MILK QUALITY AS A FUNCTION OF TEMPERATURE-CYCLED, REDUCED-FAT MILK STORED IN VARIOUS SIZE CONTAINERS

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Summary

Packaged, reduced-fat milk was subjected to a 20 min/day temperature cycle during a 7-day refrigeration period to determine the effect on milk quality. Temperature cycling did not affect the compositional or microbial counts in reduced-fat milk stored in various package sizes. Analysis of headspace compounds during the 7 days of storage, however, showed that benzaldehyde, 2-butanone, 2-heptanone, hexanal, and octanal concentrations significantly changed, indicating that milk flavor was altered. Concentration of heptanal, a compound associated with lipid oxidation, was higher in milk packaged in half-gallon and 1-gallon containers, compared with milk packaged in 1-cup containers.

(Key Words: Milk Flavor, Packaging Size, Temperature Cycling.)

Introduction

Milk consumption is increasing, partly because of new packaging. Children disliked traditional gable-top cardboard milk cartons. They found them difficult to open, leaky, or to have an odor, whereas plastic bottles were easy to open, hold, and re-close. It is known that the packaging material can impart an off-flavor in milk in as quickly as 24 hr of refrigerated storage. In addition, milk packaged in 1-pint cartons had more off-flavor than milk packaged in 1-quart or half-gallon cartons. The container-size effect has been attributed to increased surface area to volume ratio.

Today, the most common milk container is the 1-gallon, high-density polyethylene (HDPE), single-use plastic jug. These containers are designed for multiple serving times; therefore, the milk has the potential to develop off-flavors during its life at the "consumer" residence. On the other hand, milk is packaged in single-service containers ranging in size from 1 cup to 1 pint and normally in packaging material different than the HDPE 1-gallon container. Thus, it isn't surprising that some children comment that school milk or food service milk "tastes different than milk at home."

The Pasteurized Milk Ordinance (PMO) mandates that high-temperature, short-time (HTST) pasteurized milk must not exceed 45ºF after processing. Milk stored and maintained at ≤ 40ºF has increased shelf-life because psychrotrophic microorganisms grow more slowly, and off-flavors may not be detected for 10 to 14 days, whereas psychrotrophic microorganisms grow quickly and cause detectable off-flavors after a few days if milk is stored at 46 to 60°F. Cold milk temperature has been reported to increase by 10ºF in 20 min when milk was placed at room temperature. Thus, removing milk from refrigerated storage for any period of time, such as retrieving a glass of milk for a meal, has the potential to increase off-flavors, reducing consumer acceptability. Hence, the objective of this study was to evaluate reduced-fat milk quality as a function of carton size and temperature cycling during a 7-day period.

Procedures

Reduced-fat milk was obtained within 2 days of production from the Kansas State University dairy plant, packaged in 1-cup, half-gallon, or 1-gallon plastic (HDPE) containers. Milk was processed at 174 ± 1ºF for 20 seconds and homogenized at 1500 lb/in^2 (psi). Reduced-fat milk samples were then placed in brown paper bags and stored at 40ºF. For 7 consecutive days, milk samples were removed from refrigerated storage and placed in a 72ºF incubator for 20 min. Five ounces of milk was removed from the 1- and half-gallon containers, which were then replaced in 40ºF storage. For the smallest container size, 1 cup, an individual container carton was used each day, but cycled the correct number of times. Milk samples were analyzed for headspace composition, microbial counts, and chemical contents, according to standardized, published procedures. The experiment was repeated 3 times, and resulting data were analyzed statistically. Results are presented from days 0, 2, 4, and 7.

Results and Discussion

Temperature Change. Table 1 displays the average temperature of the milk samples after the 20-min temperature cycle, as a function of container size. The average temperature increase by container size was: 1.7, 2.9, and 8.3ºF for 1 gallon, half gallon, and 1 cup, respectively. The smallest container size was affected more by temperature cycle than the larger containers. The temperature increase did not exceed the upper cap in the PMO for the 1- and half-gallon containers, but did for the 1-cup containers. It was expected that a trend would occur that milk temperature would increase over time, as milk was removed from the 1- and half-gallon containers each day (5 ounces for testing), but that did not occur, perhaps because the 1- and half-gallon milk containers still contained about 73% and 45%, respectively, of their original volumes at the end of the study.

Observed temperature change in our milk samples was not as dramatic as in previous reports, perhaps because of controlled temperature conditions we employed. It has been reported that many home refrigerators are not maintained at ≤ 40ºF, but rather approach the upper level of the refrigerated temperature definition of 45ºF. In some situations (perhaps late spring and early fall), “room temperature” may exceed 72ºF. These 2 differences could contribute to a larger temperature change than was observed in our study.

Compositional and Microbial Analyses. Milk samples did not differ in compositional or microbial quality. Mean compositional contents for the reduced-fat milk were 1.96% fat and 10.9% total solids. Microbial counts did not differ either, as all total plate counts were ≤ 500/mL, even at the end of the study. The compositional and microbial data agree with the temperature data. The cycling treatment did not induce great (≥ 20ºF) temperature fluctuations in the milk samples; thus, microbial counts probably would not increase dramatically during a 7-day storage period. Previous research has indicated that microbial numbers need to approach or exceed 10,000,000/mL to degrade milk components to such an extent that certain off-flavors can be detected.

Headspace Analysis. More than 35 peaks were obtained on each chromatogram from the reduced-fat milk samples. From these peaks, 7 headspace compounds were identified and quantified in most samples: benzaldehyde, 2-butanone, heptanal, 2-heptanone, hexanal, octanal, and pentanal. These compounds have been reported in the past to be present in both fresh milk and milks with off-flavor. Some headspace compounds, such as hexanal, have been implicated in off-flavored milks, such as those having oxidized flavor.

Statistical analysis indicated that headspace concentrations were not affected by container size or temperature cycle, but were affected by day, indicating that reactions were on-going throughout the study. These differences are shown as significant means for headspace compound concentrations as a function of day in Table 2. Results indicate that the quantities fluctuated throughout the study, not always showing a steady increase or decrease, which is in agreement with other studies. Many of these compounds are reaction compounds and, in turn, become a substrate for another degradative reaction. Heptanal concentration varied slightly throughout the 7-day storage period, which wasn't expected. Previous research indicated that heptanal concentration would not change if milk was protected from light during a 6-week storage period. Because our milk samples were protected from light by placement in a brown paper bag at all times (to identify the temperature cycling effect only), we suggest that heptanal concentration could be affected by time, and the frequency of testing may be critical in verifying that effect. Pentanal concentration remained consistent throughout the study (average of about 0.994 mg/mL). Pentanal has been reported to remain consistent, provided milk remained at refrigerated temperatures of 35.6 to 41ºF. Although the temperature cycling did allow for this temperature range to be exceeded in the half-gallon and 1-cup containers, perhaps the higher temperature was not sustained for sufficient time to affect the pentanal concentration.

The milk containers used in the study were made from similar materials – a result of addressing student complaints about school lunch milk. Our research showed that headspace compound concentrations did not differ, regardless of container size, except for heptanal. Reduced-fat milk packaged in 1-cup containers had less heptanal than reduced-fat milk packaged in 1- or half-gallon container. Heptanal is a product of the oxidation reaction, which can be initiated by light, metal, or oxygen exposure. Although milk was protected from light, over time, the 1- and half-gallon containers had an "air space" above the milk, especially by the end of the study, suggesting that perhaps the oxygen in the air space above the milk catalyzed the oxidation reaction. The fact that the container size wasn't a factor in our study refutes previous research that container size was an important contributor to the milk flavor. Differences in experimental design, packaging materials, and storage conditions could be responsible for the differences reported.

Headspace compound concentrations were not affected by temperature cycling in this study, which wasn't expected. Other researchers have reported, however, that the milk processing and storage temperatures were primary factors related to headspace compound concentrations in stored milk. Our work seems to support this, because our experimental design was set to maintain and control the milk processing and storage temperatures. Our overall results indicate that milk packaged in single-service containers similar to the commercial, plastic (HDPE) 1- and half-gallon milk containers was similar to milk packaged in larger, multiple-use milk containers.

Conclusions. Temperature cycling did not affect volatile compound concentration, compositional contents, or microbial counts in reduced-fat milk packaged and stored in various carton sizes. Temperature cycling seemed to have no effect on the growth of microorganisms, perhaps because the milk temperature increase did not exceed a 9ºF differential. Heptanal concentration was greater in reduced-fat milks packaged in 1- and half-gallon containers than in reduced-fat milk packaged in 1-cup containers. Headspace compound concentrations were affected by time rather than by container size or temperature cycle.

Perhaps the time (20 min) or the temperature increase (1.2 to 9.6ºF) were not sufficient to catalyze reactions that would result in great changes of headspace compound concentrations. Further work is needed to see if headspace compound concentrations increase with extended storage or extended temperature cycling.

Table 1. Average Temperature of Reduced-fat Milk Packaged in Various Container Sizes after a 20-minute Exposure to Room Temperature during 7 Days of Storage[1]

	Days of Storage			
Container Size	0	2	4	7
	Temperature, °F			
1 gallon	42.8	41.5	41.2	41.4
½ gallon	43.5	43.0	42.0	43.3
1 cup	47.1	48.7	47.7	49.6

[1]72°F for 20 min each day for 7 consecutive days.

Table 2. Mean Headspace Compound Concentrations (mg/mL) of Various Flavor Compounds Associated with Temperature-cycled Reduced-fat Milk during 7 Days of Storage[1]

Headspace Compound	Days of Storage			
	0	2	4	7
	Means ± SD (n = 9)			
Benzaldehyde	0.899 ± 0.009[a]	0.895 ± 0.009[ab]	0.874 ± 0.009[b]	0.877 ± 0.009[ab]
2-Butanone	0.751 ± 0.176[b]	0.976 ± 0.176[a]	0.923 ± 0.176[a]	0.846 ± 0.176[ab]
Heptanal	0.739 ± 0.004[a]	0.737 ± 0.004[a]	0.732 ± 0.004[b]	0.734 ± 0.004[ab]
2-Heptanone	0.454 ± 0.001[a]	0.453 ± 0.001[ab]	0.452 ± 0.001[b]	0.453 ± 0.001[b]
Hexanal	0.431 ± 0.002[a]	0.433 ± 0.002[a]	0.425 ± 0.002[b]	0.426 ± 0.002[ab]
Octanal	0.892 ± 0.035[a]	0.830 ± 0.036[b]	0.747 ± 0.038[c]	0.818 ± 0.036[b]

[a,b,c] Means within row having different superscripts differ ($P<0.05$).
[1]Temperature was 72°F for 20 min each day for 7 consecutive days.