White paper

Laatu.

Non-thermal, in-plant microbial reduction solution for dry foods.

Innovations for a better world.

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Content.

1. Food Safety — a global challenge

In February 2019 the United Nations, World Health Organization (WHO), World Trade Organization and African Union came together for the first time in their history to address one of the greatest challenges of our time, the threat of food-borne diseases are posing to human health.

The conference called for greater cross sectorial cooperation and for the private sector to use their knowledge to better exploit and develop new technologies to help drive down the burden of food-borne diseases. Bühler has been rising to that challenge and through this white paper we explain the development of the new food safety solution Laatu, a breakthrough microbial reduction technology for dry foods.

The meeting held in Ethiopia's capital, Addis Ababa, had been called at a pivotal moment. Every year one-in-10 people in the world falls ill from eating contaminated food, impacting human health, life expectancy and economic development. Food producers and regulators are currently also having to address the challenges of climate change along with profound demographic and lifestyle shifts taking place across the planet.

As global temperatures become more unpredictable, so the food safety risks associated with the production, storage and distribution of food increase. Population growth is also posing new challenges for food safety standards as we make the best of the resources we have and look for alternative protein sources. A growing global middle class is developing a desire for ever-more diverse foods while increased urbanization means many of us are relying on restaurants and ready-to-eat foods to help with the time challenges posed by city life. Cities also create more diverse communities, resulting in increasing numbers of people developing a taste for ever-more exotic and international foods.

Wherever you live these factors are pushing up the demand for overseas foods. As demand has risen so the complexity and inter connectivity of the food chain has had to evolve. What used to be a local food safety scare can today quickly become of international concern. Over the past decade we have seen how the globalized food trade can quickly result in the spread of an outbreak. In 2011, for example, an outbreak of Enterohaemorrhagic Escherichia coli (EHEC) linked to contaminated fenugreek sprouts that originated in Germany affected eight countries in Europe and North America resulting in 53 deaths and significant economic losses.[1]

1.1. Food safety — a risk for public health

According to the most recent WHO figures on the global burden of food-borne diseases each year 600 million people fall ill after eating contaminated foods resulting in 420,000 deaths. Children are the most vulnerable, with 125,000 of those deaths being under the age of five. The WHO also estimates that unsafe food impacts economic growth costing low-and-middle-income economies an estimated $95 billion in lost productivity each year.[1]

According to the WHO there are 31 food-borne agents that are responsible for causing food-related illnesses. Foods containing harmful microorganisms, such as bacteria, viruses, parasites or chemical substances, can cause more than 200 different types of illnesses ranging from diarrhoea to cancers. The most common form of illness caused by contaminated foods are diarrhoeal, responsible for 550 million people falling ill every year and leading to 230,000 deaths[1].

1.2. Food recalls — significant commercial losses

Food contamination not only impacts human health and economic development, but it also can impact seriously on businesses. Food recalls are primarily a public health issue, but they can also cause significant commercial losses with most recalls being due to microbial contamination. According to a joint industry study by the Food Marketing Institute and the Grocery Manufacturers Association, the average direct cost of a recall to a food company is $10m. This does not include costs from brand damage and lost sales. Costs for larger brands may be significantly higher, based on preliminary recall costs reported recently by firms affected.[2]

As the global population grows so we have to make the most of the resources we have. That means cutting back on waste, especially due to contamination. It is estimated that a third of food produced globally for human consumption every year — about 1.3 billion tons — is either lost or wasted[3]. According to Bondi et al (2014), an estimated quarter of this is because of spoilage caused by microorganisms.[4]

2. Dry foods as carriers of pathogenic bacteria

Dry foods with low-water activity (aw) are either naturally low in moisture or they have been dehydrated. Examples of dry foods (aw < 0.85) include spices, cereals, cocoa, dried fruits and vegetables, herbs, dried meat, powders, pasta, peanuts and tree nuts, grains, and seeds. Spoilage can occur when raw materials containing pathogens or microorganisms are introduced to a food product during or after processing. Dry foods do not support microbial growth and so are often considered a low risk. However, that does not mean they are without risk and this needs to be taken into consideration. One key risk is that microorganisms can survive the drying processes. When desiccated, their metabolism is greatly reduced. However, while growth does not occur in dried foods vegetative cells and spores can remain viable for several months or even years.[5] This means that dry foods may still carry food-borne pathogens, such as *Escherichia coli* O157:H7 or *Salmonella* and so pose a significant risk to consumers.

3. Conventional pathogen inactivation technologies — drawbacks

It is up to the food industry to reduce risk to the consumer as much as is possible. When it comes to producers of dried foods they need to be aware of the many different ways consumers might ultimately use their products.

One example could be sprinkling herbs onto salads. If contaminated, those herbs are being added to a water-rich food with no cooking process to kill the pathogens and so pose a potential risk to consumer health. When considering the potential microbiological risk posed by dried foods then any pathogen inactivation process has to factor in the way the consumer will ultimately use the product.

The success of a microbial inactivation treatment in eliminating or reducing contamination and therefore preventing food-borne illnesses depends on the type of treatment and processing that takes place.6 The conventional methods of microbial inactivation and insect disinfestation used for dried foods today have several drawbacks.

3.1. Steam

This is a thermal treatment during which the product is exposed to steam for a short period so that pathogens become inactive and the total microbial load in the food product is reduced.[7] Temperatures of 121°C or higher are needed for dry foods contaminated with spore-forming bacteria.[8]

However, effective decontamination with steam can alter the sensory, nutritional and functional properties in dry foods and cause color degradation, decrease aroma compounds and increase moisture content, which can lead to a reduced shelf-life.[7] In addition investment costs can be high and the process consumes large quantities of water.

3.2. Chemicals

Fumigation is applied widely to dry foods to reduce bacterial load or for complete sterilization. However, fumigation can cause color changes in some foods, such as paprika and turmeric.[9] In addition, volatile compounds that are responsible for aroma can be reduced.[10]

Furthermore, several chemicals used for fumigation, such as ethylene oxide (EtO), are considered carcinogenic[11] and the fumigation processes are not easy to perform because of the potential health hazards to workers and the environmental pollution risk.

Because of the carcinogenic properties of EtO, safety standards have restricted its use and several countries have even prohibited it. Currently, residue levels of 50ppm are allowed in the United States.[12] In the European Union (EU) use of EtO, as a food fumigant, has been banned since 1986[13] by Directive 79/117/EC, because of concerns about the potential toxic risks to workers and consumers. Other chemicals used for decontamination of food products, such as propylene oxide and methyl bromide, are also considered either toxic or carcinogenic.[14]

3.3. Irradiation

Irradiation of food uses ionizing radiation from gamma-rays, X-rays or electron beams.[15]

- Gamma-rays are emitted continuously from ^{60}Co or ^{137}Cs isotopes.
- X-rays are produced by the impact of high-speed electrons on a metallic target, which decelerates the electrons and emission of electromagnetic radiation.
- Electron beams are produced by accelerating electrons, focusing them into beams that can be targeted on food products.

Unlike gamma-rays and X-rays, electron beams have limited penetration, depending on the energies of the electrons.

The decontamination of foods with irradiation must be outsourced to food irradiation facilities[16] and might not therefore be easily accessible to food processors because of logistics and transport costs. Also, because irradiation of food products usually takes place at the end of the processing chain, when products are already in ready-to-sell packaging, irradiation treatment can be used to mask unhygienic food production practices, such as inadequate GMP's (good manufacturing practices).[17]

Safety and efficiency of food irradiation has been recognized by organizations, such as the WHO, the Food Agriculture Organization (FAO), and the International Atomic Energy Agency (IAEA).[18] From a regulatory perspective, spices can be treated with ionizing radiation. And when spices are used as ingredients, labelling is not necessary in the USA or Canada.[19] The regulatory status for the technology and its application is under evaluation in the EU.[20] In the USA, to get approval for a new source of radiation or its use, a petition must be submitted to the Food and Drug Administration (FDA).[21]

4. Laatu — a breakthrough microbial reduction solution

4.1. Developing a new microbial inactivation solution

The development of alternative solutions for microbial inactivation has been driven by both the limitations of conventional technologies and increasing consumer demand for fresh, natural and minimally processed foods.

Novel and advanced non-thermal technologies have the added advantage of making food production more sustainable by replacing conventional energy consuming techniques and so cutting production costs and energy consumption.[22]

Bühler is constantly working on pioneering, innovative and sustainable food safety solutions. One aim is to find gentle, sustainable and environmentally friendly decontamination solutions for foods, not only to ensure food safety but also to preserve food quality.

In 2012 Bühler began a study in response to the market and consumer needs. The study screened 18 existing physical technologies based on their suitability for microbial inactivation in dry foods, food quality preservation, and scale-up potential (Figure 1).

The research explored how pollution prevention and cutting wastewater along with conserving non-renewable resources could significantly reduce processing costs.[23] These were considered, together with energy consumption, cost-efficiency and usefulness, to assess the full potential of the technology for industrial and commercial purposes.

Unfortunately, for most potential solutions it was their scalability and suitability for industrial application that proved to be the limiting factors. High investment costs, efficacy in providing safe food, incomplete control of process variables and lack of regulatory approvals were also found to be constraints when it came to considering them as industrial-scale solutions.

The screening study revealed the low-energy electron beam technology to be the most promising solution for industrial applications and commercialization. Consequently in 2014, together with external partners from industry and academia, Bühler began developing the low-energy electron beam treatment process and its applications for dry food decontamination. Today Bühler is proud to be able to present Laatu — a breakthrough microbial reduction solution for dry foods.

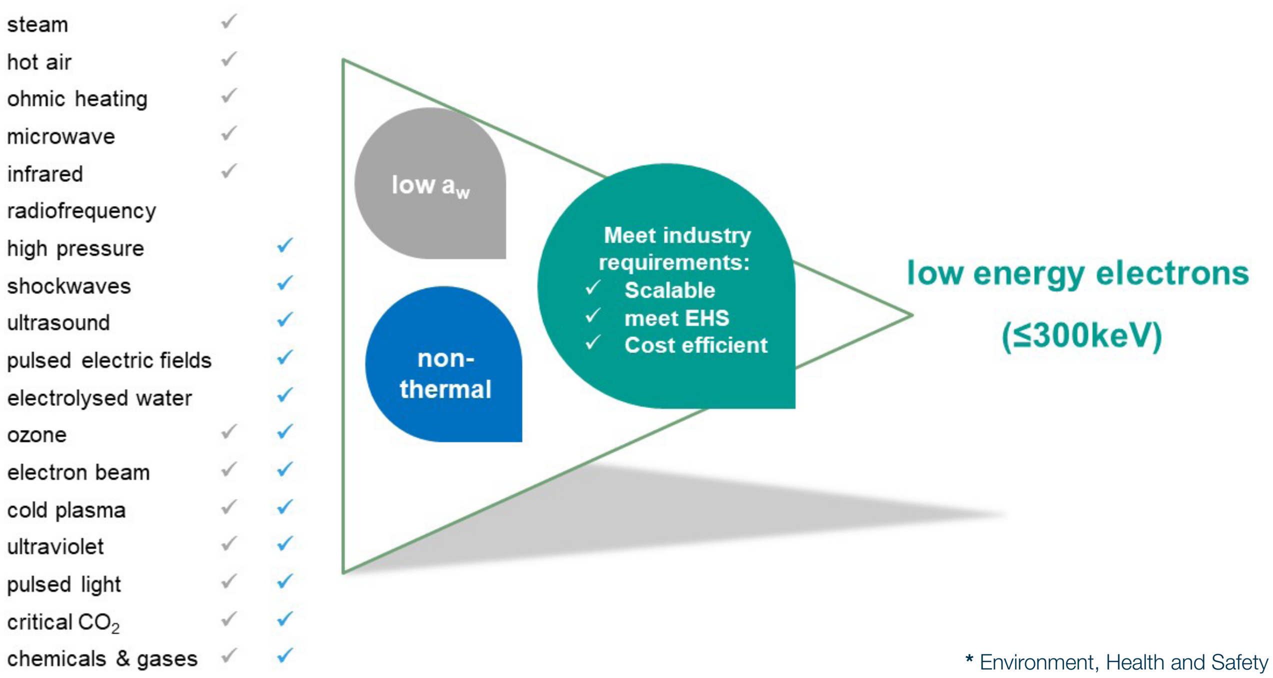

Figure 1. Screening of inactivation solutions

4.2. How it works

At the heart of Laatu is the idea of inactivating the pathogenic microorganisms on the dry food by damaging the DNA and RNA through exposure to a low-level electron beam.

The beauty of Laatu is that it only takes milliseconds to sufficiently inactivate the microorganisms. Each seed is homogeneously exposed to low-energy electrons, in a free fall space (Figure 2). The effect and depth of inactivation can be controlled via the energies of the electrons.

To date, Laatu has been successfully tested for three different types of pathogens — *Salmonella*, *E. coli*, *B. cereus* — and for natural contamination. As an example, Laatu can reduce 5Logs of *Salmonella* (>99.999%) in spices and the technology is showing promising results for significant log reduction in other dry food commodities.

A key feature of decontamination treatment with low-energy electron beam is that it can be confined to the surface. The ability to control the power of the low-energy electron means being able to control whether it penetrates the surface of the product or not. Since the microorganisms contaminating dry foods reside on the food's surface, the inner parts need not be exposed to the decontamination treatment.[24]

The lower the electrons energies, the lower their penetrability. Hayashi et al (1998) defined electrons with energies of 300 keV or lower, as low-energy electrons or "soft-electrons".[25]

Low-energy electrons have less energy than high-energy electrons. This is why their interaction with food molecules decreases much faster and the inactivation effect is limited to the seed surface, whereas electrons with high energies would travel through the seed and may damage internal quality.

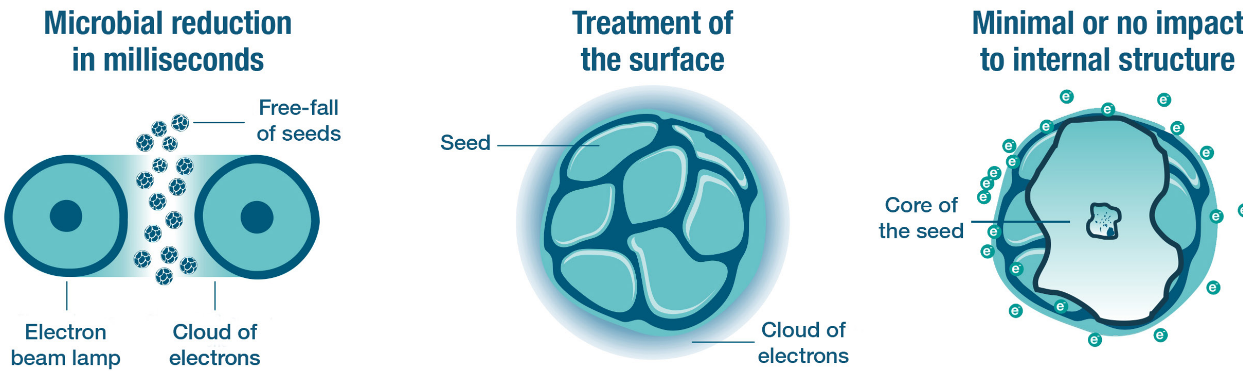

Figure 2. The principle of Laatu. The curtain of seeds free-fall through low energy electron beam lamps where each seed is homogeneously exposed to a cloud of electrons. Due to the low energies of the electrons, only surface of the seed is treated, preserving the internal quality of the seed.

4.3. Better preservation of quality

As a non-thermal treatment, Laatu provides an effective but gentle surface decontamination for dry foods. Due to the electrons' low energies, it can preserve both nutritional and organoleptic (i.e. taste, smell, appearance) properties of dry foods.

As both a non-thermal and surface limited method, Laatu maximizes the quality conservation of dry foods, while offering an efficient food safety solution. As an example, the germination capacity of mung bean seeds treated by low-energy electron beam, was compared to seeds treated with high-energy electron beam (10 MeV).

Since the low-energy electrons will not reach the embryo of the seed, the embryo remains undamaged and the seeds can germinate. Seeds treated with high energy electrons could not germinate, because the electrons travel through the seed and damage the embryo (Figure 3). Also, Laatu provides a better quality preservation of fat-rich dry foods, without inducing lipid oxidation.

Several studies have shown that homogeneous treatment of surfaces with low-energy electrons can decontaminate dry food ingredients without detrimental effects.[26] Also, low-energy electrons have exhibited several advantages over conventional irradiation techniques (i.e. gamma-rays or high- energy electrons (>300keV) in decontamination of dry foods.[22] For example, Kikuchi et al. (2003) recommended low-energy electron beam treatment, above gamma- irradiation, for soybean decontamination, because it induces minimum or no quality deterioration, since the electrons do not reach the internal matrix. Also, Kicuchi et al. (2003) showed that low-energy electron beam treatment did not inhibit the germination process of soybeans and can therefore be used to decontaminate seeds for sprouting.[27]

4.4. Economically and environmentally sustainable

Laatu can be scaled to industrial requirements to benefit small, medium and large operators. It has a significantly smaller footprint in comparison to conventional technologies (Figure 4) and can be operated as a stand-alone or continuous process, where it can be implemented anywhere in the processing line. Together with its recipe-based interface, the equipment is easy to operate. Time for cleaning Laatu equipment is reduced to 30 minutes, compared to eight hours for cleaning steam equipment.

Laatu is an environmentally friendly solution that does not use water or chemicals. It uses commercial energy as an energy source, without using radioactive sources. It can reduce energy consumption by up to 80% in comparison to steam and provides a cost-efficient, affordable solution for microbial reduction.

Figure 3. Mung bean seed germination after 120h. (a) Untreated seeds; low-energy electron beam treated seeds: (b) 140 keV; (c) 200 keV; and (d) High-energy electron beam treated seeds 10 MeV.

4.5 Digitalizing food safety solutions.

When Laatu is connected to the IoT platform, Bühler Insights, it becomes a powerful tool for food safety auditing that ultimately could be used as a food certification tool. It features a real-time monitoring system that captures processing parameters such as dates, times, and product batches. The information is then used to provide an automated product batch reporting system, capable of delivering an accurate and secure audit trail for food producers and the remaining supply-chain. By being able to accurately log all foods passing through the Laatu process it can then be certified as having been treated.

5. Conclusion

Food safety is one of the largest challenges the global food system faces and the potential for dry foods of plant origin to act as carriers of pathogenic microorganisms is a growing concern. Food safety outbreaks may lead to serious illnesses and even deaths. They may also lead to expensive product recalls that could significantly damage the brand. Food safety is an essential requirement and so can no longer be considered a competitive advantage. Food quality is now the front line when it comes to competition as this is where the most significant market value can be achieved.
Conventional dry food inactivation technologies are associated with several drawbacks, such as quality damage, safety hazards, high costs and risks for the environment.

To find an alternative solution, Bühler evaluated 18 existing physical technologies based on their suitability for microbial inactivation of dry foods, food quality preservation, and scale-up potential. The study showed that low-energy electron beam technology is the most promising non-thermal solution for dry foods.

This technology is called Laatu, the breakthrough non-thermal microbial reduction solution for the dry food industry. Laatu significantly reduces harmful microorganisms such as *Salmonella*, *E.coli* and spores in milliseconds. It is harsh on microorganisms yet, as a surface treatment is gentle on food, with better preservation of nutrients and organoleptic properties.

When compared to conventional technologies, Laatu has a significantly smaller footprint and can be implemented anywhere in the processing line. Moreover, Laatu provides a cost-efficient and environmentally friendly solution. It can reduce energy consumption by up to 80% in comparison to steam, without introducing water or chemicals. It also provides a speedy, accurate and efficient audit trail when linked with Bühler Insights that could be used to provide products with food safety certification.

Today, Laatu is ready for the spice market and its implementation for other dry food markets is under development.

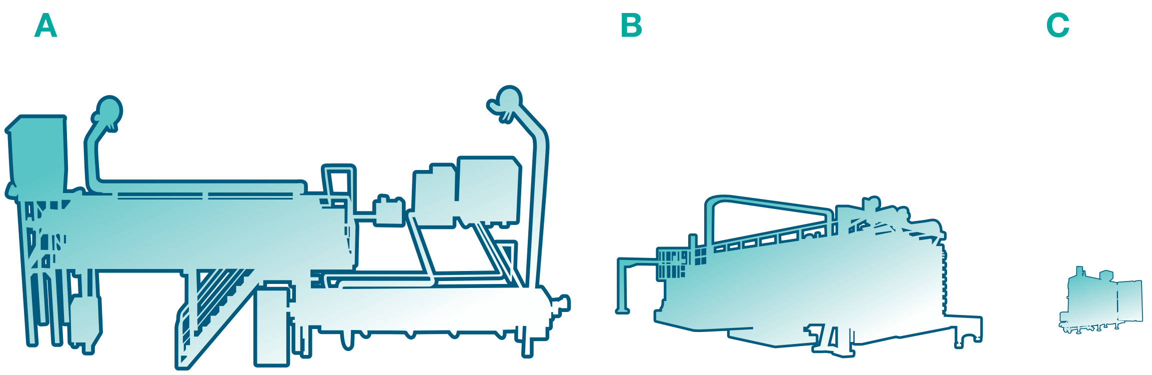

Figure 4. Size comparison of Laatu. A) Steam equipment B) Chemical equipment C) Laatu

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April 2019

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Laatu Whitepaper en 0319 Z&B 191014