White Paper

SAFELINE
X-ray Inspection

White Paper

How Safe is X-ray Inspection of Food?

Contents

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Some food manufacturers have reservations about the adoption of x-ray inspection as a method of product inspection. They are concerned that their staff will object to bringing x-rays into the workplace and that consumers could switch to another brand that's not been subject to x-ray inspection.

People are right to be wary of radiation. But that does not mean they should be worried about the use of x-rays in food inspection. The levels of radiation used for x-ray inspection in the food industry are extremely low, and the use of x-ray inspection equipment is both highly regulated and increasingly common.

This white paper assesses the safety of x-ray inspection of food.

1. Why Use X-rays to Inspect Food?

Food manufacturers use x-ray inspection technology to ensure product safety and quality. X-ray inspection gives them exceptional levels of metal detection for ferrous, non-ferrous, and stainless-steel. The technology is also extremely good at detecting other foreign bodies such as glass, stone, bone, high density plastics, and rubber compounds (Figure 1). X-ray systems can also perform simultaneously a wide range of 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.

Figure 1: X-ray image of a contaminated can of milk powder

Increasing line speeds and consumer expectations have put pressure on food 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, and Good Manufacturing Practice, as well as 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 food manufacturers comply with national and international regulations, local legislation, and standards set by retailers.

2. X-ray Radiation vs. Radioactivity
2.1. What are X-rays?

X-rays are invisible as they are a form of electromagnetic radiation, like light or radio waves. All types of electromagnetic radiation are part of a single continuum known as the electromagnetic spectrum (Figure 2). The spectrum runs from long-wave radio at one end to gamma rays at the other.

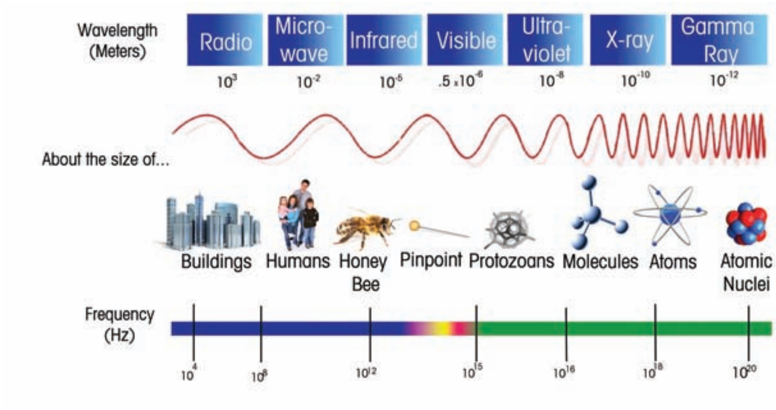

Figure 2: Electromagnetic specturm

The wavelength of x-rays enables them to pass through materials that are opaque to visible light. The transparency of a material to x-rays is broadly related to its density and that's why x-ray inspection is so useful in the food industry. The denser the material, the fewer x-rays that pass through. Hidden contaminants, like glass and metal, show up under x-ray inspection because they reflect more x-rays than the surrounding food.

X-rays used in food inspection systems **should not** be associated with radioactive materials such as uranium. Radioactive materials are physical sources of radiation. They emit radiation in the form of alpha particles, beta particles, and gamma rays– and they do it continuously, which is why they cannot be switched off. The only way to contain radiation from a radioactive material is to encase it in a substance that absorbs radiation.

X-rays used in food inspection are different. Like light from a bulb, they can be turned on and off at will. Switch off the electricity supply to the x-ray system, and the flow of x-rays ceases instantaneously.

Figure 3: X-rays can be turned on and off like a light bulb

2.2. Radiation in Everyday Life

X-rays are just one of several naturally occurring sources of radiation. The combined effect of all these sources is known as background radiation – and humans have been exposed to it since the beginning of time. Our modern daily dosage is higher than for previous generations because the radiation used in medical science has contributed to an increase of background radiation received by about 18%. That might sound like a big increase, but the overall levels are so small that the increase is negligible.

The chart below (Figure 4) shows the four major sources of radiation that add up to the background radiation received by a typical person.

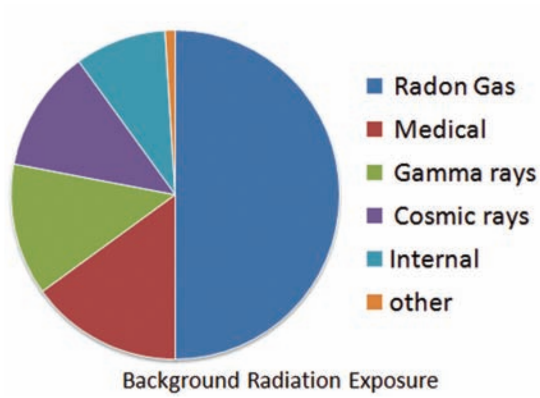

Figure 4: Major sources of background radiation

Radon Gas
Produced by the decay of radium-226, which occurs wherever uranium is found. Radon seeps out of uranium-containing soils and rocks, typically granite. The proportion of radon in background radiation varies, but is typically around 50%. It's often the single largest contributor to background radiation.

Cosmic Radiation
Cosmic radiation rains down on earth from space. All living things are exposed to cosmic radiation, although the earth's atmosphere filters some of it out.

Internal Radiation
Internal radiation occurs when someone inhales or ingests radioactive material, usually in the form of fine dust. Radiation from these tiny particles reaches the internal organs.

Medical Radiation
Chest and dental x-rays are the chief source of artificial radiation. They contribute 15% of all background radiation.

2.3. Putting Radiation Doses into Context*

From the point of view of occupational exposure, the accrued radiation dose is the most important measure. Occupational exposure limits are given in terms of the permitted maximum dose. The SI unit of radiation dose is the sievert (Sv). As occupational exposure levels are normally low, smaller units – millisievert (mSv: a thousandth of a sievert) or microsievert (µSv: a millionth of a sievert) – are more commonly used. The radiation dose rate measures the rate at which radiation is absorbed over time. This is expressed in µSv/h (Dose Rate = Dose (µSv) ÷ Time (hours)).

For the average human, natural background radiation contributes about 2,400 µSv (2.4 mSv) of radiation in a year from natural sources (Table 1). This typically far exceeds the radiation exposure received from an x-ray inspection system in the food industry. The typical maximum dose rate immediately adjacent to an x-ray inspection system is <1 µSv (0.001 mSv) per hour. Which means an operator would receive 2,000 µSv (2 mSv) per year when working 50 weeks a year and 40 hours each week in direct contact with an x-ray system.

Source	Average Dose (mSv/year)	Typical Range (mSv/year)
Space	0.4	0.3 - 1.0
Earth	0.5	0.3 - 0.6
Human body	0.3	0.2 - 0.8
Radon	1.2	0.2 - 1.0
Total (rounded)	**2.4**	1 - 10

Table 1: (Source: Radiation Threats and Your Safety, Armin Ansari, 2010, page 10)

Naturally occurring x-rays come from outer space. Our daily dose is small because the atmosphere filters most of it out. The filtering effect declines with altitude. Those who fly absorb more x-rays than those who stay on the ground.

A frequent flyer, for example, absorbs around 8% more radiation 200 µSv (0.2 mSv) than a non-flyer. The frequent flyer's typical annual dose is about 2,600 µSv (2.6 mSv) a year. Pilots and cabin crew absorb more still: about 4,400 µSv (4.4 mSv) a year, depending on routes flown and total flying time. Their annual dose of radiation is typically greater than workers at a nuclear plant – and almost twice as high as those who spend their lives at ground level. Even so, the frequent flyer's additional dose of radiation is extraordinarily low. If you ate one jar of mussels every week for a year, you'd absorb an extra 250 µSv (0.25 mSv) – more than the frequent flyer.

Whatever you do on planet Earth, you come into contact with radiation.

Figure 5
Eat a jar of mussels every week for one year = 250 µSv/year

Figure 6
Frequent flyer's = 200 µSv/year; Airline pilots and air crew = 200 µSv/year

Figure 7
Maximum permitted leakage levels from an x-ray system:
1 mSv/year (RoW regulations),
5 mSv/year (US regulations)

3. X-ray Inspection vs. Food Irradiation

Food processors use x-rays in two ways:

1. To inspect food for contaminants or quality control, and
2. To irradiate food (a process that destroys bacteria)

The technologies are similar – both processes involve radiation – but that is where the similarity ends. Dose levels equivalent to several orders of magnitude separate food irradiation from food inspection.

X-ray inspection of food doesn't cause it to become radioactive, just as a person doesn't become radioactive after having a chest x-ray.

There is scientific evidence to show that x-rays do not harm food. A 1997 study by the World Health Organisation (WHO) confirmed that food radiation levels up to 10,000 Sv do not affect food safety or nutritional value. That means the food was subject to radiation doses around ten million times as strong as those used in x-ray inspection. It proved that the food remains safe to

* For the purpose of this document only the measurement Sievert (Sv) is used although it is common to use Gray (Gy) as the standard unit of absorbed radiation dose (1Gy = 1Sv).

eat and that it loses none of its nutritional value. This view is supported by the experience of leading brands across the world. Those that have already switched to x-ray inspection find that consumers experience no change in quality.

The dose levels used in x-ray inspection are less than one ten millionth of those used in the WHO study. Food that passes through an x-ray inspection system spends about 250 milliseconds in the x-ray beam. During that short time it receives a radiation dose of around 200 µSv (0.2 mSv). The levels are so low that organic food can be subject to x-ray inspection with no diminution of its organic status.

In comparison to x-ray inspection the dose levels for food irradiation are much higher and range from 500 Sv up to 10,000 Sv in approved protocols for food items.
(Source: Radiation Threats and Your Safety, Armin Ansari, 2010, page 311)

Whichever way you look at it, food that has passed through an x-ray inspection system is as good and tasty to eat as it was before it was scanned. There are no measurable changes to flavours, textures, or nutritional values: food that has been x-rayed is indistinguishable in every respect from food that hasn't.

Good food remains good food.

4. X-ray Systems are Safe by Design

There are three key components of an x-ray inspection system: (Figure 8):

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

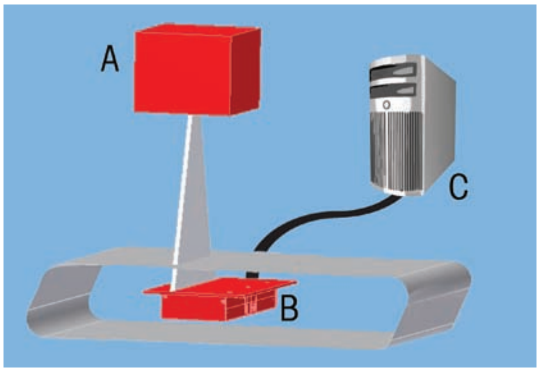

Figure 8: Components of an x-ray system

After leaving the exit window of the x-ray generator, the x-ray beam travels in a straight line through a collimator (a device for narrowing the stream of x-rays to typically a 2mm wide fan beam), through the food product, and on to the detector.

Figure 9: Stainless steel x-ray cabinet

The whole assembly is encased in a stainless steel x-ray cabinet (Figure 9) with a highly visible lamp stack that signals the system status. The lamp stack (Figure 10) is wired to a safety circuit; if the lamps fail, the x-ray source automatically switches off. All access to primary x-ray beam radiation is protected by two forced break interlocks and monitored by a Safety Relay.

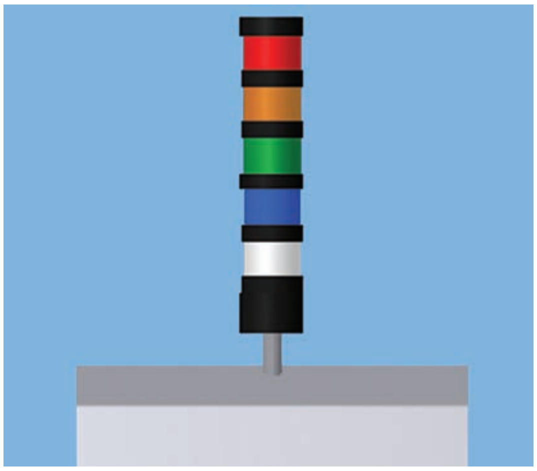

Figure 10: Highly visible lamp stack

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4.1. Protection Principles

X-ray systems are safe by design; they generate x-rays only when the unit is switched on. During that period, the risk of being exposed to radiation can be controlled through any or all of the two protection principles:

- **Distance**
- **Shielding**

Distance:
Radiation intensity tails off rapidly as you move away from the source. (Figure 11). It declines in proportion to the square of your distance from the source. But space is tight in a food processing plant; moving away is not always practical.

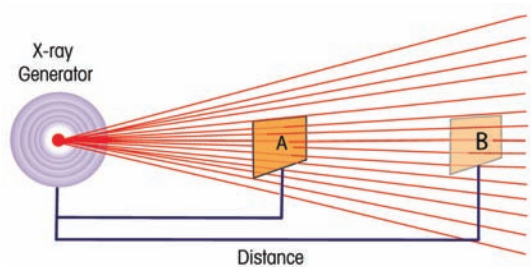

Figure 11: Radiation intensity

Shielding:
Since the shielding of equipment is entirely within the control of the x-ray system manufacturer, it's the most common way to control emissions. The denser the material, the better the shielding effect. (Figure 12) That's why x-ray machines tend to be made of, and encased in, stainless steel.(Figure 13).

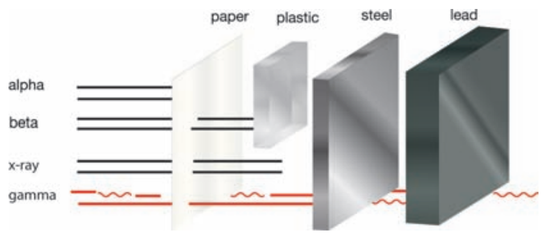

Figure 12: Shielding materials and effects

With adequate shielding, an x-ray inspection unit poses no health risk to the people who work with it.

Since the detectors on modern x-ray systems are highly sensitive, manufacturers have been able to reduce the power of the x-ray source. A less powerful source emits less radiation, which in turn requires less shielding.

4.2. Safety Regulations

The manufacture and supply of x-ray inspection equipment is subject to regulation. In the UK, these are the Ionising Radiations Regulations 1999. And in the US, they are the American Standard 1020.40CFR. The regulations ensure that the equipment is safe to use, even if an operator had to stand next to the machine for every hour of the working day.

In practice, operators spend very little time close to x-ray inspection equipment. Modern systems are automated to minimise operator involvement. Nevertheless, a well-designed x-ray inspection system has to comply with local rules and the regulations on the use of ionising radiation.

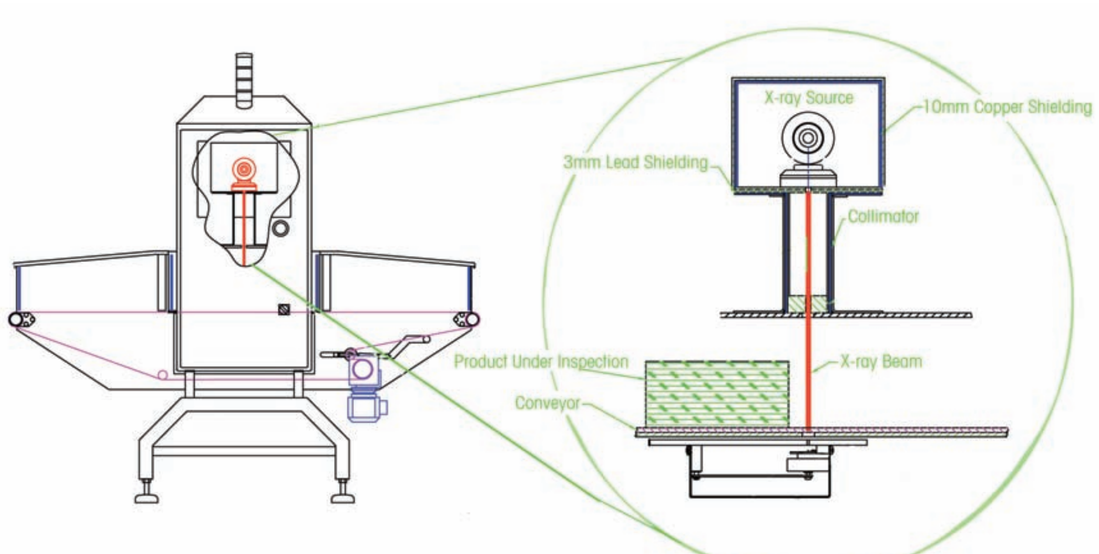

Figure 13: Shielding of the x-ray beam inside an x-ray system

4.3. Safety Design Features

Standard safety features should include tunnel curtains to retain emissions, a safety interlock design, and the x-ray system can also be fully integrated with the manufacturer's production-line safety circuit if required. Other vital features should be lockable power isolators, accessible emergency stops, and a top-mounted lamp stack with 360° visibility. (Figure 14).

Figure 14: Standard safety features

Once installed, the unit must by law be given a final, critical x-ray survey. If it passes, a certificate is issued. This is either done by the x-ray system manufacturer or by an independent inspector.

Before they start work, staff should be trained in the proper use of the equipment and in the relevant health and safety issues.

5. Conclusion

Low level radiation is part of everyday life and humans have been exposed to it since the beginning of time.

X-ray inspection of food is increasingly a feature of our daily life. With each passing year, more well-known brands are subjecting their foods to x-ray inspection. But that's not a cause for fear. Food that's good to eat before being x-rayed is as tasty and nutritional afterwards. Evidence comes from those brands that have adopted x-ray inspection already and their customers do not detect any change in flavour or texture.

Staff working with x-ray inspection systems are protected by legislation and by design. The regulations set safety levels, while equipment manufacturers build even greater safety margins into their designs. Live radiation sources such as uranium are not used. Instead, the x-rays within an x-ray inspection system are electrically generated, which means they can be turned on and off. Providing the safety guidelines are followed, modern x-ray inspection systems provide a safe working environment within the food industry.

The equipment wouldn't be there if it didn't serve a purpose. The real risk to human health comes from food contaminants such as metal, glass, stone, and bone and x-ray inspection systems are used to detect and reject contaminated food from the production line. Since x-ray inspection is good at catching contaminants (and checking product integrity) without affecting the food or the people who operate the equipment, it's fair to say that x-ray inspection is a force for improving food safety and quality, not reducing it.

6. Glossary

Orders of magnitude -
(http://en.wikipedia.org/wiki/Order_of_magnitude)
Orders of magnitude are generally used to make very approximate comparisons. If two numbers differ by one order of magnitude, one is about ten times larger than the other. If they differ by two orders of magnitude, they differ by a factor of about 100.

Sv: Sievert (unit of radiation dose)
mSv: Millisievert (a thousandth of a sievert)
μSv: Microsievert (a millionth of a sievert)
SI: The International System of Units (abbreviated SI from the French **S**ystème **I**nternatinal d'Unités)

Further Information about X-ray Inspection

FREE Technical Guide
Make an informed decision

METTLER TOLEDO has published an authoritative product inspection guide for x-ray inspection systems.

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- **Metal Detection, X-ray Inspection or Both: Making the Right Choice**

This webinar unspells the myths when to use metal detection or x-ray Inspection.

- **X-ray - More than just Contamination Detection**

There is more to x-ray inspection than just contamination detection. X-ray technology can simultaneously spot a wide range of product faults, ensuring product integrity.

- **X-ray Can Inspection Turns Throughput into Profit**

This webinar covers all the topics a canning manufacturer needs to know when considering installing an x-ray system on their production line.

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