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*Thank you to Brandon Riesgaard and Andrea Domen for their efforts to create this photo.*

# Rework Practices Used During Milk Processing: An Industry Survey

## ABSTRACT

Rework is a common practice in the dairy industry for processors to minimize waste while recovering costs from products that are unsaleable. Regulations related to reworking fluid dairy products are focused on product safety; however, rework in the fluid milk industry and its implications for product quality have not been previously investigated. Our objectives were to characterize current industry practices for reworking fluid dairy products and identify scenarios that could contribute to reduced product quality, particularly microbial spoilage. Seven commercial fluid milk processors from the Pacific Northwest were interviewed regarding their rework handling practices. Processors used various terms (rework, reclaim, and rerun) to describe specific product recovery, storage, and reprocessing procedures. Processors reported nine typical rework motivations, with reclaim and packaging problems the most common; however, rework also played an important role in handling special circumstances. Milk products were reworked as soon as 3 days after production up to the code date (21 days) at dilution rates of ≤20% rework to ≥80% fresh product. Rework conditions with the potential to influence product quality or shelf life of milk products were identified.

## INTRODUCTION

Industrial-scale food processing has evolved over the last century to become increasingly efficient, reducing processing time and labor costs while increasing yield and optimizing product quality. Despite this emphasis on continuous improvement, product loss and waste generated during processing are common consequences; thus, 100% of the raw ingredients do not end up in a saleable finished product container. A number of factors contribute to processed product "waste," such as a resulting by-product (e.g., whey from cheese processing), diluted beverages discharged from the pipelines to the drain following cleaning and sanitation, blended flavors between product changeovers, excess unsold product that has not left the processing facility, and products that do not meet legal standards (e.g., incorrect labeling or underfilled). The U.S. Environmental Protection Agency *(31)* estimated that in 2018, 103 million tons (93 million

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metric tons) of food was wasted along the farm-to-fork continuum, with the manufacturing and processing sector accounting for almost 39% of the waste. Each sector of the food industry has a unique processing system and will differ in product loss and waste generation. Although some food manufacturers have discovered economically advantageous ways to transform their waste through by-product utilization (e.g., whey from cheese processing made into whey protein), other processors have implemented creative solutions to capture potential waste and utilize these recovered materials in their final products. This general practice of recovering and reprocessing product loss or waste into a saleable product is generically termed "rework."

Rework is defined in federal regulations as "clean, unadulterated food that has been removed from processing for reasons other than insanitary conditions or that has been successfully reconditioned by reprocessing and that is suitable for use as food" *(32)*. The Dairy Practices Council *(10)* provides additional information on the sources and handling practices of rework in the dairy industry, including product drained from processing equipment at the end of a production run and product recovered from containers or pipes. Other terms used throughout the literature and the industry to describe rework or types of rework include "reclaimed," "reconditioned," and "repasteurized" *(10, 32, 33)*.

The general strategy of rework in the food industry is common; however, processes and procedures for handling and processing rework will be unique to each commodity and specific processing facilities. Effective implementation of rework strategies provides a competitive advantage by reducing waste but also presents new challenges for traceability and potential impacts on finished product quality. Although the traceability challenge may be solved through documentation and technology, determining the implications of rework practices on product quality requires a processor to consider each step within the processing system that may contribute to the finished product. Currently, very few sources can be accessed by the industry for guidance on rework parameters, one of which was produced in 2005 by The Dairy Practices Council *(10)*. With limited guiding resources, milk processors feel uncertain about their decisions regarding rework.

Although the production of dairy milk in the United States has increased by 14% over the past decade *(30)*, fluid milk sales have been trending downward *(29)*. However, over the last year, the volume of milk sales has increased by 1.9% and that of flavored milk has decreased by 0.8% *(9)*. With the increase in production and rapidly changing consumer demands, processors may also be generating more product loss and waste. Because product loss and waste are impacted by challenges within the plant and in the marketplace, the cost of product loss can quickly add up for a dairy processor. In a Hungarian milk processing facility, investigators found that the majority of milk production losses were from technology and automation, the design of the plant, and overproduction, estimating that ca. 1% of a 140,000-L production run of milk is lost to the drain *(26)*. A major equipment manufacturer reported that a typical dairy plant can lose 3% of product to clean-in-place washes in a 500,000-gallon (1,900,000-L) processing run *(25)*. In a case study assessing a small- to medium-size Canadian dairy processing facility, the yearly product loss associated with three products (chocolate beverage, skim milk, and homogenized milk) from the fillers was calculated at $163,800 in raw milk costs *(2)*. Reworked fluid milk and flavored milk products are sold at the same price and grade as nonreworked products. The average price of raw milk fluctuates but reached a high of $24.07/hundredweight ($0.47/kg) in 2014 and was down to $18.30/ hundredweight ($0.36/kg) in 2020 *(30)*. Thus, it can be economically advantageous for a processor to recover any product that can be reprocessed into a saleable commodity. Reducing the amount of product that enters a dairy processor's waste stream is especially critical from an environmental perspective. Dairy processing contributes to the generation of industrial wastewater, which carries large amounts of organic and inorganic substances (e.g., solids, phosphorus, nitrogen, fats and oils, sugars, and chemicals) that can harm the environment when not properly managed *(1, 16, 21, 22)*.

Characterizing rework practices and processing decisions along with targeted product testing, experimentation, and modeling could help explain the potential risks of reworking fluid dairy products. Current regulations for rework are based on repasteurizing the product, product eligibility, and refrigeration of the finished product *(33)*. However, pasteurization is not a sterilization step, and the microbiological quality of products and ingredients influences the quality of the finished product and the shelf life of pasteurized fluid milk held for extended time at refrigeration temperatures *(12, 14, 19)*. Our overall objectives were to characterize common rework practices, terminology, and motivations in the dairy industry, specifically in fluid milk processing plants, and to understand how these practices may influence the quality and shelf life of products containing reworked ingredients, particularly from a microbiological perspective.

## MATERIALS AND METHODS

Fluid milk processors were individually invited to participate in interviews about rework practices used in the dairy industry. Between 2019 and 2020, representatives from seven commercial fluid milk processors from the Pacific Northwest were interviewed in person at their respective facilities ($n = 3$), via telephone or video call ($n = 2$), or in person away from their facilities ($n = 2$) about their rework handling procedures. Prior to each interview, the processors were assured of the anonymity of their answers and practices. Interviews were conducted in an open conversational format that included prompts of 16 questions aimed at understanding dairy

**TABLE 1. Rework survey questions asked during interviews with fluid milk processors ($n$ = 7)**

| Survey Question |
|---|
| 1. How do you define 'rework' in your facility? |
| 2. What is the motivation for rework? |
| 3. What types of products are reworked? What are the most common reworked products? |
| 4. Which products are reworked into which products? |
| 5. What products cannot be reworked and why? |
| 6. Can products that leave the facility be reworked? (ex: over-shipment) |
| 7. How are the products reworked? |
| 8. What dilution rates do you use for rework, and how were these parameters defined? |
| 9. How long can the product typically be stored prior to being reworked? Is there a maximum time frame the product is stored prior to being reworked (code date range, in storage tanks, etc.)? |
| 10. Does the product undergo quality testing prior to being reworked or during the rework process? |
| 11. Are there differences in quality testing for finished reworked product? |
| 12. Is reworked product sold at the same price and grade as nonreworked products? |
| 13. Do customers request or decline products that contain rework? |
| 14. How much rework is completed each day, week, or month for your facility? |
| 15. What are some issues or defects that have been observed from reworking products in this facility? |
| 16. What other information would be valuable to you as a processor that could be obtained during this rework investigation? |

processing rework practices, including the definition of rework, frequency of rework, business motivation for reworking product, rework dilution rates, common noticeable defects, quality testing parameters, and rework management practices *(Table 1)*. During the interview, processors were also asked to share a general description of the company and product line. In-person interviews at the facility consisted of a tour of the production floor and a demonstration of rework procedures. At the conclusion of each interview, the processors were provided an opportunity to share any other information pertaining to rework that they were interested in learning or that was not covered during the survey.

## RESULTS AND DISCUSSION

### Surveyed facilities

The average daily production volume of the seven surveyed processing facilities was 7,000 to 100,000 gal (26,500 to 378,000 L) per day, and these facilities manufacture products for the retail and foodservice markets. A summary of the pasteurization processes and the products, packaging type, and packaging sizes produced by each facility are shown in *Table 2*. All seven facilities use rework practices and subsequently answered all survey questions, including a description of the current operation.

### Defining rework

When discussing rework, all seven processors used "rework" as a blanket term to describe a product, an ingredient, and a process. The U.S. Pasteurized Milk Ordinance (PMO) uses "rework" to discuss allergens and the "disposal of recalled milk" and uses the term "repasteurization" to discuss rework parameters *(33)*. In the Code of Federal Regulations, rework is defined as "clean, unadulterated food that has been removed from processing for reasons other than insanitary conditions or that has been successfully reconditioned by reprocessing and that is suitable for use as food" *(32)*. Conversely, the U.S. Department of Agriculture *(28)* outlines specific rework and reclaim guidelines for dairy products made from grade B fluid milk (e.g., butter, cheese, and dry milk) using language similar to that used by the processors that were surveyed. Aligning the language in regulatory documents or providing clarification and/or definitions for rework, repasteurization, and reprocessing in the PMO for grade A fluid milk processors would likely assist the industry in discussing challenges related to these practices. Training may be necessary to support effective communication between production and quality personnel to understand the nuances of when packaged product can or cannot be reworked.

**TABLE 2. Pasteurization method, product types, and packaging type and size used by dairy processing facilities (A through G) participating in the rework survey**

| | Milk Processing Facility | | | | | | |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G |
| **Pasteurization Method** | | | | | | | |
| High temperature short time (HTST) | | X | X | X | X | X | X |
| Ultrapasteurized (UP) | X | X | | | | | |
| **Product Types** | | | | | | | |
| Pasteurized milk | X | X | X | X | X | X | X |
| Half-and-half | X | X | X | | | X | X |
| Cream | X | X | X | X | X | X | X |
| Flavored milk beverages | X | X | X | X | | X | X |
| Eggnog | X | X | X | | | X | X |
| Lactose-free milk products | X | X | X | | | | |
| Ice cream | X | X | X | | | | X |
| **Packaging Type and Size** | | | | | | | |
| Carton (waxed, paperboard) | | | | | | | |
| ½ pint | X | X | X | | | | |
| Pint | X | X | X | | | | X |
| Quart | X | X | X | | | | X |
| ½ gallon | X | X | X | | | | |
| Jug or bottle (plastic) | | | | | | | |
| 16 oz. bottle | X | | | | | | X |
| ½ gallon | | X | X | X | X | X | X |
| Gallon | | X | X | X | X | X | X |
| Bag-in-box (2.3 kg [5 lb]) | X | X | X | | | | |

The majority of processors (five of seven) broadly defined rework as a product that failed a quality standard such as low butterfat content, cosmetic packaging defects, or approaching the sell-by date. Some facilities used supplemental synonyms to name specific types of rework. The lexicon introduced by survey respondents for rework included reclaim (three facilities), recovery (one facility), and rerun (one facility). Two facilities utilized reclaim to describe packaged products that were predetermined as rework and immediately removed from the processing line. Conversely, one facility specifically delineated reclaim as unpackaged product that had been recovered directly from the fillers, whereas another facility designated this product as recovery. One facility employed rerun as a substitute term for rework. Two processors distinguished rework as the commingling of separate lots. These two facilities can recover product from the production line and immediately add it back into the balance tank during the same production run; thus, the collected and commingled product would retain the same lot code and was not considered to be reworked.

All surveyed processors indicated that reclaiming fluid milk from butterfat standardizations for rework is the most frequent (daily) rework strategy. Reclaim from butterfat standardizations consists of the "diluted" product being reclaimed when changing from a lower fat milk to a higher fat milk. Other products that are held for rework include lactose-free fluid milks (three facilities), whipping creams (six facilities), half-and-half (three facilities), and blended flavored products such as chocolate milk, coffee creamers, and ice cream mixes (six facilities) *(Fig. 1)*. However, not all products are held for reworking. All four of the surveyed facilities that manufacture strawberry-flavored milk reported that this product is not typically retained for rework. One processor stated that this decision was founded on quality defects associated with their strawberry milk products, including a noticeable premature degradation of the red color

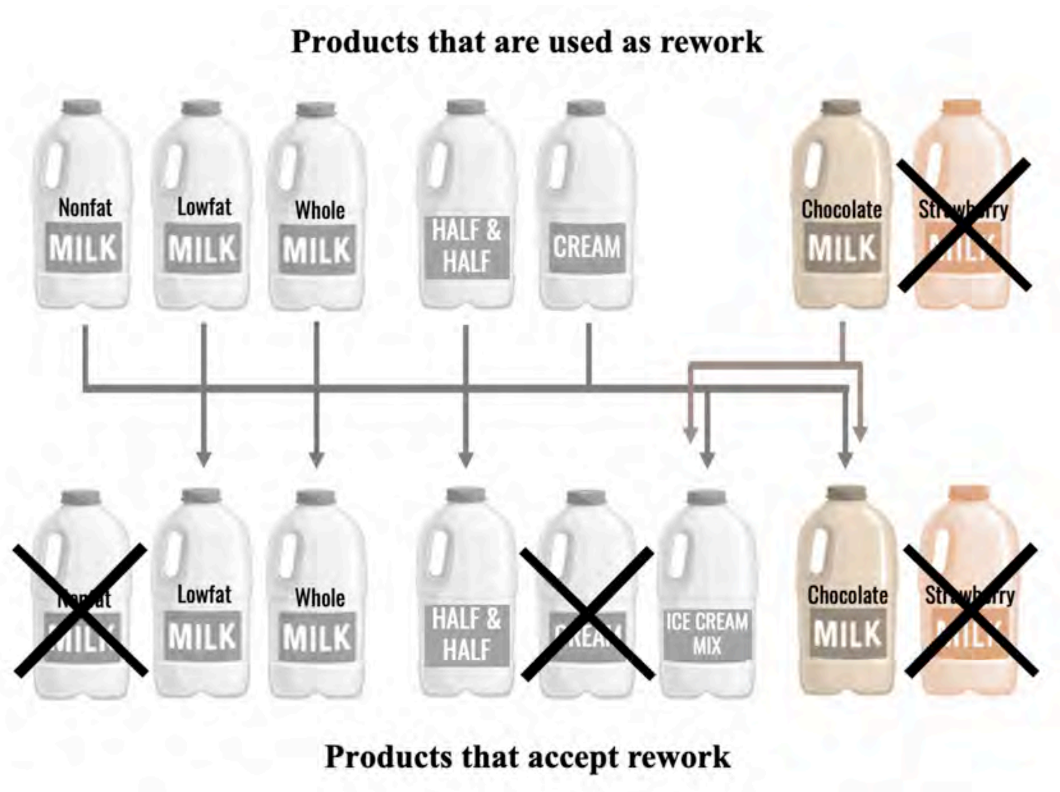


**Figure 1. Fluid milk products that can serve as the source or recipient of rework.**

(typically FD&C Red No. 40) during storage. Each fluid milk processor reported a composition and/or quality analysis of product prior to approving it for rework. All facilities reported compositional analysis of butterfat content and solids to facilitate adjustments in the final formulation of the finished product. Six facilities analyze rework for titratable acidity (TA) and conduct an informal sensory analysis for aroma and flavor. Two facilities that rework into cream products also perform functionality tests for whipped cream.

Fluid milk processors reported a total of nine typical motivations for rework in their facilities *(Table 3)*. The most common motivations were packaging errors, recovered product loss (reclaim), and unsold product approaching code date. According to the PMO *(33)*, not all products are eligible for repasteurization (reworking). Mishandled products, contaminated or adulterated product, damaged or leaking containers, out-of-code containers, and temperature-abused products are all disqualified from being reworked into grade A dairy products. All surveyed processors echoed many of these reasons that milk products would be classified as ineligible for reworking in their facilities. Products reported to be rejected for rework by all processors included temperature-abused or adulterated products, products that have surpassed the printed code date on the container, and products that have left control of the facility. Processors also reported that products containing rework cannot be reworked again. Processors indicated that products ineligible for rework were either discarded, donated as animal feed, or donated to a food donation distribution warehouse, depending on the reason the product could not be reworked.

**Packaging problems**

Packaging problems included underfilled (short filled) containers, incorrect labeling, and damaged or defective containers. All processors reported that they rework packaged products that were underfilled. Packaging flaws included mislabeled products, misshaped or cosmetically damaged containers, and missing caps. Two facilities disclosed that they rework leaking containers. These "leakers" are packaged products in which the packaging, usually the carton or jug seal, is damaged enough to lose product. Two facilities reported reworking packaged products that had come into contact with the floor or another non-food-contact surface, typically due to milk crates falling over during storage or transport within the facility. Containers were inspected and when they remained integrous, they were resanitized prior to being opened and incorporated into rework.

**Reclaim: recovering loss from product changeovers**

All surveyed facilities reported using reworking strategies to recover off-specification product associated with product

**TABLE 3. Rework motivations reported by dairy processing facilities ($n$ = 7)**

| Rework motivations | Facilities indicating motivation |
|---|---|
| Underfilled containers | 7/7 (100%) |
| Packaging flaw (cosmetic) | 6/7 (86%) |
| Code date (unsold product) | 5/7 (71%) |
| Packaged reclaim[a] | 5/7 (71%) |
| Elevated microbial counts | 4/7 (57%) |
| Unpackaged reclaim[a] | 3/7 (43%) |
| Packaging leakers | 2/7 (29%) |
| Resanitized containers[b] | 2/7 (29%) |
| Temperature dependent[c] | 1/7 (14%) |

[a]Reclaim: product captured following sanitation and product changeovers.

[b]From products stored in milk crates that fell over during storage or transport within the processing facility.

[c]Temperature-dependent motivations are associated with products that are reworked due to not being refrigerated immediately following packaging.

changeovers. Most processors refer to this process as reclaim. Common transitions for fluid milk processors include skim milk removed during butterfat standardization, transitions from lower butterfat products to higher butterfat products, transitions from dissimilar product changeovers (i.e., fluid to flavored), and product recovered from the pipes prior to and/or after sanitation procedures. Processors typically flush a predetermined volume through the fillers for immediate disposal prior to collecting and capturing the reusable volume of product. Processors decide what is eligible for collection based on visible cues and/or product testing. For visible cues, some processors described that they begin to capture the reclaim when the product flowing through the fillers visibly appears to be mostly milk because it is white in color. Some processors have previously tested the amount of product that needs to be flushed through the pipeline before they start to collect the reclaim, typically based on solids and/or butterfat content of the product. Some processors use TA on reclaimed product to verify that residual sanitizer from the clean-in-place step is minimized. Reclaim procedures are designed to minimize the time between product recovery and reprocessing. Therefore, reclaimed milk is unlikely to have a negative impact on the microbial load and shelf life of the final product.

Surveyed processors described two types of reclaim systems: bulk reclaim and packaged reclaim *(Fig. 2)*. Three of the surveyed facilities use a bulk reclaim system to divert product away from the fillers to a holding tank or storage vessel, where it may be stored for up to 3 days at ≤ 7°C (≤ 45°F) prior to reworking. Two of the facilities have a bulk reclaim system that consists of a conduit draining system that is installed directly under the fillers. It is programmed to flush the initial unusable product volume for immediate disposal, and then the operator will manually switch the system to reclaim a predetermined volume of product that is pumped into a holding tank. One facility manually collects reclaim in 10-gal (38-L) stainless steel milk cans and immediately transfers it into the balance tank for incorporation into the same production lot. If the lot has since changed or production has stopped for the day, this reclaimed product will be stored in the milk cans at ≤ 7°C until it can be incorporated into a subsequent product lot. These scenarios present different traceability challenges for rework within a single facility.

Four milk processors reclaim off-specification product in packaged form. In these facilities, the initial diluted product is flushed through the fillers down the drain, and once milk product begins to flow through the fillers, packaging begins. The first 20 to 30 filled containers will not meet product specification. These containers are immediately removed from the line and held in cold storage (up to a processor's specified code range) until they are reworked in a later production lot. The number of packaged reclaim units removed from the line is dependent on facility conditions and is established prior to collection to ensure that the finished packaged products have hit targeted specifications and are unadulterated by other constituents.

One facility takes a mixed approach to reclaim using a combination of bulk and packaged strategies. In this facility, the fillers are flushed, and then a predetermined volume of

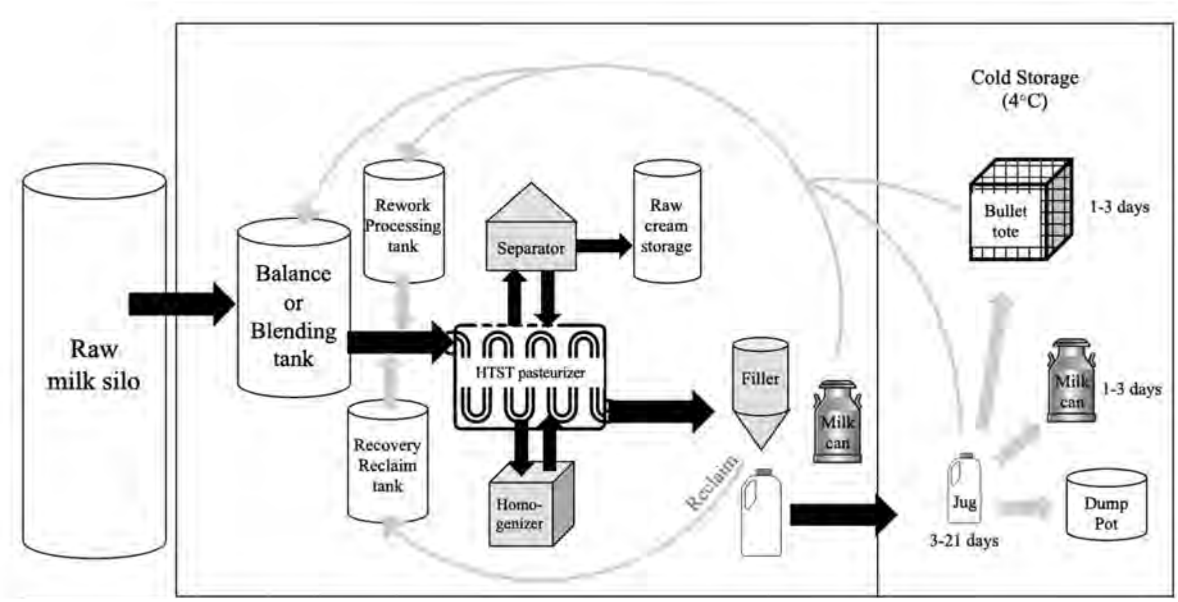


**Figure 2. Collection, storage, and incorporation of milk processing streams that are used as rework into fluid milk. Black arrows indicate typical fluid milk processing flow. Gray arrows indicate rework introduction into the typical processing flow.**

product is reclaimed by pumping directly into a holding tank. After this initial bulk reclaim, packaging begins; however, the first 18 to 20 containers are immediately removed from the line and donated to a local food bank. The packaged products reclaimed for donation may be slightly diluted or have mixed or weak flavors from product changeovers.

**Unsold (code-date challenged) product**

Code-date challenged product is product that is stored at the production facility and is unsold and approaching its sell-by date. This concern was common for processors that produce milk for the school lunch program (half-pint [0.24-L] cartons), especially when school breaks (spring, winter, and summer) create disruption in product demand. Each processor established their own standard for the code range in which a product is eligible for rework. One facility's ultrapasteurized products can have a printed code date of 65 to 100 days depending on the product and can be reworked up to 7 days within these code dates. Three high temperature-short time pasteurization (HTST) facilities rework products to within 5 (two facilities) or 7 (one facility) days of the code date. One facility reported reworking their HTST products up to their printed code date of 21 days from production. At the other extreme, another facility reworks product that is within only 3 days of the production date. Their decision to not rework code-date challenged product was based on in-house studies that showed an increased potential for premature spoilage when including product stored beyond 3 days after processing. Only two facilities reported that they performed microbial testing (standard plate counts [SPCs] and coliform counts) but only when < 50% of the code date remained. Samples for these analyses are taken from the bulk tank or from a package prior to opening and are mixing in the storage or rework tank. Results from all tests are received and reviewed prior to the product being reworked.

Many variables in a dairy processing system could contribute to spoilage; however, two main factors require consideration for reworked products: (i) pasteurization efficacy and (ii) storage time and temperature. Although rework products are reprocessed, pasteurization is not a sterilization step and milk is a nutritious growth medium that allows for bacterial growth. Endospore-forming psychrotrophic bacteria, predominantly *Bacillus* and *Paenibacillus* species, are passed from the farm environment to the raw milk as heat-resistant spores *(8, 18, 34)*, which can survive pasteurization, germinate into vegetative cells *(20, 23)*, and subsequently grow under refrigeration conditions *(4, 15, 24)*. However, all cells may not germinate after pasteurization, and in theory some species could sporulate in milk during extended periods of refrigeration *(4, 24)*. The survival of just one spore of *Paenibacillus*, the dominant bacteria isolated at the end of the shelf life of pasteurized fluid milk, is capable of growing to spoilage levels at refrigeration temperatures before the end of the 21-day shelf life *(3, 4, 15, 19, 23, 27)*. Therefore, psychrotrophic heat-resistant spore-forming bacteria should be of most concern for causing spoilage in rework products.

All products classified as rework or reclaim are stored for various amounts of time at ≤ 7°C before they are reprocessed, which may allow increases in bacterial counts and sporulation. Multiple processors rework products between 15 and 21 days of the code date. Products also may be stored for another 24 to 72 h during processing, depending on facility practices. Thus, rework products could be up to 24 days old by the time they are repasteurized, which could increase the levels of psychrotrophic spoilage bacteria in the finished product. Buehler et al. *(4)* modeled the growth of spore-forming bacteria commonly isolated from pasteurized milk and found that the growth rate of the organisms and low storage temperatures (4°C) were the two most important factors in controlling spoilage outcomes. Because spores are likely the most influential factor causing quality defects in reworked products, an understanding of the sporulation behavior of *Bacillus* and *Paenibacillus* species in pasteurized milk over the product shelf life is critical information for a processor. Research on the sporulation of *Paenibacillus* in milk products is underway in our laboratory.

**Elevated microbial counts**

Four facilities reported reworking products with elevated microbial counts (e.g., SPCs) or thermoduric counts obtained from routine testing of finished product as part of a quality assurance program. Processors will rework these types of products only when they are within the specified bacterial limits for grade A raw milk as outlined in the PMO (SPC ≤ 300,000 CFU/mL when commingled with other producer milk prior to pasteurization) *(33)*. Two facilities indicated that elevated microbial counts were their top motivation for rework. These facilities rework microbially challenged product only when counts are < 3 log CFU/mL; otherwise, these products are discarded. One facility reported reworking product containing elevated coliform counts (>10 CFU/mL) as their only microbial motivation. Three processors do not rework products with elevated microbial counts; instead, these products are either donated for use as animal feed or discarded.

**Special situations**

Although dairy processing is an organized system, operational errors due to equipment failures or human mistakes occur and can make a large volume of processed product unsaleable. In unexpected circumstances where product may have been compromised, dairy processors can employ rework strategies to manage the inherent product loss or waste. Two examples were shared by facilities in which rework was employed in special situations: (i) a tool was found in the bottom of a processing tank following a production run, and the facility chose to rework the product lots that had passed through this processing tank; and (ii) ultrapasteurized product was unrefrigerated (> 45°F) for >1 h due to an emergency line shutdown, and the facility chose to rework the product.

**Processing rework and dilution rates**

All processors dilute their rework with fresh product to minimize potential quality defects that would be perceived with product that was simply reprocessed. Most facilities rework their unflavored fluid rework and/or reclaim products into other unflavored products (five facilities) and/or flavored or blended dairy products (six facilities) *(Fig. 1)*. Two facilities do not rework into unflavored fluid milk. Processors reported that skim milk and whipping creams typically do not receive any reclaimed fluid milk because of the difficulty in meeting the target butterfat requirements. One facility incorporates rework only into their ice cream products. To successfully incorporate rework into fresh product, the rework should be mixed in uniformly. The strategy for successful incorporation of rework is slightly different for unflavored fluid milk than for flavored or blended dairy products.

When processors rework fluid dairy products into fresh unflavored fluid dairy products, the rework and reclaim products are transferred from the storage tanks, storage vessels, or original packages and commingled into a rework tank, a batch tank, or a bulk tank. Five facilities have a specific rework tank in which the transferred products can be stored for up to 24 h in the production area. (Two facilities do not have a separate rework tank and must process their rework immediately after it enters the production floor.) The tank is then joined to the processing line, and the rework tank is discharged into the raw milk line, where the rework mixes with fresh raw milk and then proceeds through the typical processing stages (i.e., pasteurization and packaging). All five facilities that rework into unflavored milk products use a dilution rate of ≤ 20% (20% rework:80% fresh product).

When processors rework into flavored or blended milk products, previously flavored or unflavored rework products can be either pumped from a storage tank or bullet tote or dumped directly from the container or milk can into a batch or blending tank, where these products are commingled with other ingredients (e.g., stabilizers and flavor adjuncts). For large volumes, the composition is tested to ensure the appropriate ratio of ingredients. The batch is then blended with raw milk and the rest of the ingredients until the target formulation has been obtained. Maximum rework dilution rates in flavored or blended products differed by facility, from 3 to 5% in two facilities to ≤ 20% in one facility. The facility that reworks into ice cream mixes does not have a set maximum rework rate; however, rework can be as much as 40% of the finished product.

Because flavored products contain additional ingredients, surveyed facilities reported that different types and flavors of rework products can be reworked into other flavored and blended products. Four facilities typically combine like and unlike rework products into flavored and blended products with reclaim, fresh milk, flavoring adjuncts, and other ingredients into the blending tank to reach the composition of the final target product (e.g., chocolate flavored milk and ice cream mixes). The reported like products include similar flavored milks, whereas unlike products can comprise whipping creams and/or half-and-half products. Two facilities only rework like products into their finished flavored products along with reclaim, fresh milk, and other ingredients. All surveyed processors estimated the typical volume of rework they process within their facility in 1 month as 1 to 2% of total production volume (three facilities) or < 1% of total production volume (four facilities).

**Quality implications associated with rework**

Processors conduct shelf-life evaluations on designated products from each lot. Some processors described a stress test performed on their products in which products are held at ≥7°C and analyzed for quality defects such as flavor or texture deviations. Based on these internal results, six processors reported that discernable quality implications or a diminishing shelf life were more commonly observed in products that contain rework than in products that do not contain rework. The defects described are not exclusive to dairy products containing rework. Four facilities noted an intermittent "athletic tape" or "bandage" aroma and flavor in their chocolate and/or lactose-free milks that contained rework. One of these facilities reported other flavor defects in finished products that contain rework, specifically "banana" or "fruity" off-flavors in chocolate milk and a "nutty" flavor in fluid milk. Two facilities reported that when chocolate milk contained reworked unflavored fluid milk, the products developed flavor defects more commonly than when they contained reworked flavored milks. Two facilities reported elevated microbiological counts (SPCs and thermoduric counts) in finished product containing rework. Two facilities indicated that their finished flavored products containing >10% rework were more likely to separate due to air intrusion, stabilizer imbalances, and/or overworking. One facility has not noticed any discernable flavor defects or diminished shelf life in products that have been reworked compared with nonreworked products.

Although some guidelines are available to processors in the PMO and from the Dairy Practices Council, the focus is on food safety, not on quality. Individual processors make decisions about rework practices at the facility level, with drastically different amounts of supporting evidence. Two facilities indicated that they had performed in-house studies to support their rework practices, which resulted in practices unique to their facility. One processor decided to rework products only within 3 days of the production run due to a risk of increased thermoduric counts. Another processor noted a predictable flavor defect ("band-aid") in chocolate milk when batches included >10% rework and decided to set this amount as the rework threshold for chocolate milk. Supplementary analyses were also used at multiple facilities to identify quality issues prior to final testing of the finished pasteurized products; TA tests were the most common. TA can be used as an indicator of increased microbial counts in pasteurized milk due to changes in acidity *(35)*; however, one of the processors relied on TA as an indicator of alkali in their reclaim captured after the sanitation step. These analyses are not required, but they assist processors in making informed decisions regarding their rework practices. Processors also have to consider their customers when making decisions around rework. Two processors stated that they have customers with contracts that prohibit rework in their finished products; thus, they do not process reworked products during these production runs.

Quality implications of rework have been previously investigated for other dairy products, including butter *(6, 11, 17)*, ice cream *(7, 13)*, and processed cheese *(5)*. The quality implications of rework practices used in fluid milk processing have not been investigated; however, our discussions with processors indicated that they associate increased or unique defects with products containing rework. Although some processors are making decisions to process their rework based on the data they have collected internally, others have not performed these tests, and there is no shared industry data available. All processors must weigh the cost of < 1 to 2% of product waste against the risk of quality loss of an entire production lot. To evaluate the risk, processors should consider the quality of the original milk product, the storage time and temperature prior to reworking, and the product expectations throughout the shelf life of the product containing rework.

## CONCLUSIONS

Rework, particularly reclaim, is a daily reality for all surveyed dairy processors that helps mitigate product loss and reduce waste while recovering some ingredient costs. Rework is also a strategic option for processors to repasteurize products that have been compromised due to unpredictable circumstances into saleable products. The results of this industry survey provide a detailed summary of a diverse set of rework practices used at fluid milk processing facilities ranging in size and production type. Survey results revealed rework conditions, particularly for code-date challenged product, that have the potential to influence the microbial quality and shelf life of products containing reworked ingredients. Microbiological testing of product approaching the code date is a recommended strategy for identifying causes of spoilage defects associated with reworked product and determining practical guidelines for establishing maximum storage times prior to reworking product into fluid milk.


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