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Volatile Compounds in UHT-Sterilized Milk During Fluorescent Light Exposure and Storage in the Dark[1]

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ABSTRACT

When ultra-high-temperature sterilized milk (140 C for 3.5 sec) was exposed to fluorescent light over a 30-day period at 22 C, acetaldehyde, propanal, pentanal, and hexanal increased in concentration. On storage of the milk in the dark, after a 2-week period of light exposure, these same compounds decreased in concentration. No characteristic patterns were noticed in the other chromatographic peaks. When a five-fold diluted distillate of light-exposed milk was added to normal milk, a taste-panel criticized the milk as pronounced oxidation, tallowy or oily.

The adverse effect on flavor of exposing refrigerated milk to fluorescent light is well known (*1,2,4,5,6*). Increases in concentrations of acetaldehyde, propanal, n-pentanal, and n-hexanal in milk have recently (*1*) been associated with light-activated off-flavor. Samuelsson (*8*) reported methyl sulfide, methyl mercaptan, formaldehyde, acetaldehyde, and propanal increased on exposure of milk to light and were related to the off-flavor. Although many researchers have studied the increases in the concentration of these and other compounds when milks are exposed to fluorescent light, no one has reported changes in exposed milks after dark storage.

This paper describes changes in some volatile materials in milk exposed to fluorescent light and then placed in the dark.

MATERIALS AND METHODS

Nine batches of raw milk with fat contents of 3.13 to 3.80% ($\bar{x}$ = 3.50) and total solids 11.16 to 12.18% ($\bar{x}$ = 11.80) were ultra-high-temperature (UHT) sterilized (140 C for 3.5 sec), packaged aseptically and then stored at room temperature 2 to 42 days in either aluminum foil-lined cartons or polyethylene-lined cartons before use. Samples for our light-exposure study were selected during this 42-day period. Although cartons of milk initially had different pre-trial storage periods, changes in these milks were minor compared with those that occurred when they were exposed in glass to fluorescent light. Each of these packaged UHT milks was aseptically transferred into either glass-stoppered or non-absorbent cotton-plugged, sterile liter or 2-liter glass Erlenmeyer flasks. Mouths of these flasks were covered with heavy duty aluminum foil before sterilization. The flasks, approximately half filled with sterile milk, were exposed at 22 ± 2 C to 2150 lx of light from two 40-watt cool-white fluorescent tubes. Tests for microbiological spoilage were the same as those used by Mehta and Bassette (*7*). Aseptic techniques were used to remove the 50-60 ml of milk necessary for testing at each time interval. Volatile materials present were determined by gas chromatography (GC) (*7*).

Two sets of milk samples were observed. During Phase I samples were exposed to fluorescent light in glass-stoppered Erlenmeyer flasks and examined at 0, 10, 20 and 30 days. During Phase II samples in sterile cotton-plugged Erlenmeyer flasks were exposed to light and examined at 0, 1, 2, 7, 14, 21 and 28 days. Half the samples in this second phase were exposed to light throughout a 4-week period and the other half to light for 2 weeks and then stored in the dark.

Because of the intensity of the off-flavor, no systematic organoleptic studies were conducted on these milks. Five milliliters of distillate from 50 ml of one of the milks which had been exposed to fluorescent light for 20 days, however, was added to 245 ml of pasteurized-homogenized 3.5% fat whole milk. This represented a five-fold dilution of flavor in the distillate compared with that of the light-exposed milk. This sample was evaluated according to procedures of the National Collegiate Student Judging Contest by an experienced five-member taste panel.

RESULTS AND DISCUSSION

All the GC peaks observed previously in stored sterile milk (*7*) also were observed here. Changes in concentrations when light-exposed samples were stored in the dark, however, were observed only for acetaldehyde, propanal, pentanal and hexanal.

The changes in concentration of propanal with time are shown in Fig. 1. The X-axis represents the number

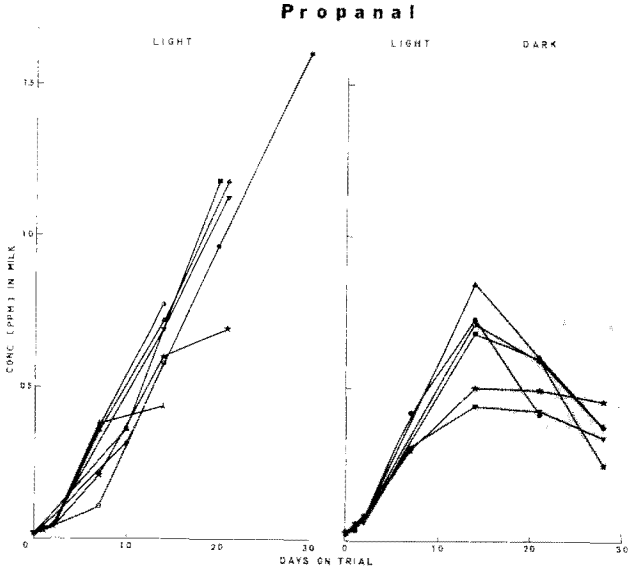

Figure 1. *Changes in propanal concentrations after prolonged fluorescent light exposure of UHT milk in glass Erlenmeyer flasks and after dark storage.*

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of days the sample was on trial, and the Y-axis the ppm of propanal in the milk. The graph on the left shows eight milk samples exposed to light throughout the study. Each line on the graphs designates a different sample of milk. The graph on the right shows the six milks in Phase II that were stored in the dark (see shaded area) after a 2-week period of light exposure. Upon being exposed to light, propanal increased in concentration. When the samples were removed from the light at the end of 2 weeks and stored in the dark, it decreased. Almost all samples examined showed similar trends. Day et al. (*3*) reported the flavor threshold level of propanal in milk to be 0.43 ppm; for most of our samples this level was passed at about 10 days. Propanal concentrations of those samples remaining in the dark decreased below this threshold value in most instances. This does not mean the flavor would have been acceptable since several of the carbonyl compounds that increase on exposure to light have additive, if not synergistic, effects on flavor (*3*).

Changes in pentanal were similar to those of propanal (Fig. 2); however, almost from 0 day, pentanal concentrations were above the reported threshold levels of 0.13 ppm (*3*) and stayed that way even when the milk was stored in the dark. Hexanal (Fig. 3) also showed similar changes and trends as pentanal. Again, the hexanal concentrations observed at 0 days were higher than the reported flavor threshold value of 0.049 ppm (*3*).

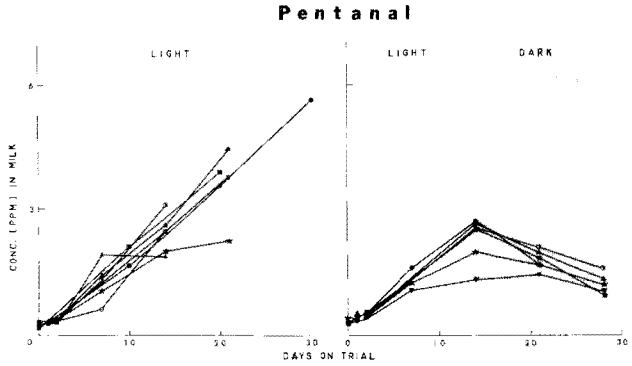

Figure 2. *Changes in pentanal concentrations after prolonged fluorescent light exposure of UHT milk in glass Erlenmeyer flasks and dark storage.*

Figure 4 shows changes in acetaldehyde during prolonged light exposure and dark storage periods. The results for acetaldehyde were unusual compared with the other components. As previously mentioned (*7*), pretreatment of milk cartons with ethylene oxide resulted in some milks having high initial acetaldehyde concentrations. The shorter the time interval between carton pre-treatment and packaging, the higher the acetaldehyde concentration. The acetaldehyde concentration decreased with the storage of milk; note on the left-hand side of Fig. 4, the five lines starting at high levels and declining rapidly. In this figure, besides observing the increase in acetaldehyde due to light, we also are observing the effects of ethylene oxide pre-treatment of the milk cartons. If we could visualize the elimination of

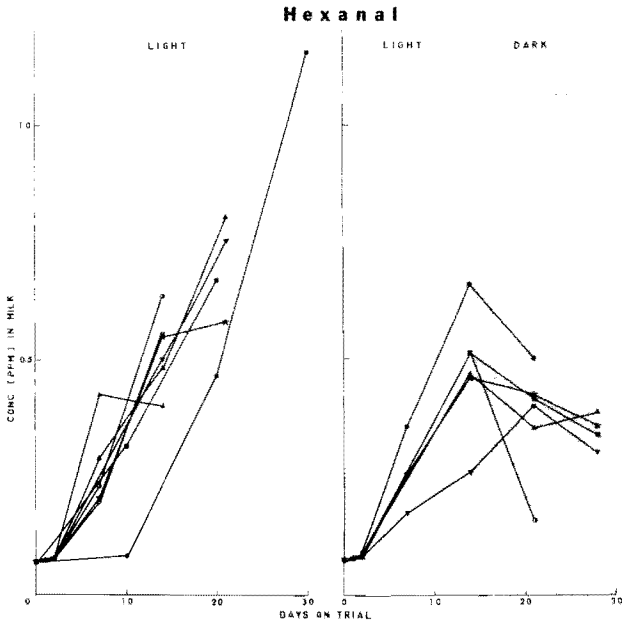

Figure 3. *Changes in hexanal concentrations after prolonged fluorescent light exposure of UHT milk in glass Erlenmeyer flasks and dark storage.*

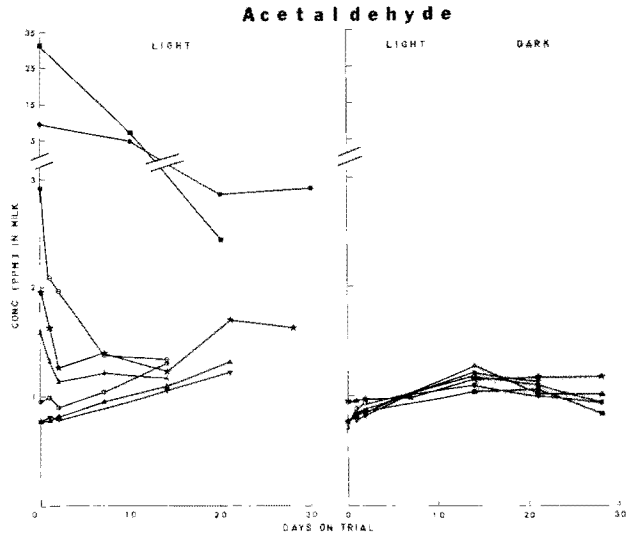

Figure 4. *Changes in acetaldehyde concentrations after prolonged fluorescent light exposure of UHT milk in glass Erlenmeyer flasks and dark storage.*

the effect of high initial acetaldehyde, it is likely that acetaldehyde trends are similar to those of the three other components.

In spite of the differences in the age of the UHT milks at the beginning of the experiment, the initial concentrations of propanal, pentanal, and hexanal were about the same for all milks. Although there was a considerable degree of uniformity in patterns of volatile materials throughout this experiment, there also were some deviations. Replicate analyses as shown by separate lines on the figures did not agree closely. This may have been due to the dynamic system that we dealt with, involving: (*a*) loss of volatiles through the mouth of the

TABLE 1. *Comparing the flavor of reference milk with a reconstituted milk[a] made from 5 ml of distillate from 50 ml of milk exposed to fluorescent light for 20 days blended with 245 ml of reference milk.*

Panelist number	Reconstituted milk[a]		Reference milk	
	Flavor score	Comments	Flavor score	Comments
1	32.0	pronounced oxidized, oily	38.0	less than definite cooked
2	31.0	very pronounced oxidized, slightly cooked	38.0	more than slightly cooked
3	31.0	very pronounced oily	38.0	more than slightly cooked
4	32.0	pronounced oxidized, more than slightly tallowy	38.0	less than definite cooked, very slightly oxidized

[a]Prepared by steam-distilling 50 ml milk exposed in glass to fluorescent light for 20 days at 22 C and adding the 5 ml distillate to 245 ml of normal milk.

flask, (*b*) reduction in the concentration of a volatile through its interaction with other components, and (*c*) increase in concentration by a chemical change of a component of the milk. Thus, the rates at which the changes in volatile compounds occur probably depend on the milk, the permeability of the closure, and the amount of radiant energy present on the surface of the milk.

These results indicate that light-induced, volatile compounds are produced constantly in large amounts only when the milk is exposed to light and not when it is in the dark. This would lead us to postulate that the reaction rate is not maintained by the process of autooxidation. The reaction apparently is photocatalyzed and requires a constant source of radiant energy to be maintained.

Results comparing the flavor of normal (reference) milk with milk with added distillate from the light-exposed milk (diluted 5 ×) are in Table 1. The panel judged the sample with the added distillate as strongly oxidized, tallowy or oily. Panelist 4 who criticized the control milk as very slightly oxidized may have experienced a slight carry-over of the flavor from one extremely oxidized sample. The off-flavor of the light-exposed sample was so intense that we did not include similarly prepared samples in other panel meetings. Apart from the five-member panel evaluation of milk plus sample distillate, one panel member evaluated the light-exposed milk directly (without distilling and reconstituting the distillate into regular milk). This panelist tasted these milks at a time different from the regular panel meetings. His conclusions were: at the end of one day, the milk was slightly oxidized; at 2 days, it was definitely oxidized; at 7 days, it was strongly oxidized; and after that it progressed to tallowy.

ACKNOWLEDGMENT

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REFERENCES

1. Bassette, R. 1976. Effects of light on concentrations of some volatile materials in milk. J. Milk Food Technol. 39:10-12.
2. Coleman, W. W., G. H. Watrous, Jr., and P. S. Dimick. 1976. Organoleptic evaluation of milk in various containers exposed to fluorescent light. J. Milk Food Technol. 39:551-553.
3. Day, E. A., D. A. Lilliard, and M. W. Montgomery. 1963. Autoxidation of milk lipids. III. Effect on flavor of the additive interactions of carbonyl compounds at subthreshold concentrations. J. Dairy Sci. 46:291-294.
4. Dimick, P. S. 1973. Effect of fluorescent light on the flavor and selected nutrients of homogenized milk held in conventional containers. J. Milk Food Technol. 36:383-387.
5. Gregory, M. E., A. P. Hansen, and L. W. Aurand. 1972. Controlling light-activated flavor in milk. Amer. Dairy Rev. 34(4): 10-11, 47-50.
6. Hansen, A. P., L. G. Turner, and L. W. Aurand. 1975. Fluorescent light-activated flavor in milk. J. Milk Food Technol. 38:388-392.
7. Mehta, R. S., and R. Bassette. 1978. Organoleptic, chemical and microbiological changes in ultra-high-temperature sterilized milk stored at room temperature for 6 weeks. J. Food Prot. 41:806-810.
8. Samuelsson, E. G. 1962. Experiments on sunlight flavour in milk-S^{35}-labelled milk. Milchwissenschaft 17:401-405.