White Paper

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

Contents

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What is DEXA technology and How Does it Measure Fat Content of Meat?

Dual Energy X-ray Absorptiometry (DEXA) technology is already well-known in the medical industry where it's been utilized for many years for bone density scanning and is typically used to diagnose osteoporosis and other conditions causing bone loss, as well as measure body composition. Airport security scanners are also based on DEXA and are capable of detecting anything from fruit and organic matter to explosives and weapons.

As profit margins tighten, the meat industry is increasingly realizing DEXA's potential as a non-invasive and highly-accurate inline method of measuring the chemical lean (CL) or fat content of meat trimmings and ground beef.

By determining the CL value of fresh, chilled and frozen meat, DEXA allows meat processors to inspect 100 percent of throughput in real time and is capable of improving their bottom line by offering unprecedented fat management capabilities.

But what exactly is DEXA technology, how does it actually work, and 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.

Please note that while aimed at anyone involved in the production or processing of meat, including plant and quality managers of slaughterhouses and abattoirs, meat packers, distributors and processors, for simplicity, the paper refers to everyone collectively as meat processors.

DEXA is an enhanced form of x-ray technology and the latest development in x-ray for product inspection. Designed to discriminate between materials based on their atomic number, it enables real-time scanning of meat trimmings and ground beef for meat composition.

For this reason, the white paper will begin by explaining what x-rays are and the main components and operating principles of an x-ray inspection system, before focusing specifically on how DEXA technology works, and exploring its primary benefit and typical applications in the meat industry.

1. What are X-Rays

X-rays are one of several naturally-occurring sources of radiation and are an invisible form of electromagnetic radiation like radio waves or visible light. All types of electromagnetic radiation are part of a single continuum known as the Electromagnetic Spectrum (Figure 1), which is arranged according to frequency and wavelength, and runs from radio waves at one end (which have a long wavelength) to gamma rays at the other (which have a short wavelength).

The short wavelength of x-rays enables them to 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 - the denser the material, the fewer x-rays that pass through.

Dense foreign bodies like glass, bone and metal show up because they absorb more x-rays than the surrounding product, which is why food manufacturers across the globe rely on x-ray systems to detect and reject contaminated products from the production line in order to protect consumers, reduce the risk of product recalls and safeguard their brands.

2. Principles of X-ray Inspection

In simple terms, an x-ray system uses an x-ray generator to project a beam of low energy x-rays onto a sensor or detector. X-ray inspection involves passing a product or pack through the x-ray beam before it reaches the detector. The amount of x-ray energy absorbed during the beam's passage through a product is affected by the product's thickness, density and atomic number. When the product passes through the x-ray beam, only the residual energy reaches the detector and measurement of the difference in absorption between the product and a foreign body is the basis of foreign body detection in x-ray inspection.

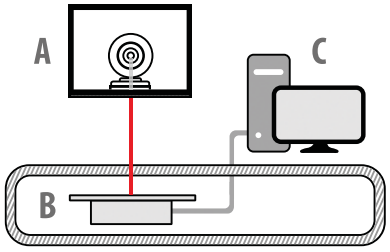

Figure 2: Components of an X-ray System

2.1 What Makes Up An X-ray System?

There are three key components of an x-ray inspection system:

- An x-ray generator (A)
- A detector (B)
- A computer (C)

The x-ray beam is generated by an x-ray tube encased in the x-ray generator. It leaves via an exit window and travels in a straight line through a collimator (a device for narrowing the stream of x-rays to a smaller fan beam). The x-ray beam then passes through the product or pack being inspected, before finally reaching the detector.

2.2 X-ray Generator

The x-ray generator contains an x-ray tube which generates an x-ray beam. Modern x-ray tubes consist of a glass envelope, a filament cathode, a copper anode and a tungsten target. The cathode (A) which

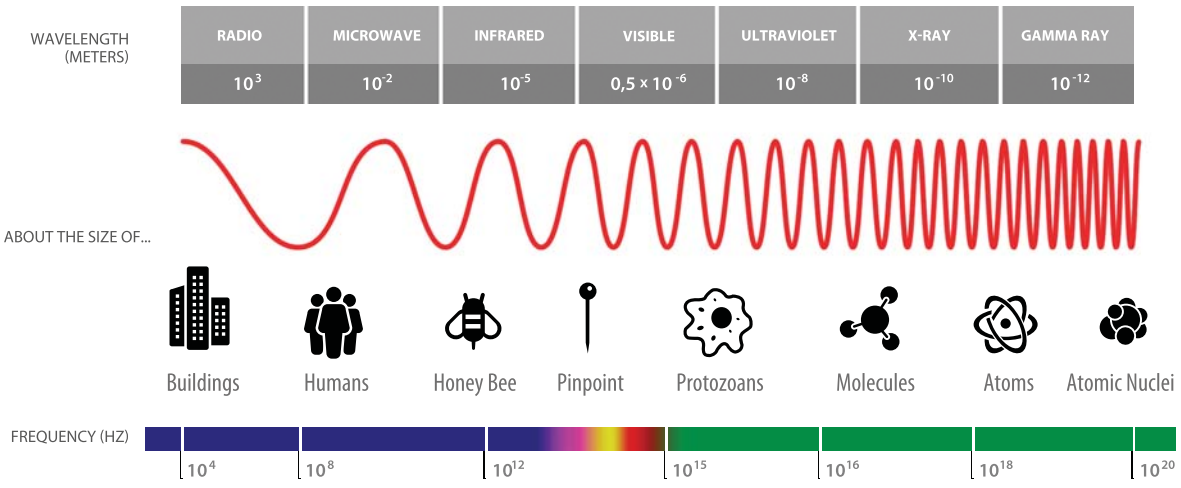

Figure 1: Electromagnetic Spectrum

is the source of the electrons is a tungsten filament heated to incandescence by an electrical current. The electrons are accelerated to the target (B) by applying a high voltage between the anode (C) and the cathode.

When the electrons hit the tungsten target mounted inside the copper anode, they decelerate rapidly and this deceleration creates the x-ray emissions (Figure 3). Depending on the application, different x-ray tubes can be selected to optimize the sensitivity of detection and overall performance (Figure 3).

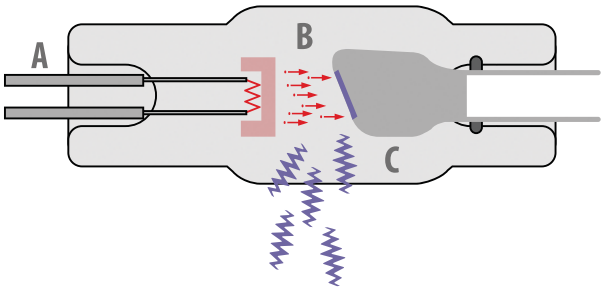

Figure 3: X-ray Tube

2.3 X-ray Beams

Choosing the right system is fundamental to the success of x-ray inspection as systems can't optimally detect foreign bodies unless each element from beam angle to reject mechanism has been chosen to best fit the application. Most x-ray systems use a vertical x-ray beam from the generator to scan the product as it passes through the x-ray system (Figure 4).

2.4 X-ray Detector

An x-ray detector is to x-ray as a camera is to light, a way of capturing x-ray energy and converting it into an image form that can be processed by electronics. Regular x-ray systems contain one detector which consists of individual elements called diodes that convert the level of detected x-ray energy into an electrical signal that's sent back to the machine's onboard computer.

2.5 Building an Image

An x-ray inspection system is essentially a scanning device. When a product passes through the system at a constant speed, the x-ray detector captures a 'greyscale' image of the product, which is generated by measuring the amount of x-ray energy reaching the detector (Figure 5).

Each image is made up of 'pixels' and the x-ray energy absorbed by each pixel creates a value on a greyscale (from black 0 to white 255). As the product or pack passes over the detector, each line of grey level data is added to previous lines, much like slices of bread can be added to form a loaf, resulting in a complete product image.

Software within the x-ray system analyses the image and compares it to a predetermined acceptance standard. On the basis of this comparison, the system either accepts or rejects the image (and the product/pack it represents) and in the case of rejection, software sends a signal to an automatic reject system, which then removes the product from the production line (Figure 6).

3. How Does DEXA Technology Work?

Like standard x-ray systems, DEXA technology involves using a generator to project an x-ray beam onto a detector and passing a product through the beam.

However, DEXA diverges from regular x-ray inspection as it uses two energy spectrums to discriminate

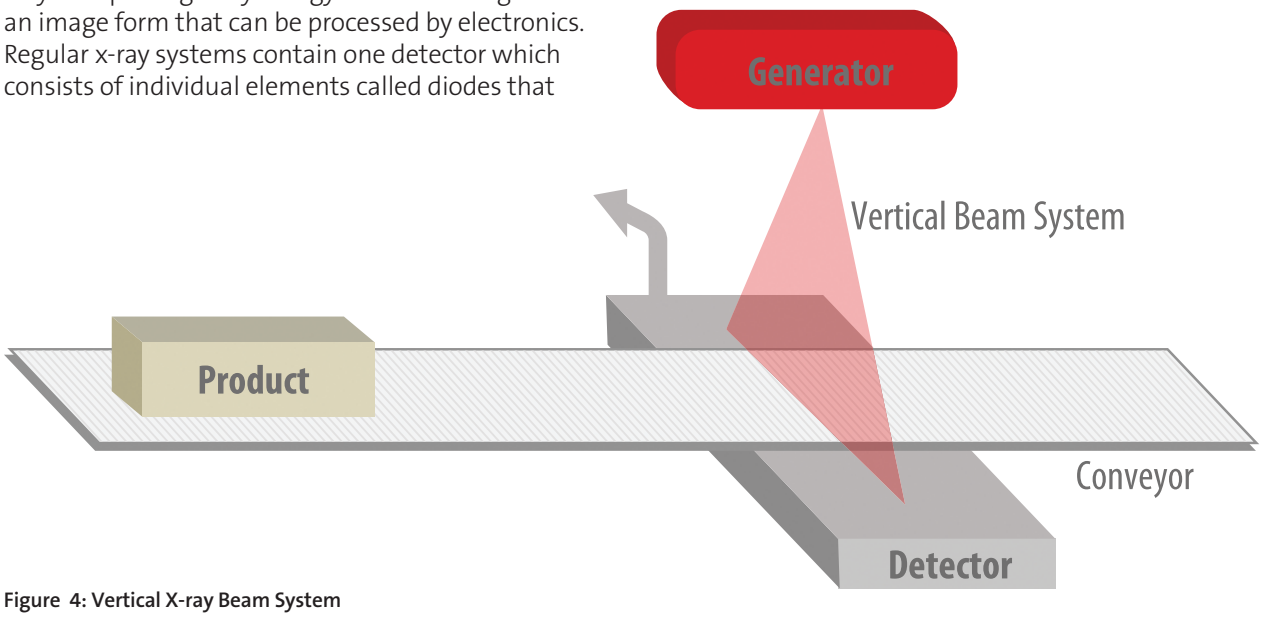

Figure 4: Vertical X-ray Beam System

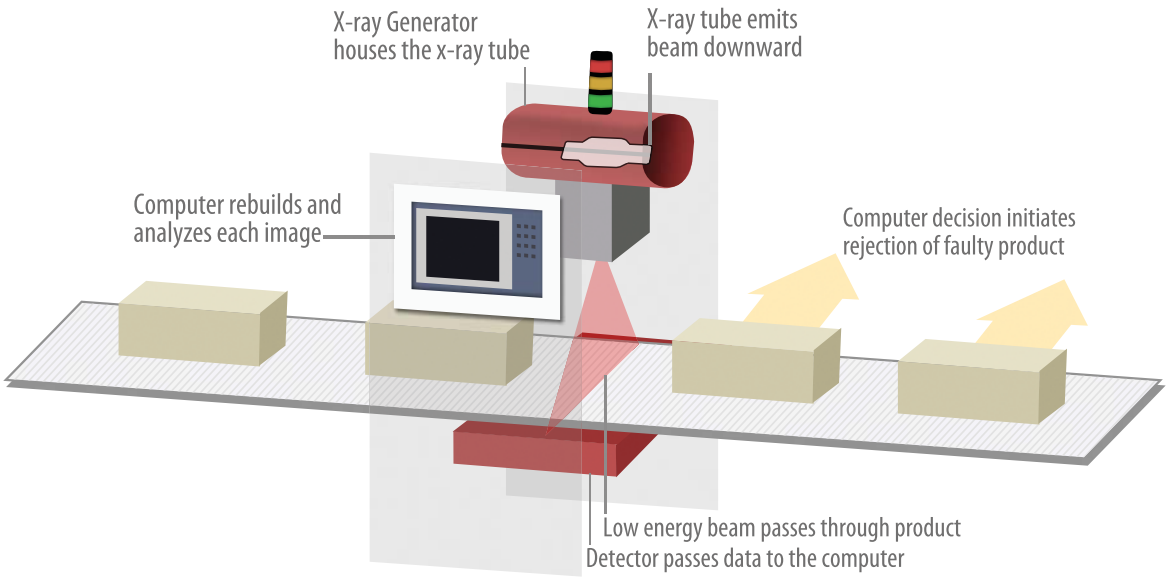

Figure 5: Building the X-ray Image

between high and low channel x-rays, as well as two detectors - one sandwiched on top of the other.

While the top detector has a chemistry that makes it sensitive to lower energy (longer wavelength x-rays), the bottom detector has a chemistry that makes it sensitive to higher energy (shorter wavelength x-rays).

This creates a combined detector array that, when illuminated by x-rays from the top, is capable of sensing x-rays at two different groups of wavelengths or energies, thus constituting the "DEX" or "dual energy x-ray"part of DEXA (Figure 7). If an x-ray beam is projected through a vacuum onto the detector array, signals from each detector will correspond directly to the output from the x-ray source as nothing is in the way to absorb or scatter the x-rays.

However, when an x-ray beam is projected through a piece of meat, some of the energies will be absorbed while others will pass through. What gets absorbed and what passes through depends on the meat's composition.

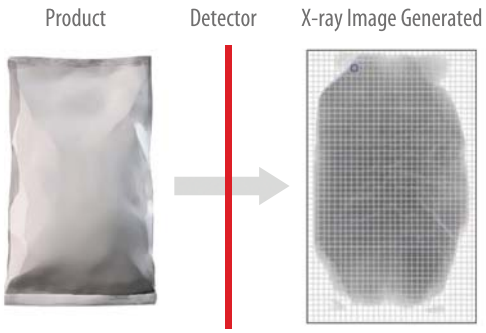

Figure 6: X-ray Image Generation

Meat is made up of elements and each element has its own atomic number. For a given x-ray energy, as the atomic number increases, the element absorbs

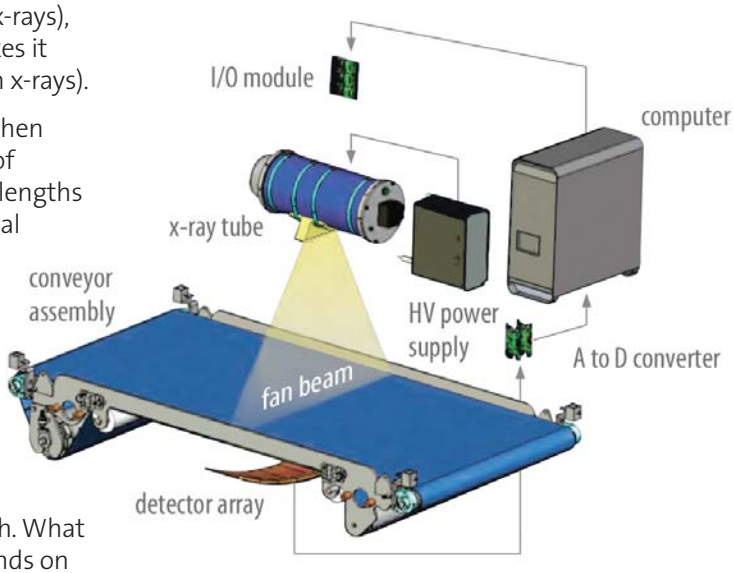

Figure 7: DEXA System Components

more x-ray energy and passes less. So carbon, with an atomic number of six, absorbs much less x-ray energy than lead, with an atomic number of 82. Lead absorbs almost all x-ray energies which is why it's commonly used as shielding in places like medical x-ray labs.

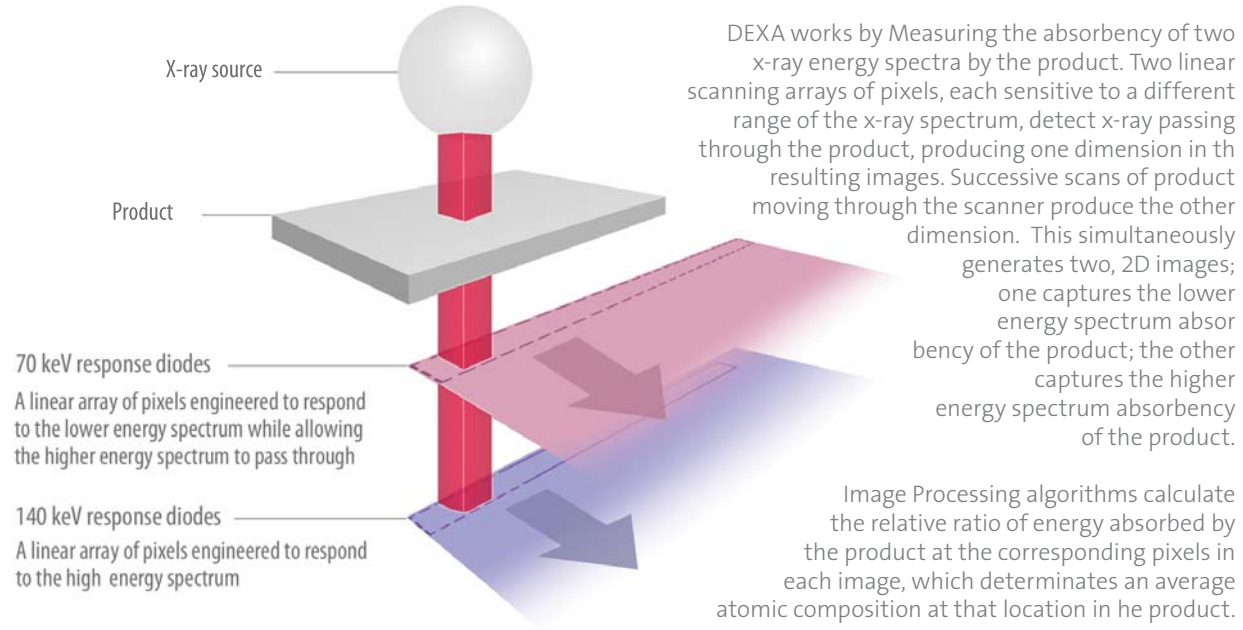

Figure 8: How Dual Energy X-ray Absorptiometry Works

3.1 How does DEXA Measure Chemical Lean?

Chemical Lean (CL) is a numerical value that represents the crude fat content of a portion of meat. While DEXA is capable of reporting CL, it doesn't directly measure it. CL is calculated by subtracting fat percentage from a flat rate of 100, i.e. CL = 100 - chemical fat percentage. This means that a fat percentage of 10 will result in a CL value of 90.

CL is the fundamental determiner of value in meat trimmings, with CL percentages used by the meat industry to establish products' pricing Whether packing or processing meat, knowing the actual lean point enables meat processors to capitalize on its true value.

Traditionally CL is measured in a laboratory procedure called the Soxhlet method where a sample of meat is weighed, the fat is extracted from the sample and weighed, and the weight of the fat divided by the weight of the sample yields fat percentage. CL is therefore presumed to be anything that's not fat.

The Soxhlet method is the industry standard reference model against which other fat analysis methods are compared for measurement agreement. In order to reconcile a varying ratio of x-ray energies with this classic model, a mathematical technique called regression is used, which maps the DEXA ratios to Soxhlet values. This means that when a DEXA ratio is detected, it can report a value that's valid with the Soxhlet method.

In addition to the Soxhlet method, a number of other methods of determining the fat content of meat exist, including Anyl-Ray and NIR and NIT Spectroscopy, which are the most common methods of CL testing used by meat processors today.

A separate white paper entitled Can You Guarantee Your Chemical Lean Values? explores these methods in greater depth, as well as their applicability for current market pressures, and highlights several inherent limitations that make it difficult for meat processors to guarantee the fat content of meat using them.

The white paper concludes that the focus is now shifting to inline analytical methods of calculating CL using DEXA technology, which are capable of meeting recent trends calling for highly-accurate and rapidly-obtained CL values.

4. Fat Management

A fine line divides success and failure in today's highly-competitive meat industry. With meat processors operating on very tight profit margins, there's little scope for error in production processes.

DEXA technology can play a critical role in helping meat processors manage fat in order to secure the best value and improve their bottom line.

For slaughterhouses, fat control is driven by reduction of seen (and unseen) lean giveaway, as well as the costs associated with fat claims. For meat processors, it's driven by recipe management, reformulation and efficiency.

Meat processors who rely on traditional laboratory CL testing methods can't be certain of the accuracy of their fat control as they can't characterize 100 percent of their production. Consequently, to avoid

costs associated with fat claims*, they're inclined to purposefully overpack lean via visual lean (VL) measurement**. The net result is that they tend to give away up to several percent. In contrast, by inspecting 100 percent of throughput and accurately producing CL values within +/- 1CL (this means it will be within 1 CL of the real CL value), DEXA technology offers greater precision and has the capacity to eliminate fat claims and lean giveaway. For the first time, it allows users to claim that the 'spec you buy is the spec you get'.

Furthermore, as lean has high value and fat has low value, it's in meat processors' profit interests to pack as much fat as possible with lean without violating customers' packing specifications. If they don't, that fat goes to rendering at low value. Fat management is about recovering this value.

By allowing tighter production control and enabling meat processors to make optimal use of raw materials by getting fat content consistently right, DEXA affords meat processors unprecedented fat management capabilities.

In addition to calculating the CL value of meat, DEXA technology combined with traditional x-ray systems used in the food industry can simultaneously yield weight measurement which is critical for batch and recipe management, and can also help meat processors comply with rigid food safety standards by detecting foreign bodies, such as metal, glass, stone and calcified bone.

5. Applications

Unlike other methods of CL testing, DEXA technology is not limited to boneless, ground meat and is capable of inspecting all uncooked meat, whether fresh or frozen, bulk, blended or packaged in cartons, providing it's devoid of other ingredients. In addition, it's not affected by freeze/thaw plant conditions, metal foil or meat conductivity. Applications include meat cartons, bulk meat and bulk meat blend control.

Two separate white papers will also be released in November 2012 which specifically address the needs of slaughterhouses and meat processors, and expand on how DEXA works in different applications.

6. Conclusion

DEXA is an acronym for Dual Energy X-ray Absorptiometry, an enhanced form of x-ray technology.

As this white paper illustrates, DEXA shares some similarities with regular x-ray inspection, but also diverges.

The technology works by measuring the amount of x-rays that are absorbed by fat and lean through the use of two specific x-ray energies. By taking the ratio of energy absorbed at a high energy to the level of energy absorbed at a lower energy, the resulting ratio can be used to infer the average atomic numbers of the scanned material.

Two separate images are then generated by the two spectra of energy and a relative ratio of energy absorbed can be calculated to determine a material's average atomic composition.

By quickly and accurately establishing the composition of meat, DEXA enables tighter production control and affords meat processors heretofore unprecedented fat management capabilities.

As a result, DEXA technology is blazing the trail in CL conformance and proving to be indispensable for meat processors keen to improve their bottom line and become key players in the highly-competitive and increasingly global meat industry.

* A fat claim is a penalty a purchaser of meat product charges a supplier for the supplier's failure to deliver a meat shipment that meets required fat/lean specifications.

** Visual lean measurement is a subjective estimation of fat/lean in meat trim made by a person experienced in making such estimations strictly on visual appearance alone. Generally, visual lean is considered to be within ~ +-/5 points of chemical lean.

NOTE: All methods for rapid CL analysis are based on 'indirect' analytical methods. This means the result is not generated from a direct measurement, as is the case for many of the traditional laboratory methods. Indirect methods must be verified periodically according to reference methods.

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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 Thank 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; its 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?

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

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.

Free X-ray White Papers

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X-ray More Than Just Foreign Body Detection

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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.

Notes

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