Next Beam

A NextBeam technical brief for procurement and food-safety leaders · 2026

Electron Beam Treatment as a Non-Thermal Kill Step for Raw and Minimally Processed Pet Food

How manufacturers can eliminate dangerous microbes while preserving product integrity

Raw & Minimally Processed Products | HPP Alternative | Includes a "How To" Roadmap

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Executive Summary

Demand for raw and minimally processed pet foods in fresh, frozen, and freeze-dried form factors has grown rapidly as pet parents look for less-processed, high-quality diets. But the category has scaled faster than the industry's ability to consistently apply a compatible kill step—a gap clearly reflected in Animal & Veterinary FDA recall data. Traditional pet foods, such as kibble and canned food, rely on heat-based processing to reduce microbial risk.

Raw and minimally processed products cannot take that same path without compromising the texture, nutrition, palatability, or raw positioning consumers expect. The result is a fast-growing category with a harder food safety problem. Manufacturers need a validated kill step that can reduce pathogens without compromising premium/raw attributes.

Approaches such as high-pressure processing (HPP) may play a role, but each comes with limitations around product format, packaging, application, recontamination risk, or process control. Electron Beam (E-Beam) treatment offers a non-thermal, high-performance, and precisely controlled process that can be validated to reduce pathogens such as *Salmonella, Listeria,* and *E. coli*. Since E-Beam can be applied after final packaging, it can also help prevent recontamination while preserving the product's nutrition, palatability, and premium raw or minimally processed positioning.

This brief explains where E-Beam fits, how it compares to the alternative kill steps, and the practical path to qualify a product line in E-Beam.

Part 1: Evaluate the Options

1. The Risk Is Rising, But The Product Is Changing Too

Consumers have made it clear that they want raw and minimally processed products. Fresh, frozen, and refrigerated pet food accounted for about 7% of total dog and cat food sales in 2025 and is projected to grow 15% to 20% annually, according to Packaged Facts data reported by Pet Food Processing.

Pet parents increasingly choose diets they perceive as closer to whole food: raw, fresh, frozen, freeze-dried, semi-moist, and other minimally processed formats. That preference is reshaping the premium pet food category, and it is exactly what makes pathogen control harder. Without a thermal/cooking step, raw and lightly processed products carry whatever the incoming protein carries.

The typical pathogens of concern—*Salmonella, Listeria monocytogenes*, and Shiga-toxin–producing *E. coli*—present significant risks to pets and their human families. FDA's position on *Salmonella* in pet food is straightforward: if pet food could contain *Salmonella* and will not later undergo a commercial process that kills it, FDA considers that product adulterated[1]. FDA regulations already recognize irradiation as an approved method

[1]FDA, Compliance Policy Guide Sec. 690.800, "*Salmonella* in Food for Animals" (2013). FDA treats pet food as adulterated when contaminated with *Salmonella* and not subsequently subjected to a commercial heat step "or other commercial process that will kill the *Salmonella*."

for microbial disinfection and control in animal diets, pet treats, and chews under 21 CFR Part 579. E-Beam fits within that established regulatory framework as a non-thermal, precisely controlled treatment option.

There is good reason for manufacturers and customers to be concerned about raw food safety. Based on NextBeam's analysis of FDA recall and advisory data, raw pet foods appear to be linked to pathogen-related recalls at more than 20x the rate of non-raw pet foods. This leaves manufacturers needing a solution that a) controls pathogens without sacrificing premium product attributes and b) satisfies regulatory requirements.

2. Why Today's Safety Methods Force A Tradeoff

	E-Beam	High Pressure Processing (HPP)	Bacteriophage
Packaging Flexibility	Can treat **final packaged products** or **bulk ingredients** Works with **existing pack types** (cardboard boxes, flexible, rigid, MAP, pouches)	Can treat raw materials or finished packaged products, but requires HPP-compatible packaging or containment.	No special packaging requirements because treatment is applied during formulation or processing, not after final packaging
Scalability For Commercial Manufacturing	**High throughput, continuous process at scale**	Batch process – lower throughput, higher capital and operating cost	Scalable application, but product-specific
Validated Kill Step	**Repeatable,** dose-based treatment with strong process control	Effective, but formulation, package/containment, and process dependent	Targeted, but pathogen-specific and contact-dependent
Recontamination Risk	**Low** — Can treat after final packaging	High if treated before further processing. Lower if treated sealed.	High — Applied early in the process.
Ease of Evaluation	**Rapid sample testing before scaling**	Requires product and packaging/containment compatibility testing	Requires product-specific pathogen validation

High-pressure processing (HPP) applies isostatic pressure of roughly 400–600 MPa for a few minutes and inactivates vegetative bacteria, parasites, and many viruses without added heat. It is a useful tool, but it has real limits for this category. It does not reliably inactivate bacterial spores.[2] It requires flexible, water-resistant packaging — no rigid containers, glass, or metal — and it is a poor fit for low-moisture and freeze-dried formats. Pressures above roughly 400 MPa also denature meat pigments and proteins, lightening color and giving raw meat a partly "cooked" appearance.[3] And when HPP is run on bulk chubs that are later opened, re-portioned, and repackaged, the product is re-exposed after treatment, which reintroduces contamination risk.

[2]EFSA (2022) opinion on HPP; OSU Extension fact sheet FST-FABE-1001. HPP at commercial conditions does not reliably inactivate bacterial spores.

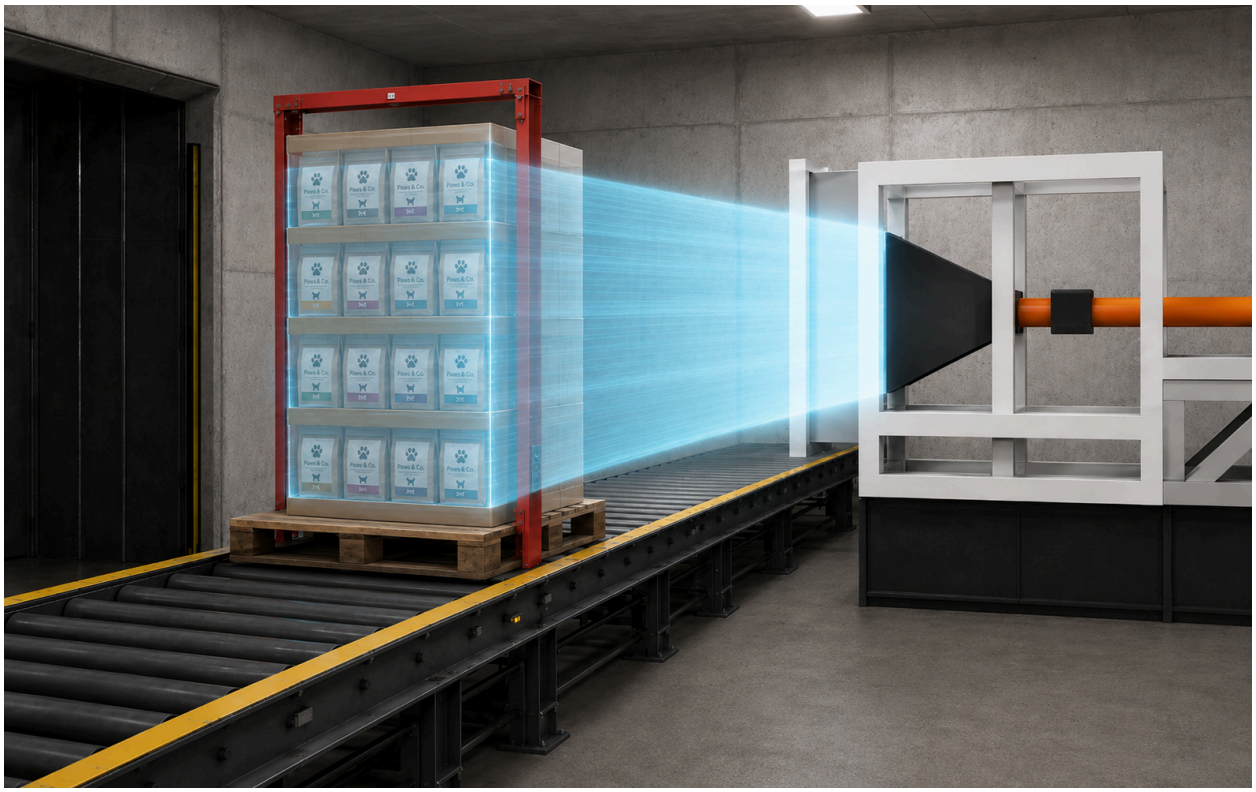
[3]Bolumar et al., Compr. Rev. Food Sci. Food Saf. (2021): pressures above ~200–400 MPa denature meat pigments and proteins, increasing lightness and reducing redness.

Bacteriophage treatments use naturally occurring viruses that infect and lyse specific bacteria. In food safety applications, phages are typically applied as targeted antimicrobial interventions against organisms such as *Salmonella* or *Listeria monocytogenes*. They can be useful because they are selective and can be applied without heat, but they are narrow by design. A phage preparation must match the target bacteria, and performance can vary based on strain coverage, food matrix, application method, contact time, temperature, and dose. For raw and minimally processed pet food, bacteriophage may support a hurdle-based food safety program, but it does not offer the same broad, validated kill-step role as a process designed to treat the full product under controlled processing conditions.

The three kill steps differ less in whether they reduce pathogens than in what they cost the product and the operation. The table below summarizes the practical differences that matter to procurement and food-safety teams.

Other non-thermal options exist but are narrow. UV-C and cold plasma act mainly on surfaces and do not penetrate dense products. Organic-acid rinses typically deliver only modest or pathogen-specific reductions and are difficult to control, and are not validated standalone kill steps. Modified-atmosphere packaging slows spoilage but does not kill pathogens. Each can complement a kill step; none replaces one.

3. Burning Down Recall Risk - Without The Heat



Illustrated example of pet food being treated inside a 10 MeV E-Beam facility like NextBeam's. E-Beam can penetrate sealed packaging and shipper boxes to deliver a controlled, non-thermal dose without radioactive material or residue.

Electron beam treatment uses a beam of accelerated electrons produced by an industrial accelerator — a machine that is switched on and off. Radiation is created from electricity - radioactive materials are neither used nor created. At the regulated energy ceiling of 10 MeV for electron beam,[4] the process induces no radioactivity: FDA is explicit that irradiated foods do not become radioactive.[5] There is no radioactive material to store, secure, or dispose of.

As a kill step, E-Beam targets exactly the pathogens this category worries about. Representative D10 values — the dose for a decimal reduction or log reduction — are roughly 0.24–0.31 kGy for *E. coli* O157:H7, 0.4–0.6 kGy for *Listeria*, and 0.6–0.8 kGy for

[4]21 CFR 579.22 (ionizing radiation for treatment of animal diets, treats, and chews; up to 50 kGy for microbial disinfection/control). 21 CFR 579.40 covers poultry feed (2.0–25 kGy, *Salmonella*). Energy limits in 579.40(a): machine electrons ≤ 10 MeV; X-rays ≤ 5 MeV (7.5 MeV for certain targets).

[5]FDA, "Overview of Irradiation of Food and Packaging." Irradiated foods do not become radioactive; the food passes through a beam and never contacts a radioactive source.

Salmonella; about 4 kGy typically delivers on the order of a 6-log reduction in ground beef.[6] Doses may be tuned to the product and the target organism, or applied based on best practices.

Two properties make E-Beam especially relevant here:

1. It is **non-thermal**. There is no cooking involved, so the raw character, composition, and palatability of the product are preserved at validated doses.
2. It can be applied in **bulk or after final packaging**. When applied after final packaging, the beam penetrates sealed packaging and leaves no residue, which prevents recontamination after treatment — the single most valuable property for products that cannot be cooked.[7]

E-Beam also has the highest throughput of the irradiation modalities; its tradeoff is limited penetration (roughly 6–8 cm in product with density ~1 g/cm^3 treated from both sides)[8], which is why some dense (e.g. frozen) or thicker products require planning around how they are packaged / presented to the beam. Most pet food products are E-Beam compatible in their normal shipper boxes, or can alter shipper box sizing (not unit-level package) to be process-capable. For instances where the product is too large or too dense for E-Beam, X-ray, a derivative accelerator-based technology, may be used.

4. When E-Beam Makes the Most Sense

While E-Beam can be used on a wide array of pet food types and formats, it is most compelling when:

- **Heat is off the table.** If cooking would erase the raw or premium claim, or degrade nutrition and palatability, a non-thermal kill step could be considered in order to preserve the product's identity.
- **The product is freeze-dried or dehydrated (it has minimal water activity).** E-Beam is especially relevant for these minimally processed pet food and treat formats. E-Beam treatment is often more economical because it occurs only on the final product – not the 60-70% of product water weight that will be removed prior to packaging.

[6]Representative D10 values (dose for one log / 90% reduction): *E. coli* O157:H7 ≈ 0.24–0.31 kGy; *Listeria* monocytogenes ≈ 0.4–0.6 kGy; *Salmonella* ≈ 0.6–0.8 kGy. Values vary with matrix, temperature, and atmosphere. Approx. 4 kGy yields ~6-log reduction in ground beef. Sources: peer-reviewed irradiation literature (NIH/PMC), ASTM F1356, Table X1.1

[7]FDA, "Overview of Irradiation of Food and Packaging"; CDC/Emerging Infectious Diseases (2001): treatments applied after packaging, when recontamination is virtually impossible, offer the greatest potential for long-term safety improvement.

[8]E-beam penetration is roughly 6–8 cm in product treated from both sides at 10 MeV; throughput is the highest of the three irradiation modalities. X-ray penetrates more deeply but is slower; gamma is deep but slow and relies on a radioactive isotope. Source: AIChE/CEP, "Introduction to Electron-Beam Food Irradiation."

- **The product needs treatment in its final form.** E-Beam can be applied after final packaging, helping reduce recontamination risk from downstream handling, portioning, or packaging.
- **Recontamination is the real risk.** When the safety gap is contamination of the final product, treating the sealed package closes it in a way upstream interventions cannot.

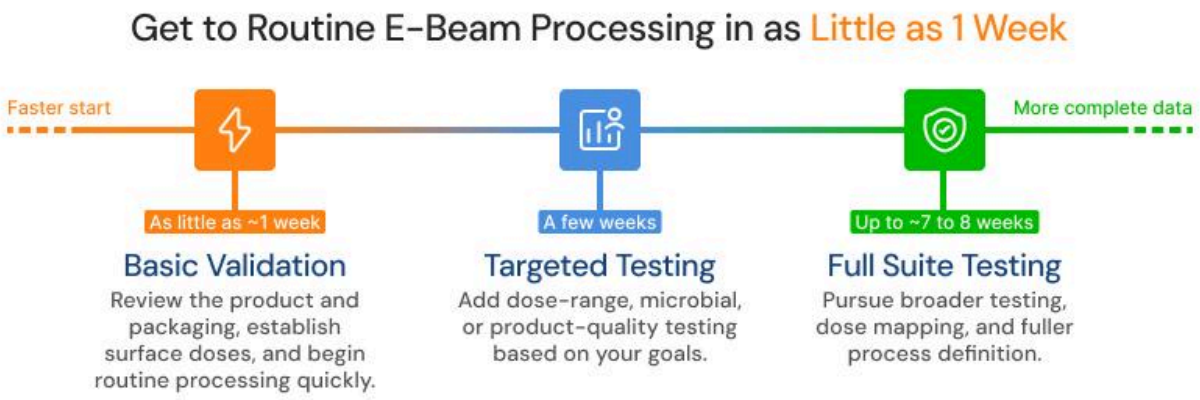
Additionally, the relatively high recall risk of raw and minimally processed foods is becoming more significant as this category continues to grow – and grow quickly. More scale demands better risk management. When retailers, customers, regulators, or the broader market are raising the bar, a validated, documented kill step is a concrete answer rather than a promise.

Part 2 — Implement E-Beam

Now, the question becomes: could E-Beam work for your product, and what would it take to find out?

This section outlines the typical path from product review to routine processing. If you would rather talk through your product format, packaging, target pathogens, timing, or testing requirements with an E-Beam expert, please reach out to us. We can let you know in 30 minutes or less if your product is a good fit for E-Beam.

5. How To Rapidly Evaluate E-Beam For Your Product



Qualification starts with a product profile. The more precisely a product is described up front, the faster feasibility can be determined.

1. **Start with the product details**: Include format (raw, frozen, freeze-dried, semi-moist), bulk density, package type and dimensions, storage and shipping temperature, and target pathogens. Density and package geometry drive penetration and dose uniformity; storage temperature can affect both microbial response and product quality. Based on the above, our team at NextBeam can rapidly assess whether E-Beam will be an effective and efficient solution for your specific product.
2. **Send samples for feasibility testing**. Should NextBeam's analysis suggest your product is a good candidate for E-Beam, it's time for a feasibility test. Early, small-scale testing is designed to answer whether E-Beam is a realistic fit for a product before committing to full validation. It determines the dose range experienced by the product, the expected quality impact, and any penetration constraints early, when changes are cheap.
3. **Use early results to gauge cost, risk, and timeline**. Feasibility testing is intentionally lightweight relative to full validation. It lets a team make evidence-based decisions about whether to proceed, adjust the product or

packaging, or stop. In the pet food industry, customers have different objectives when it comes to implementing E-Beam as a kill step. Overall microbial reduction, analyzing whether there is any measurable degradation to the product, and optimizing for lowest possible cost are typical goals – but customers prioritize these differently (and our team can help guide you through this process).

6. What the Testing & Qualification Process Looks Like

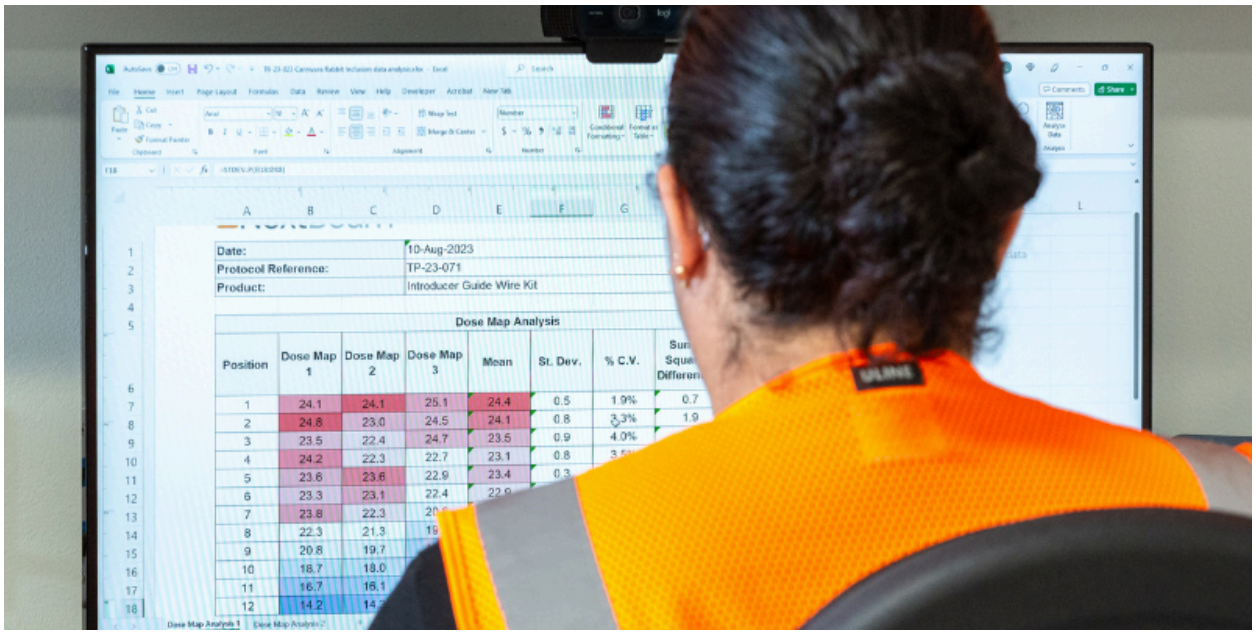
A typical qualification moves through three stages, each building on the last.

1. **Dose-range testing**. Treat the product across a range of absorbed doses to see how it responds, and then bracket the working window between effective pathogen reduction and minimizing any other detectable impact to product integrity. This could include assessing the treated product for taste, odor, texture, appearance, nutritional content, shelf life, or all of the above. The result should be the determination of a maximum-allowable dose.
2. **Microbial inactivation testing**. Challenge or verify against the relevant pathogens to confirm the log-reduction the product actually achieves at candidate doses, establishing the minimum effective dose.
3. **Dose mapping**. Determine the production configuration(s) of the product and optimize the processing specification that will assure that dose is delivered within the acceptable window, while minimizing total cost to the customer *(more on that below)*.

Peer-reviewed work on irradiated meat shows minimal change to composition and sensory attributes at the lower doses typically used in this application, with effects increasing as dose rises;[9] the goal of stages 1–3 together is to find the dose that clears the pathogen target while staying comfortably within the dose range defined above.

[9]Peer-reviewed meat irradiation literature (MDPI Foods, 2025): minimal change to proximate composition and sensory attributes at doses up to ~3 kGy; effects are dose-dependent. FDA states irradiation does not compromise nutritional quality or noticeably change taste, texture, or appearance (FDA, "Food Irradiation: What You Need to Know," fda.gov, accessed June 11, 2026.)

7. Why Dose Mapping Matters



With dose mapping, E-Beam becomes a repeatable, validated kill step that helps manufacturers reduce pathogen risk before product reaches the market.

The goal of dose mapping is to establish a repeatable routine process that can be used every time that product is received for treatment. While this level of sophistication and rigor is required by regulations for sterile products such as medical devices or pharmaceuticals, customers in less regulated industries like pet food have flexibility in what level of precision to adopt when defining a process.

How it works: Dose mapping measures how absorbed dose is distributed throughout the product and package, identifying the lowest-dose zone (D_{min}) and the highest-dose zone (D_{max}). It confirms that every part of the product receives a dose inside the intended range — enough to achieve the kill at the cold spot, without exceeding the quality limit at the hot spot.

Dose mapping is what turns E-Beam from a one-time test into a repeatable production process. It shows how the product, packaging, and treatment setup perform together, then gives NextBeam the information needed to define the routine process for future runs. The result is a validated process that can be repeated with confidence each time the product is received for treatment.

8. Labeling and Customer Communication

E-Beam irradiation leaves no radioactive material behind.
The Radura symbol simply identifies a regulated treatment process.

Irradiated food carries a recognizable mark: the **Radura** symbol — a stylized plant within a circle — together with the statement *"Treated with radiation"* or *"Treated by irradiation."* These requirements are defined for human food at 21 CFR 179.26(c) and reach pet food through 21 CFR 579.12, which incorporates the Part 179 rules "as applicable" to animal feed and pet food.[10] In plain terms: if the finished pet food is irradiated, the package is expected to carry the Radura and the irradiation statement.

Two practical nuances help procurement and labeling teams. First, products shipped business-to-business for further processing must carry a "do not irradiate again" version of the statement on labels and on invoices or bills of lading. Second, an irradiated ingredient blended into an otherwise non-irradiated finished product does not, by itself, trigger the consumer-facing Radura requirement on that finished product.[11] Because pet-food enforcement runs largely through state feed-control officials, confirm current application

[10] 21 CFR 179.26(c) sets the Radura logo and "Treated with radiation" / "Treated by irradiation" statement for irradiated human food. 21 CFR 579.12 incorporates Part 179 "as applicable" to animal feed and pet food, which is the legal basis for applying these labeling rules to irradiated pet food. Confirm current application with counsel and your state feed-control official.

[11] 21 CFR 179.26(c)(3): product shipped to a manufacturer or processor for further processing must bear "Treated by irradiation—do not irradiate again" on labels, labeling, and invoices/bills of lading. Under specific conditions, an irradiated ingredient incorporated into a non-irradiated finished food does not trigger the consumer logo/statement on that finished product.

with counsel and your state official; note too that FDA has treated irradiation as inconsistent with a "natural" claim under the AAFCO definition.

While labeling can occasionally trigger questions from consumers, food products treated with E-Beam irradiation are not radioactive and carry no radiation-related risks. E-Beam processing of human and pet food per the standards promulgated in their regulations has been endorsed for decades as safe by the FDA, USDA, World Health Organization, and others.

9. Operational Considerations

E-Beam is designed to slot into an existing production and logistics flow. In practice, the product is manufactured and packaged as usual, then treated — often in its final package — before or during outbound distribution.

Packaging. Materials must be irradiation-compatible (most common food packaging is), and package geometry should suit E-Beam's penetration. Thinner, uniform packs treat most easily; dense or thick formats need dose planning, and some may be better matched to X-ray.

Cold chain and logistics. Frozen and refrigerated products can be treated while keeping the cold chain intact; removal from refrigerated storage is brief, with handling and staging around it. Turnaround, routing, and staging are planned so the product moves through treatment without breaking temperature control.

Documentation and scale-up. Treated lots are supported by a Certificate of Irradiation that documents the delivered dose — the paperwork that makes the process auditable. Because E-Beam is continuous and high-throughput, a process validated at pilot scale extends to commercial volume without changing the underlying method.

10. Next Steps for Manufacturers

The process is simple and straightforward:

1. **Share product and packaging details** — package dimensions, density, storage requirements, target pathogens, and any other specific requirements. For most products we can typically provide high-confidence guidance with this information alone.
2. **Send samples for testing** — so feasibility can be assessed for the actual product. Min/max dose testing and dose mapping may be recommended depending on product and customer requirements.

3. **Assess results and define the process** — based on the tests performed, finalize customer requirements and an approved process specification.
4. **Begin production** – once a process specification is defined, regular production irradiation can begin.

11. From Recall Risk to Process Control

With E-Beam, manufacturers of raw and minimally processed pet food do not have to choose between stronger food safety and product integrity. E-Beam removes the pathogen risk that defines the category's exposure without cooking away what makes the product valuable, and it can do so on the final package, where recontamination could otherwise undo upstream kill steps. Qualification is fast and evidence-based, and the resulting process is controlled, documented, and defensible. The shift it offers is exactly the one the market and regulators are pushing toward: moving away from reacting to product recalls and towards operating a validated, repeatable kill step.

Recommended Next Steps

→ Share this white paper with a colleague
→ Keep a pulse on the sterilization industry by subscribing to *Irradiation, Illuminated*
→ Instantly book a call with a NextBeam sterilization expert to discuss E-Beam compatibility