UHT vs ESL beverages: Advantages, Disadvantages and a Unified Testing Platform

Introduction

The global aseptic food and beverage packaging market is expected to reach $35 billion by 2025. Some of this growth is due to the increased popularity in dairy products. This has fueled the demand for products with longer shelf lives and room temperature storage. As a result, the demand for aseptically packaged beverages has grown significantly.

Aseptic packaging and filling is a specialized process in which product is sterilized separately from the packaging, and then filled into sterile containers under extremely clean environments to maintain sterility and long shelf life. This method requires extremely high temperatures for short bursts of time so that it maintains the freshness of the contents and ensures that it is not contaminated with microorganisms.

> "Aseptic packaging and filling is a specialized process in which product is sterilized separately from the packaging"

While ideal for many foods and beverages, aseptic processing poses both advantages and disadvantages for milk and milk-derived beverages. In addition, it poses new obstacles: the need for extra equipment, processes and technologies. This means higher processing costs which are often recouped at a premium price, but this is not the case for milk. Therefore, many dairies have been looking for better ways to process milk for consumer use, especially in emerging markets where milk is often distributed at ambient temperatures.

Milk products are generally required to be processed by thermal methods such as pasteurization, as has been done for decades. Drawbacks to this are it still has the restrictions of limited shelf life, chilled distribution, and must be stored refrigerated after purchase. This paper will look at two additional processing methods which offer some advantages and disadvantages over processing, followed by a summary of the best way to test final products.

Milk Processing Overview

Pasteurization is defined as a heating process of not less than 63°C for 30 min (batch method) or 72°C for 15 sec (HTST, high temperature short time) in approved equipment. According to the U.S. FDA Pasteurized Milk Ordinance and the International Dairy Federation (IDF), this heat treatment is considered adequate exposure for the destruction of *Coxiella burnetii* and *Mycobacterium tuberculosis/M. bovis*, the main milk-borne pathogens of concern. The shelf life of pasteurized milk varies greatly in different countries and regions. Pasteurized milk can have a shelf life from only a couple of days in some countries to over 20 days in the U.S. due to a well-established cold chain at 4°C.

The shelf life and quality of pasteurized milk can be affected by spore load in raw milk, pasteurization conditions, contamination from the food contact surfaces and the

environment, and particularly distribution temperature. Spore-forming bacteria such as *Bacillus* spp. (*Bacillus cereus, Bacillus subtilis, Bacillus licheniformis,* and *Bacillus pumilus)* and *Clostridium* spp. *(Clostridium tyrobutyricum* and *Clostridium sporogenes)* have been shown to be a frequent contaminant of raw and pasteurized milk and dairy products in recent decades. Silage, for example, is a significant source of contamination that allows outgrowth of spores that impacts quality of milk.

To overcome these challenges, new processing methods are being evaluated to further reduce or eliminate microbes that can cause food spoilage and disease. Two thermal processing methods are UHT (Ultra High Temperature) and UP (Ultra-Pasteurization). While UHT milk has been around for a while, it is now making a resurgence along with Extended Shelf Life milk, the latter playing an important role in the dynamics of dairy markets as they develop new processing and packaging methods.

What is UHT processing?

This method involves processing milk at high temperatures (135 – 154ºC) for short holding times (1 – 2 seconds) to achieve what is termed “commercial sterility”. Final product is tested for sterility by incubating at 55ºC for 7 days and at 30ºC for 15 days and testing for bacterial growth after this incubation time. When combined with aseptic packaging and hermetic seal, the final product can be shelf-stable (ambient temperatures) with a shelf-life of 6 to 12 months.

UHT is not an in-container sterilization process. As such, it allows for the same bacterial destruction with less chemical damage while still inactivating thermophilic bacterial spores. Therefore, the final product, while sterile, must be packaged aseptically. In addition, the FDA requires a processing authority to facilitate UHT processes. The authority is responsible for establishing a process that ensures commercial sterility not only of the product but also for the product sterilization system as well as the filler, the packaging equipment, and the packaging material.

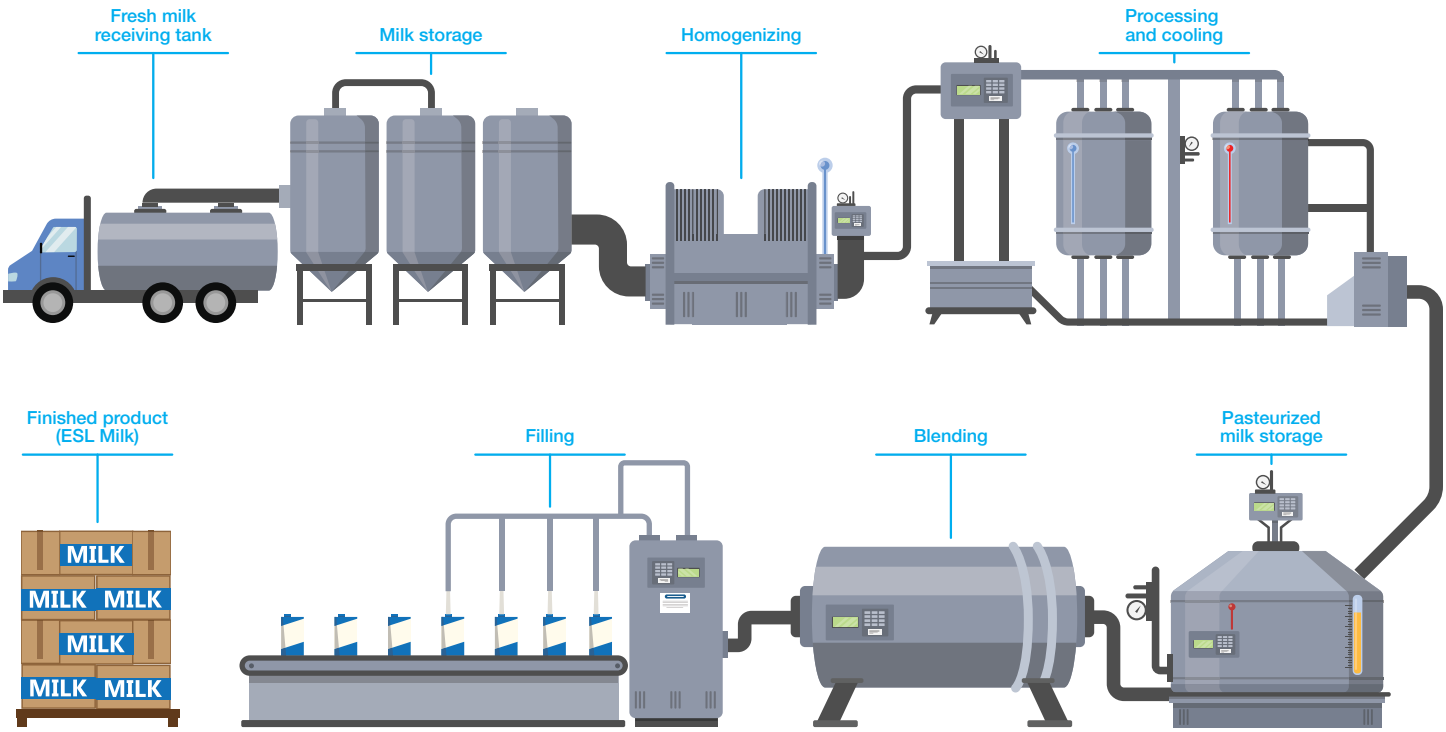
What is ESL processing?

ESL processing lies somewhere between pasteurization and sterilization. There are no specific temperature-time requirements for this type of processing in most countries. However, in the US, ESL milk, designated as “ultra-pasteurized”, must be produced by a heat treatment of > 138º C for > 2 seconds. However, commercially, some products are processed from 120°C – 140°C for 0.5 – 4 seconds. Such products have reduced microbial counts when compared to pasteurization, and packaged without a hermetic seal under hygienic conditions, so they have an extended shelf life under refrigerated conditions. Note: ESL milk is not considered “commercially sterile” either, but the shelf life is typically extended to 45 – 120 days, depending on the product and the packaging process. Other methods for ESL products have been developed but are used less often. These include microfiltration + HTST treatment, bactofugation + thermal treatment, thermal treatment + antibacterial addition, or thermal treatment combined with a non-thermal technology such as UV irradiation, pulsed-field technology, or gamma-irradiation.

Advantages and disadvantages of processing methods

Advantages of UHT milk:

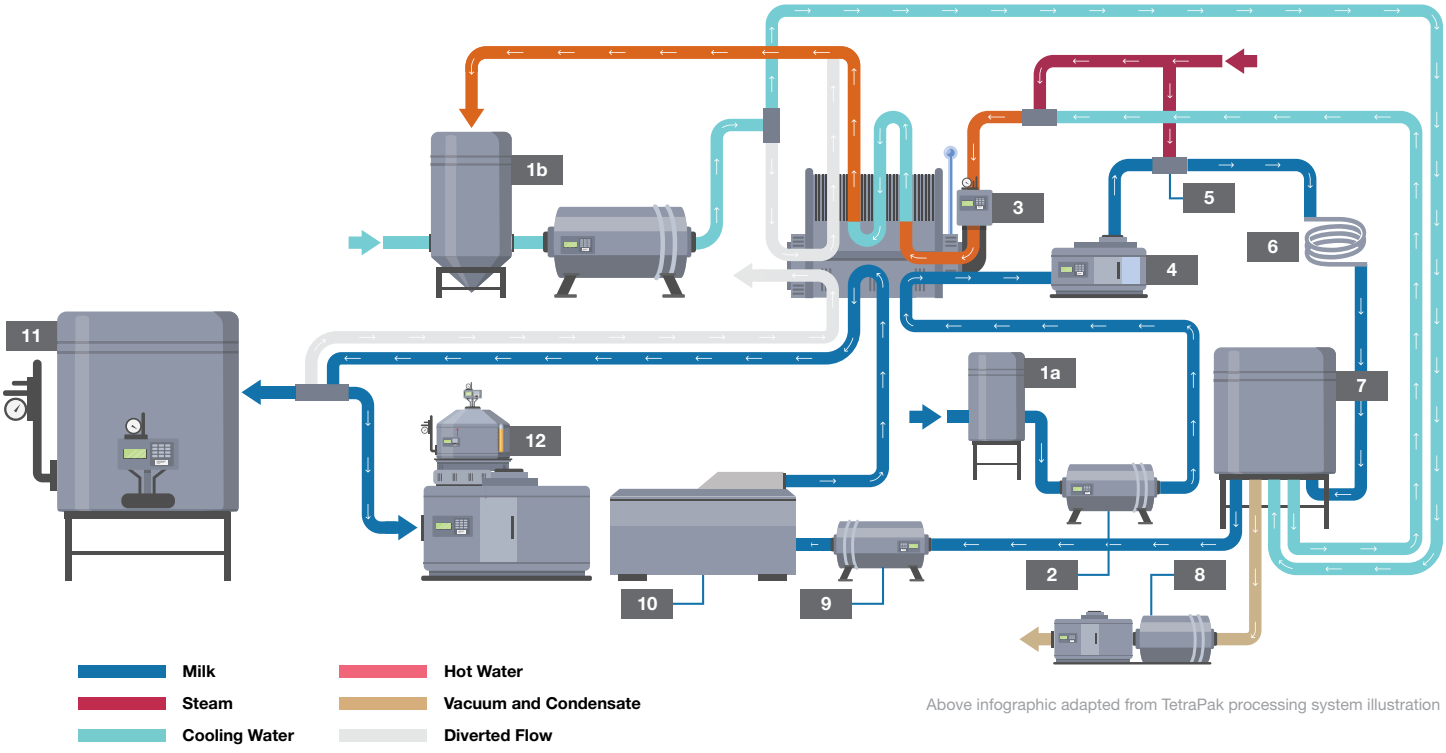
1. **Less processing time** – UHT processing is complete within seconds, making it rapid. Heating is typically done in 1-2 seconds after which product is cooled and packaged aseptically.
2. **Extended shelf life and at room temperature** – UHT milk can have a shelf life of 6 months or more without refrigeration. This simplifies the distribution of product and allows for long storage on store shelves.
3. **Reduced microbial load** – Kills up to 99.9999999999% of microorganisms (including pathogens) and inactivates spores. The only time issues arise is if the milk was contaminated with spore-forming organisms that survived the UHT treatment, if harborage or biofilm formation is found in cracked processing and filling lines, or if milk was contaminated post-processing, i.e, during packaging or handling. However, ultra-high temperature can achieve a 12-log reduction to control *Clostridium botulinum* and allow safe storage of food at room temperature in which other processing methods such as pasteurization or ESL processing cannot achieve.
4. **Safer than raw milk** – UHT milk is considered "commercially sterile" and is always packaged aseptically. It must be tested under extreme conditions to ensure no deterioration of product. Samples spend 15 days in a closed container at a temperature of 30°C; where necessary, provision can also be made for a period of 7 days in a closed container at a temperature of 55°C.
5. **No need for refrigeration for storage** – Storing UHT milk at ambient temperatures is definitely an advantage. It simplifies distribution chain management and reduces storage costs overall –at the processing facility, distribution centers, and on the store shelf.
6. **Cheaper and wider variety of packaging options/ sizes** – There are significant logistical advantages here. By eliminating large glass or plastic containers, empty packages can be stored flat until needed, simplifying storage space and allowing for larger shipments to be transported. The packaging provides space efficiencies, and a variety of sizes and shapes of empty packaging can easily be delivered via semi-trailer for filling.



Above infographic adapted from TetraPak processing system illustration

Disadvantage of UHT milk:

1. **Milk quality issues / Alteration of flavor** – Complaints include a "cooked" flavor, a stale/oxidized flavor, bitter taste due to peptides generated by heat-stable proteases, or a rancid/acid/sour flavor due to residual bacterial enzyme activity. Another major issue with UHT milk is age gelation, a process where a custard-like gel forms either in lumps, flakes, or a layer at the top of the milk. Only storing at low (4ºC) or high temperatures (35 - 40ºC) delays the onset of gelation. Fat separation and sediment formation can also occur.
2. **Decreases nutritional value of the milk** – UHT processing reduces B vitamins by 10%, folic acid by 15% and vitamin C by 25%. The fat-soluble vitamins (A, D, E) and some of the water-soluble vitamins (pantothenic acid, nicotinic acid, riboflavin, and biotin) are largely unaffected by UHT treatment, but losses of 20 and 30%, respectively, in thiamine and vitamin B12 can occur during UHT treatment. The levels of ascorbic acid and folic acid are markedly reduced in UHT milk containing a significant level of oxygen during UHT processing and storage. Vitamins B1, B12 and C are reduced by 10-20% and decreases are seen in total fat and total solids with an increase in urea.
3. **Expensive process / Energy consumption / Equipment complexity** – UHT milk containers must be filled using aseptic technologies to eliminate the risk of microbial contamination. In addition, special equipment must be installed for the processing – heating and cooling tanks, deaerators, piping, and hygienic chambers for the containers and sealing process. Furthermore, operators must be highly trained to ensure processing runs smoothly.
4. **Anonymous milk origin** – Often, raw milk from multiple suppliers is combined into one batch for processing at a facility. This makes traceability more difficult if there are issues with the batch.

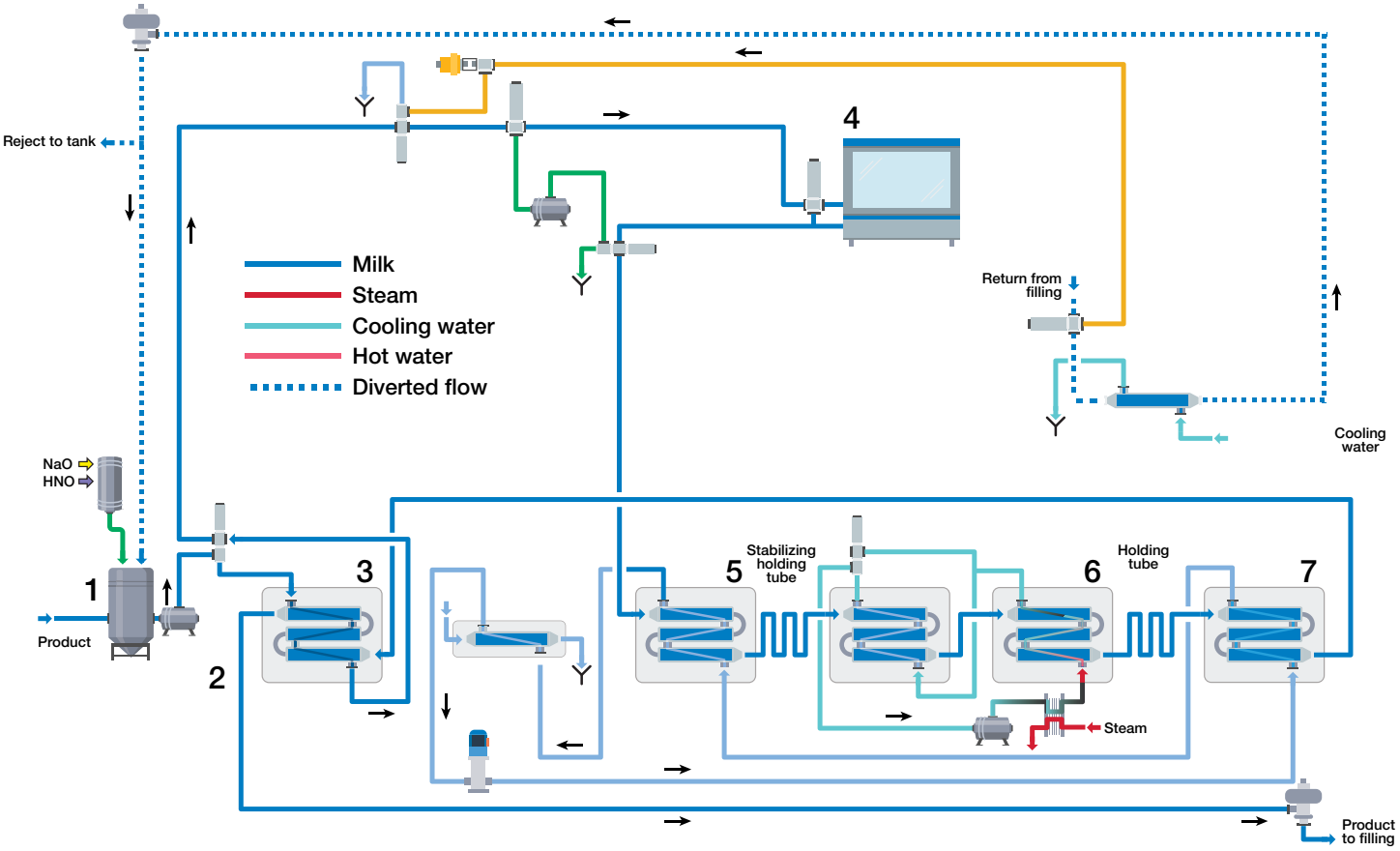


Above infographic adapted from TetraPak processing system illustration

1a Balance Tank Milk
1b Balance Tank Water
2 Feed Pump
3 Plate Heat Exchanger
4 Positive Pump
5 Steam Injection Head
6 Holding Tube
7 Expansion Chamber
8 Vacuum Pump
9 Centrifugal Pump
10 Aseptic Homoheniser
11 Aseptic Tank
12 Aseptic Filling

Advantages of ESL milk:

1. **Organoleptic properties are similar to pasteurized milk** – ESL milk does not have a strong cooked flavor that is characteristic of UHT milk. This makes it more pleasing to drink.
2. **Extended shelf life** – Compared to standard pasteurization, ESL milk has a much longer shelf life. Depending on the product and the processing time/temperature used, considerable extensions of shelf life are observed. Other variables include storage temperature, additional processing such as aseptic filling or filtration/bactofugation. Shelf life ranges from 30 days to 60 days.
3. **Less expensive than UHT processing** – While more expensive to implement than standard pasteurization, ESL processing is simpler than UHT processing due to lower temperature requirements and simpler packaging processes such as using non-aseptic but clean areas for filling.



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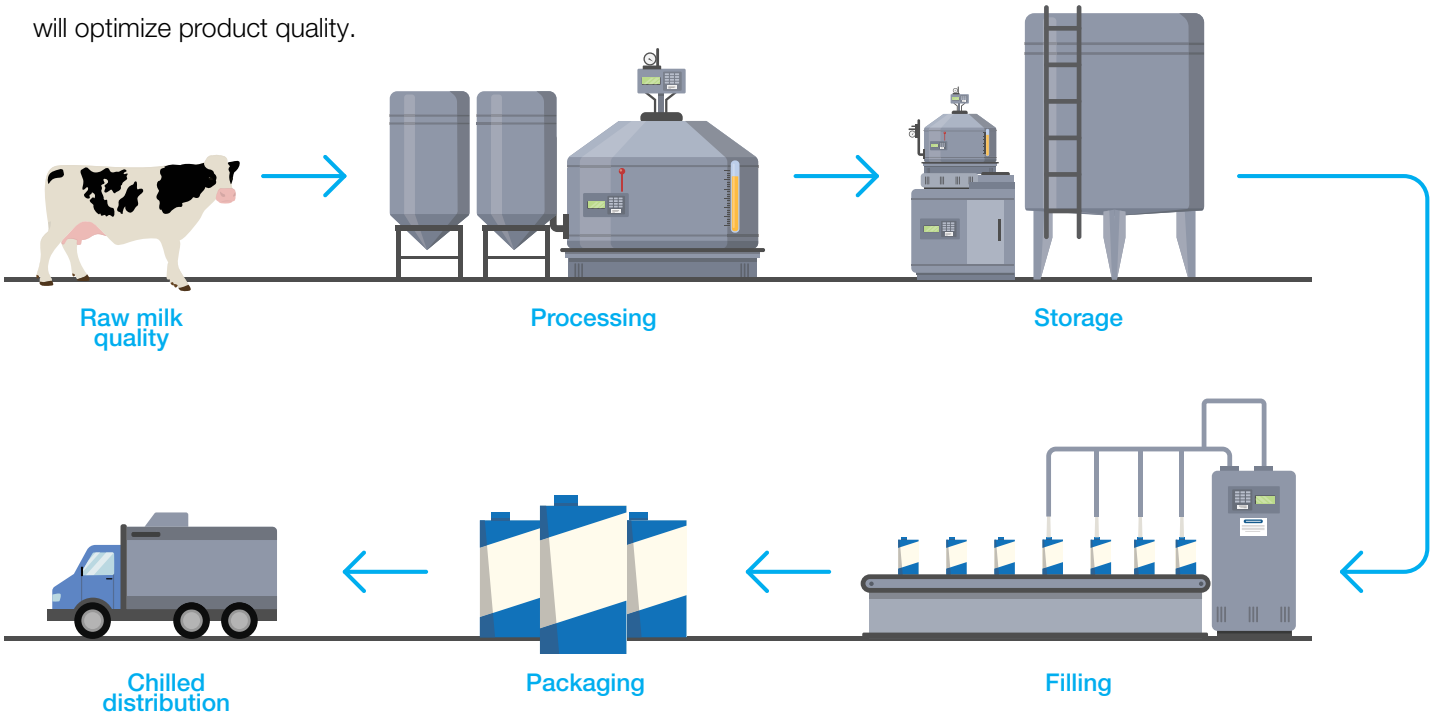
Disadvantages of ESL milk:

1. **Potential for contamination** – ESL milk is packaged under very clean but not aseptic conditions, so the risk of contamination from the environment is very possible. The biggest risks are psychrotrophic spore-formers such as *Bacillus cereus* when milk is not heated over 134°C. There is a delicate balance between increasing the time and temperature for sterilization – too long or too high can be detrimental to the product, while too low and too short reduces the bacterial kill rate, increasing contamination risk.
2. **Potential for flavor issues** – ESL milk can become bitter from bacterial proteases produced in the milk prior to processing and light-induced oxidation can alter flavor. However, the right processing technique and parameters will optimize product quality.
3. **Texture and appearance defects after prolonged storage** – The most common changes involve the separation of the lipid phase, sedimentation of denatured proteins, and age gelation.
4. **Difficult to remain competitive** – Dairy processors must optimize heat recovery, use of materials and other utilities, and find ways to cut costs due to increased run times. It requires technology and experience to maximize output while minimizing costs. It can include reducing the frequency of cleaning cycles to increase production efficiency, requiring very technically skilled workers to ensure processes are standardized and run smoothly. ESL milk must also be refrigerated, incurring the same storage costs as pasteurized product.



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Microbiological Testing

No matter what process you choose for milk processing, they all have one thing in common: microbiological testing is required.

While the details of the testing requirements vary – for example, UHT milk must be tested per 21CFR Parts 108, 113 and 114. Section 113 40 (g) lists specific requirements for aseptic processing and packaging systems in general. In addition, packaging is considered an indirect food additive and is governed by Title 21, parts 174-179. Pasteurized, ESL, UHT, and raw milk fall under the FDA Pasteurized Milk Ordinance. They also require a processing authority.

The microbial limit for ultra-pasteurized ESL milk is <20,000 total bacteria/ml. Although, this is the critical limit under FDA guidelines, most dairies that process ESL milk will have operational limits of <10 cfu/ml. For UHT milk, although it should be commercially sterile, testing still is required to monitor the risks of heat resistant spore-forming bacteria that can survive the UHT process. It must be free of viable pathogens and alkaline phosphatase levels must be negative.

In both cases, products will be considered adulterated when they contain *Salmonella* species, EHEC O157:H7 and other enterohemorrhagic *Escherichia coli*, *Campylobacter jejuni*, *Yersinia enterocolitica*, vegetative cells of *Clostridium botulinum*, *Clostridium botulinim* toxin, *Staphylococcus* enterotoxin, or *Bacillus cereus* enterotoxin. Also, they cannot contain levels of non-toxigenic *E. coli* above 10 MPN (most probable number) per gram in two or more subsamples or greater than 100 MPN per gram in one or more subsamples. For other organisms, levels must be below 10,000 CFU/gram.

A Single, Rapid Solution

Implementing a rapid, easy to use solution for initial microbiological testing would aid in the analysis of the final milk product for contamination. The Innovate System can deliver quality control results in less than 30 minutes, allowing dairy manufacturers to rapidly confirm the quality of the final product and release it quickly to market.

The Innovate platform features RapiScreen™ ATP bioluminescence technology, the industry standard for screening dairy products due to its speed and clear absence/presence results. ATP testing is equivalent to traditional microbiological methods but eliminates the need for plate incubation, allowing product to be released days faster. The system has the ability to run 96 individual samples at once with no secondary incubation required. This is possible due to a unique technology that eliminates somatic cell (non-microbial) ATP and allows testing products with a wide range of pH values. The Innovate System platform is ideal for UHT and ESL products as they should be either free of contaminants or contain low levels (less than 10 cfu/ml). In addition, the RapiScreen™ reagents have been validated on a wide variety of raw materials, in-process formulations, and finished goods. The automation allows simultaneous testing of 96 different samples on a single microtiter plate every 30 minutes. Subsequent assays can be prepared even while the system is in use to keep high-volume operations running smoothly.

Many processing facilities rely on pH methods. However, they require longer incubation times to see dramatic shifts in pH, a strong indication that acid producing spoilage microorganisms are present. Additionally, some dairy formulations have a buffering affect that

allows organisms to evade pH detection. Other facilities use standard plating methods. These methods require different enrichment media, long incubation times (7-14 days), and long detection times (2-5 days) to target aerobic or anaerobic bacteria and yeast/mold. Innovate was developed to simplify the workflow to detect all viable microorganisms (aerobic, anaerobic, and yeast/mold) in a single test. Validation studies are needed to identify a standard incubation time that can detect all microorganisms. Although sample product pre-incubation may be the same as plating and pH methods, Innovate is able to achieve same day "detection". The Innovate System can be adapted to determine what is "pass" or "fail" criteria, making it even easier for a factory worker to monitor testing – green is pass and red is fail. The system also enables sample data from multiple instruments to be saved to a single database on the company's secure network, helping simplify regulatory compliance. Data can be securely viewed onsite or remotely, and reports can be generated for analysis.

When utilizing the rapid screening kit for dairy on the Innovate System, dairy processors can minimize costs for warehouse space or holding product while also feeling reassured that any contamination events will be identified early. In addition, the latest advancement, Innovate Autosampler III, can be paired with the Innovate platform to prepare up to 2,000 assays per hour for analysis in the Innovate System. This simplifies the workflow even more and frees up valuable technician time.

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