X-RAY INSPECTION:
PRIMARY VS. SECONDARY PACKAGING INSPECTION IN THE FOOD INDUSTRY

A discussion on the need for X-ray inspection in the food industry.

A Mekitec Group White Paper

Food producers, packagers, and distributors are under increasing scrutiny when it comes to the safety of their products. The complexity, scope, and speed of the supply chain have made it so that a localized issue involving food-borne contaminants can quickly balloon into a nationwide recall.

The food industry has responded by implementing stringent inspection and safety processes. For detecting foreign objects in food products, X-ray technology is an established best practice.

Thanks to improved safety processes, the incidence of foreign objects in packaged foods has decreased significantly. In the most recent FDA report, "The Reportable Food Registry: Targeting Inspection Resources and Identifying Patterns of Adulteration," foreign objects accounted for less than 1 percent of reported food safety hazards.

However, when foreign objects are discovered in food, the impact on both the consumer and the brand is immediate and visceral. These foreign objects pose a significant safety risk because of the associated choking hazards. These incidents tend to be highly publicized because they are unusual and dramatic. That compounds brand damage, in addition to possible liability. As a result, food manufacturers and packagers must be meticulous in detecting and eliminating foreign objects before goods are distributed. Contamination incidents can also put contracts with large retailers at risk, depending on how stringent their requirements are.

The FDA considers a product adulterated if it contains hard or sharp foreign objects that measure 7mm to 25mm (1/4 to almost one inch) in length and is "ready to eat" or requires minimal enough preparation that cooking would not neutralize the hazard prior to consumption. These physical haz-

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ards vary depending on the type of food, but the most common objects found in food are glass, metal, plastics, wood, and stones. The contamination may occur during harvesting, processing, packaging, or at other stages in production.

While the FDA definitions only consider objects as small as 7mm, a shard of glass or piece of wire smaller than that could cause significant internal injury, particularly for small children.

Once food products are packaged, the only effective way to screen for physical contaminants is by using X-ray inspection equipment. X-rays use electromagnetic energy to provide internal imaging of food products. This allows producers to detect physical contaminants (or other defects) without damaging the food or packaging. Contaminants that are denser than the food product will show up as dark spots in the final image. The software solution managing the inspection process can be configured to initiate alerts, line stoppages, and other responses depending on the size or density of the foreign body.

These solutions can be used to detect objects in packaged goods, grade fruits and vegetables, and even detect bones in meat, poultry, and fish. They can also be configured to perform other tasks, including monitoring fill levels, counting items, identifying damaged or broken products, and detecting other types of physical defects.

X-ray inspection systems deployed at critical control points (CCPs) as defined in the Hazard Analysis and Critical Control Point (HACCP) guidelines can reduce or eliminate foreign object contamination by accurately detecting contaminated products and removing them from the supply chain prior to distribution.

For manufacturers, the key question then becomes where the X-ray inspection points should be placed — after the product has been sealed in its primary packaging, or once products have been consolidated into cases or other secondary packaging units. While the latter appears to present some installation and cost advantages by reducing the number of X-ray inspection points required, primary packaging inspection has proven to be a more reliable and cost-effective strategy.
This white paper will outline the pros and cons associated with primary vs. secondary packaging X-ray inspection strategies.

Critical Control Points For Inspection

A holistic food safety program should include raw material inspections, vender certifications, pest control at each facility, metal detectors, sanitation processes, and X-ray technology. To ensure the efficacy of these programs, the USDA created the HACCP management system to address food safety through the analysis and control of biological, chemical, and physical hazards in the food supply chain.

HACCP is organized around seven principles:

1. Conduct a food safety hazard analysis
2. Determine the CCPs (points at which a hazard is optimally controlled)
3. Establish critical limits for each CCP
4. Establish CCP monitoring procedures
5. Establish corrective actions
6. Establish record-keeping procedures
7. Establish verification procedures

The key to successfully eliminating the danger of physical hazards is to identify what the risks are (which contaminants are likely to end up in your products, given the nature of the ingredients, the facility, packaging, and equipment involved) and where those contaminants are likely to be introduced. Producers should then establish size tolerances and corrective actions.

X-ray inspection of the product should occur after the packaging is sealed and once there is no further opportunity for additional contamination. Producers then must determine where to place the X-ray equipment, how many points of inspection to establish, and at what packaging level they will conduct X-ray inspections.

Inspecting products once they are enclosed in primary packaging may entail establishing CCPs on multiple production or packaging lines to ensure that each item is fully inspected prior to being packaged for shipment.

Because the installation of X-ray devices can potentially be costly, complex, or disruptive, it is tempting to install as few units as possible, and as close to the the end of the packaging process as possible. In many cases, that means establishing a CCP after products have been placed in secondary packaging at the case level. All products would then theoretically pass through a single point of inspection prior to shipment.

However, while secondary packaging inspection can present cost benefits, this method is often less reliable and provides less value to the end user in terms of risk mitigation or additional functionality. To effectively gauge whether to utilize X-ray inspection at the primary or secondary packaging level, we will evaluate both operational and technological considerations that affect that decision.

Operational Considerations

Comparing the relative benefits of primary and secondary packaging inspection requires evaluating a number of factors. On the operational side, the velocity of the packaging operation, the nature of likely contaminants, and your company's tolerance for waste will affect your approach to the X-ray implementation. Considerations include:

Number Of Systems Required: For facilities with multiple product lines, primary packaging inspection would require multiple X-ray systems, while secondary inspection would involve fewer, larger systems. However, primary packaging systems provide a number of benefits (described below) that outweigh the additional investment. In addition, larger secondary inspection systems can be more expensive to repair and maintain over time.

Product Size And Pack Rate: Primary systems allow you to inspect smaller products at a much higher pack rate (as many as 200 to 300 packs per minute). Secondary packaging systems inspect larger pack sizes and at a much slower rate (between 10 to 20 packs per minute, on average).

Contaminant Detection Success: Primary systems provide the best contamination detection rates — less than 1.2mm (about ½ of an inch) for metals, and as low as 2mm to 4mm (about 1/16 to 3/16 of an inch) for low-density objects like glass — providing better protection than secondary systems, which may only detect objects down to 5mm or 7mm (about 3/16 to 1/4 of an inch), and may completely miss low-density contaminants.

Waste: The more homogenous the product is, the less likely it is to create false positives caused by variance in the product. In a primary inspection system, a false positive results in the loss of one package. In secondary packaging systems, a false positive can lead to the scrapping of an entire case of product, including products that are not contaminated.

Traceability And HACCP Record Keeping: Primary inspection systems provide much more granular data, including the ability to track throughput, manage images on a per-line basis, identify which line

produced the contaminated product, calculate the pack rate and time of pack production, and time-stamp rejections. Secondary systems provide poor individual product traceability. By the time the contamination is identified, you could have produced many thousands of packs between the primary and secondary pack operation. That leads to more scrapped product and more waste.

Individual Product Inspection: Primary inspection systems are optimized for an individual product, providing a lower false reject rate and better detection. Secondary pack inspection systems have compromised settings to account for a variety of products on the same line, which can lead to false positives caused by packaging or the way products are stacked in a case.

Additional X-Ray Features: Primary inspection systems provide the opportunity to take advantage of additional features that can help improve operations including size checks, closure checks, fill levels checks, and other applications that can accelerate the return on investment (ROI) in the X-ray system. In secondary inspection systems, these benefits are largely lost.

HACCP Control Point Qualifications: Secondary inspection systems may not be accepted as a true CCP because they are positioned so late in the process and may be unable to eliminate the risk of smaller or nonmetallic contaminants. Primary inspection systems are a well-accepted CCP.

Impact of System Malfunctions: If an X-ray system goes down, fewer products are affected in primary packaging inspection scenarios. If a secondary packaging inspection system goes down, the company is unable to inspect any products from all production lines.

Ease of Installation/Floor Space Considerations: Primary systems require minimal space and are easy to install. Secondary inspection systems require much more space (to accommodate larger pack sizes) and more complex installations.

Technology Considerations

There are also technological differences between primary and secondary packaging inspection solutions that affect the cost to use, maintain, and repair the X-ray equipment. These factors can affect the cost and complexity of the implementation, as well as the overall performance of the solution in a given facility. Those considerations include:

System Size And Energy Usage: Primary inspection systems are smaller and use lower energy X-rays, which affects power consumption. They also generate less heat. The heat that is emitted can be easily managed with fans. Secondary packaging systems not only consume more energy, but they also generate excessive heat that requires special air conditioning equipment to prevent overheating. For busy facilities, that heat can also damage the X-ray power supply/generator.

Shielding And Curtain Material Requirements: Secondary packaging inspection systems require more shielding to prevent X-rays from “leaking” from the cabinet compared to primary systems. They also require more curtain material for the entry and exit points on the conveyor line. The extra curtain materials can also flip lighter boxes or cause line jams if boxes cannot pass through the material.

Low-Density Contamination Detection/Contrast: Primary systems are able to better detect low-density contaminants because lower-energy X-rays provide higher contrast. Secondary inspection systems, on the other hand, perform poorly with low-density contaminants because they have reduced contrast.

Equipment Life Cycle: The lower-power X-rays in primary inspection systems typically have longer generator life than those in secondary inspection systems. Because those generators can cost upwards of $20,000 to replace, the longer life cycle in primary inspection systems can drive down the TCO.

Beam Geometry/False Reject Rates: Primary inspection systems provide an optimal X-ray beam geometry (the angle the X-ray beams passes through the product), resulting in optimal inspection and lower false reject rates. This is because inspecting individual products requires less engineering to produce a simple image. In secondary packaging systems, the beam has to pass through the full height of the package/case, and the cardboard can create dark lines transposed over the product. That means contamination detection is poor in those areas affected by the transposed image. Primary inspection systems can also use a masking feature to "mask" away the edges of a product package so the system only focuses on the product inside; this feature is nearly impossible to use in secondary packaging systems.

Conclusion

For food manufacturers and packagers, utilizing X-ray inspection systems at CCPs to examine primary packaging provides an advantage in accuracy, reliability, and cost compared to secondary packaging inspection systems. That is why primary packaging inspection has been established as a best practice in the food industry. Less than one in 40 X-ray units in place at food manufacturing facilities are large-format secondary inspection systems. The vast majority are in place to inspect singe product units.

Using X-ray systems to inspect primary food packaging enables companies to detect a wider variety of physical contaminants more accurately, which improves safety and reduces the risks and costs of false rejects. Primary packaging inspection systems are smaller and easier to install and maintain, and they can be used for additional inspection applications that can boost the return on investment in the technology.

About Mekitec

Mekitec has combined experience spanning several decades in the development, industrialization, and manufacturing of X-ray imaging systems in medical, security, and safety areas. This unique combination of in-depth knowledge of various industries has enabled the management to invest in long-term research and development, especially for the food industry. The results of this focus and dedication are the state-of-the-art X-ray food safety systems that Mekitec supplies to its customers globally. The MEKI X-ray inspection system helps maintain consistent product quality to HACCP standards. Through offices in the U.S., Europe, and Asia, it continues to expand its sales and support network globally.

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www.mekitec.com
info@mekitec.com