Risks Posed by Fluid Milk Past Its Expiration Date

Overview

Most fluid milk in the United States is pasteurized, and typically pasteurized using High Temperature Short Time (HTST) pasteurization (International Dairy Foods Association (IDFA), 2021). When milk is treated using HTST pasteurization its temperature is raised to least 161° F for at least 15 seconds. This heat treatment destroys many foodborne pathogens that may be present in the raw milk. The milk is then cooled, packaged and enters the distribution chain for eventual purchase and storage in the home refrigerator.

Milk is regulated on a state-by-state basis, but those state regulations are based on the Pasteurized Milk Ordinance (Food and Drug Administration (FDA), 2017). FDA has developed and continues to regularly modify the PMO and recommends it for adoption by states to encourage a greater uniformity and a higher level of excellence of milk sanitation practice in the United States. The PMO does not mandate a specific shelf life, and therefore milk processors typically set their own shelf life. Some states and even one city (New York) do mandate specific expiration dates (Wachter, 2009). Milk shelf life is influenced by a variety of factors including packaging material, processing conditions, microbial quality of the raw milk and storage temperature (Simon and Hansen, 2001).

When pasteurized milk develops off flavors this is typically because of the growth of spoilage bacteria (Ridgway, 1954). Milk spoilage organisms make lipases and proteinases that degrade the milk fats and proteins leading to off flavors (Rowe and Gilmour, 1985) like rancidity (Bodyfelt et al., 1988) and bitter flavor (Swaisgood, 1980) respectively.

Most HTST pasteurized milk in the US has a shelf life of about 2 to 3 weeks and this is due to the growth of spoilage microorganisms that causes undesirable changes in the milk (He et al., 2009; Ranieri and Boor, 2009; Simon and Hansen, 2001). The type of microorganisms that might cause spoilage of any one container of milk depend upon a variety of factors. An extensive study of milk samples from 18 dairy plants over 5 geographical areas (Midwest, Northeast, South, Southeast, and West) yielded 589 bacterial isolates. The most frequently isolated Gram-negative organism was *Pseudomonas* (122 isolates), while the most frequent Gram-positive organisms were *Bacillus* (240 isolates) and *Paenibacillus* (122 isolates). These authors noted that samples from only 7 plants (~39% of the plants sampled) contributed most (~95%) of the *Pseudomonas* obtained in this study. These authors were able to characterize these 7 plants as having gram-negative spoilage patterns versus the other 11 plants as having gram- positive spoilage patterns. These authors also noted that the Gram-positive pattern shifts over time as the milk spoils. More than 80% of the Gram-positive spore-forming isolates in the first 10 days were *Bacillus*, while more than 90% of isolates day 17 of shelf life were *Paenibacillus* (Ranieri and Boor, 2009).

Pseudomonas species are generally regarded as food spoilage organisms and not foodborne pathogens (Raposo et al., 2017), although it has been suggested that *P. aeruginosa* can cause diarrhea in immunodeficient individuals (Adlard et al., 1998; Ensign and Hunter, 1946). *Paenibacillus* is a genus which was originally part of the genus *Bacillus* and reclassified as a separate genus in 1993 (Ash et al., 1993). The organism is widely found in nature and is known to produce anti-microbial chemicals (Grady et al., 2016) which have been proposed as bio control agents for pathogens like *Salmonella* (Allard et al., 2014). At least some species of *Bacillus* including *Bacillus wiedmannii* are psychrotolerant and cytotoxic, can be isolated from dairy foods and dairy environments.

Pseudomonas does not form heat stable toxins. *Paenibacillus* spp. does make toxins but these appear to only affect insects (Grady et al., 2016). There are only limited investigations into pathogenic potential of *Paenibacillus* isolates but they appear to lack many of the virulence genes and toxins common in *B. cereus* (Celandroni et al., 2016). *B. cereus* is well known to produce both heat labile and heat stable toxins both of which are responsible for foodborne disease outbreaks (McKillip, 2000). *Bacillus cereus* strains which produce emetic toxin have been isolated from raw milk, cheese or the farm environment (Beattie and Williams, 1999). Research has also generally shown that *B. cereus* strains which produce the diarrheal toxins tend to be associated with food high protein like meat or and dairy products while those strain that make the emetic toxins are commonly associated with starchy foods like rice, pasta, pastry, and noodles (Martínez-Blanch et al., 2009; Reis et al., 2013; Saleh-Lakha et al., 2017). The temperature limits for emetic toxin production are being characterized, and one study which screened seven emetic strains found no growth at 10°C but did see growth and toxin production at 12°C (Finlay et al., 2000). The same study showed that toxin was detectable at 15 °C once cells reached 6 log CFU/ml but was detectable at 12 °C once cells reached 4 log CFU/ml (Finlay et al., 2000). Another study of 100 representative strains found that none of the emetic toxin-producing strains (n=17) were able to grow below 10 °C (Carlin et al., 2006). The temperatures of home refrigerators are notoriously poorly controlled with an average temperature of 6 °C (43°F), but an average maximum of 16 °C (61 °F), indicating that emetic strains of *B. cereus* could grow in milk and some home refrigerators (James et al., 2017)

Summary

Data from Ranieri and Boor (Ranieri and Boor, 2009) indicate that milk may contain 8 log CFU/ml at 14-17 days if spoiled by *Pseudomonas* and 4 log CFU/ml at 14 days and 6 log CFU/ml at 17 days if spoiled by *Paenibacillus* or *Bacillus*. *Pseudomonas* species are generally regarded as food spoilage organisms but some strains may cause diarrhea in immunodeficient individuals (Adlard et al., 1998; Ensign and Hunter, 1946). Heating the milk will significantly reduce this already low risk. There are limited investigations into pathogenic potential of *Paenibacillus* but this species appears to lack many of the virulence genes and toxins common in *B. cereus* (Celandroni et al., 2016). *Bacillus cereus* strains which produce the heat stable emetic toxin have been isolated from raw milk, cheese or the farm environment (Beattie and Williams, 1999), although strain that make emetic toxins are commonly associated with starchy foods like rice, pasta, pastry, and noodles (Martínez-Blanch et al., 2009; Reis et al., 2013; Saleh-Lakha et al., 2017). Strains that produce the amount of toxin appear unable to grow at temperatures less than 10 °C (Carlin et al., 2006). If consumers know that their milk was held below 10° C (50 °F), and if they boil that milk before use, the risk of foodborne disease appears to be very low.

Plain language summary

Milk that does not look or smell spoiled which was refrigerated below 10° C (50°F), should be safe to consume after boiling.

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