not know which technology to select. Yet either metal detector or X-ray inspection is a prudent investment versus no inspection technology.

- Our recommendation for metal detection is the Sentinel 5000 metal detector with multiscan technology. This system uses 5 frequencies simultaneously to increase the probability of detecting all metals, including slivers, needles and wire of varying sizes, in different orientation and with different compositions. Typically these systems last 10-20 years depending on the environment.

- The NextGuard C330 system is the best solution for X-ray inspection. This is an entry-level system built specifically for retail packages. It is simple to operate, cost effective and will last approximately 5-8 years.

- Another option is bulk inspection of the raw fruit directly from the field using either a metal detector or a Thermo Scientific™ Xpert B600 X-ray inspection system. Running fresh fruit in a single layer through a smaller metal detector aperture will increase the detection capabilities because the product will be closer to the coils. Inspection with an X-ray system will also be improved because the product will appear more uniform in the image, making detection of foreign materials easier.

Summary

Detection of any foreign materials has challenges; they are particularly keen when finding wire and needles in fresh produce. In the future consider your product, where the material could come from in your process, the system that best fits your process based on what you expect to find, and the cost of ownership. To make the most informed decision, ask that the inspection system manufacturer test your product on their equipment so you know the expected range of outcomes and tradeoffs prior to making a purchase. Food safety and quality are vital to the health of brands and consumers. Managing the risks with the best technologies available for the job and a strong commitment to vigilant inspection practices will help brands be ready for whatever comes their way.

Find out more at **thermofisher.com/productinspection**

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