Pulse Electric Field versus Traditional Pasteurization: A Comparison of Energy and Nutrient Retention

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Introduction

Dairy processors over the world use pasteurization to make sure their products are safe. They do this by heating the milk to a high temperature like 72° for 15 seconds. This kills the bacteria but it can also hurt the good nutrients and enzymes in the milk. On the other hand Pulse Electric Field processing uses short bursts of high voltage electricity at a temperature that is close to room temperature to kill the microbes. This way the milk stays much the same with no big changes to its nutritional value, how it works or how it tastes. In terms Pulse Electric Field can kill the bad bacteria in the milk without hurting the vitamins, proteins and flavor.

Pulse Electric Field is also better than pasteurization because it can run all the time and use less energy. It is a way to help the environment because it keeps the milk fresh for longer and uses less energy than the old way of heating it.

Energy Efficiency: PEF vs Heat

When we compare PEF systems to heat pasteurization, we see that PEF systems use a lot of energy to get the same results. The old way of pasteurizing with heat requires a lot of energy to heat up milk to a high temperature. For example, to heat one liter of milk from around four degrees Celsius to seventy-two degrees Celsius it costs around two hundred and seventy to three hundred kilojoules of energy. PEF treatments are different. They use pulses to kill pathogens, and they use a lot less energy. In fact, they use around fifty to one hundred kilojoules of energy per kilogram of milk. This is a difference.

In life PEF systems can help cut down on electricity use by around twenty percent and heating fuel use by more than sixty percent compared to the old way of pasteurizing. For example, in a study on juice PEF used around twenty percent electricity and sixty percent less boiler energy than the old way. We expect to see results with milk. The reason is that PEF does not need to use a lot of heat to work. This means it uses energy and takes less time to process. People who have reviewed PEF say that one of the benefits is that it uses less energy and takes less time to process.

Overall PEF systems are an energy efficient way to pasteurize milk and other foods. They use energy and take less time to get the job done. This makes them a better choice for people who want to save energy and reduce their impact on the environment.

Nutrient and Quality Retention

The thing about PEF is that it does not use heat, so it keeps the things in milk like nutrients and enzymes much better than heating does. For example, some research found that when milk is pasteurized using heat for a short time it loses a lot of vitamins B1, B2, C and folate. Specifically, when milk is heated it loses a lot of riboflavin which's vitamin B2 and vitamin C but PEF does not cause this loss. In fact, milk that is processed with PEF keeps all of its original vitamins and the things that give it flavor. This is what studies on juice and dairy products have found. For instance, in goat milk one study found that PEF is better at keeping the proteins, color and flavor than the usual method of pasteurizing with heat.

Table 1. Comparison of processing conditions and energy requirements for HTST pasteurization versus PEF treatment of milk

Parameter	HTST Pasteurization	PEF Processing
Operating Temperature	~72 °C (for 15–20 s hold)	~30–50 °C (during pulses; minimal rise)
Thermal Energy Input (approx.)	~300 kJ/L (to heat + hold)	~50–100 kJ/L (electric pulses)
Equipment	Heat exchangers, boilers, chillers	High-voltage pulse generator, chamber
Processing Time	Seconds (heating + holding)	Micro- to milliseconds per pulse
Pathogen Kill Requirement	≥5-log (FDA standard)	Achieved by pulse count/intensity
Energy Efficiency Notes	High energy for heating, long cooldown	Lower thermal loss, shorter processing

Case Studies in Dairy Processing

Some new research is showing that using PEF on dairy products is a good idea. For example, Ge and his team looked at what happened when they used PEF on goat milk. They used twenty-two kilovolts for one hundred and twenty seconds. Then they compared it to heat pasteurization. What they found out was that PEF was just as good at killing things as heat pasteurization. The milk that was treated with PEF had more good things like proteins and flavor.

Araújo and his team did something. They used a bit of heat after using PEF and it worked just as well as using a lot of heat. They used a short PEF pulse and then they heated the milk to sixty-three degrees Celsius. This killed a lot of bacteria. The good thing about this was that it did not use much energy as heating the milk to seventy-two degrees Celsius.

Table 2. Estimated nutrient/enzyme retention after HTST vs PEF

Component	HTST Pasteurization	PEF Treatment
Vitamin B2 (riboflavin)	Decreased ~30% (meta-analysis)	Near 100% (non-thermal; minimal loss)
Vitamin C	Decreased ~80%	High retention (PEF preserves as no heat)
Proteins (structure)	Partial denaturation	Mostly intact; solubility/emulsification often improved
Alkaline phosphatase	~100% inactivated (enzyme destroyed)	~60% inactivated (pulses partly destroy enzyme)
Bioactive peptides	Altered by heat (some loss)	Largely preserved (PEF causes little protein breakdown)
Lipase / enzymes	Fully inactivated	Some residual activity; DP of lipase ~14% inactivate
Colour & flavour	Some loss/change due to heating	Preserved (no cooked flavour)

Some other people like Taki and his team are trying things. They are using plasma and PEF together to pasteurize cow's milk. They found out that if they used a voltage, for the PEF it killed more bad bacteria. This is a way to make milk safe to drink without making it too hot. PEF is a way to pasteurize milk because it does not use a lot of energy and it helps keep good things in the milk. PEF and cold plasma can be used together to make the milk even safer.

Table 3. Case studies of PEF-based pasteurization in milk products

Study (Year)	Milk/ Product	Treatment	Key Outcome
Ge et al. (Food Control, 2026)	Raw goat milk	PEF 22 kV, 120 s	*High microbial kill; better retention of proteins, color & flavor than HTST*
Araújo et al. (Food Res. Int., 2023)	Raw goat milk	PEF (10 kV/cm, 50 µs) + 63 °C	*5-log* Listeria *reduction equal to 72 °C alone; ~50% energy saved*
Taki et al. (Food Sci. Nutr., 2026)	(Pasteurized) cow milk	Cold Plasma + PEF (5–10 kV/cm, 20–35 s)	*Increasing to 10 kV/cm gave ~4-log* E. coli *reduction: quality unaffected*
Araujo et al. (J. Dairy Sci., 2016)	Raw cow/goat milk	PEF alone vs PEF + 2 s heating (up to 72 °C)	*PEF alone <1-log kill (insufficient). PEF+64 °C = 72 °C only in kill; protein integrity preserved*

Conclusions and Outlook

For dairy engineers, PEF represents an intriguing next-generation pasteurization. Its key technical advantage is killing microbes at lower overall temperatures, thus keeping vitamins, enzymes and milk proteins largely intact. Energy models for food processing consistently show that PEF systems consume far less processed heat energy than conventional pasteurizers. Moreover, consumer trends favour minimally processed, "just-like-fresh" milk. PEF can meet that demand – studies report almost no perceptible "cooked" taste difference from raw milk while still ensuring safety.

However, PEF also has challenges. On its own, even strong PEF pulses may not achieve the required *5-log* pathogen kill in very resistant organisms (e.g. *Listeria*, spores) – hybrid approaches are often used. Equipment costs and regulatory approval are under development. Nevertheless, the scientific evidence is compelling: PEF can pasteurize milk with lower energy and better nutrient retention than HTST. As one review notes, PEF processing is gaining momentum in dairy because it inactivates microbes "with least compromise of milk flavor, color, and nutritional content". Ongoing pilot projects and case trials suggest that within this decade, non-thermal PEF pasteurization could become an industrial reality for high-quality dairy.

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