ABSTRACT

To determine the effects of light exposure on vitamin A degradation and on light-oxidized flavor development, samples of whole, reduced fat, and nonfat milk were exposed to fluorescent light (either 1000 or 2000 lx) at time intervals of 2, 4, 8, or 16 h. Measurable vitamin A losses occurred at 2, 4, and 16 h at 2000 lx for nonfat, reduced fat and whole milk, respectively. Moderate light-oxidized flavors were detected after 4 h of light exposure (2000 lx) in the whole and reduced fat milk and after 8 h in nonfat milk. The different types of milk show a significant difference in relative flavor scores. By 16 h at 2000 lx, relative light-oxidized flavor development was lower in nonfat milk than in whole or reduced fat milk. The presence of milk fat appears to protect against vitamin A degradation in fluid products, but adversely affects the flavor quality of milk after exposure to light. In summary, these findings demonstrate that even a brief, moderate light exposure (2 h; 2000 lx) can reduce the nutritional value and flavor quality of fluid milk products.

(Key words: vitamin A, light oxidation, fortified milk)

Abbreviation key: HDPE = high-density polyethylene, LDPE = low-density polyethylene, PET = polyethylene terephthalate.

INTRODUCTION

Light exposure can detrimentally affect the nutritional value and flavor quality of fluid milk products. Both natural and artificial light, particularly in wavelengths ranging from 420 to 520 nm, can induce quality defects (Bosset et al., 1994). Previous reports have detailed light-induced chemical reactions that result in vitamin A degradation and light-oxidized flavor defects (Fanelli et al., 1985; Fellman et al., 1991; Cladman et al., 1998). Off-flavors have been reported in whole milk following 2 to 4 h of exposure in a lighting system that simulated commercial display cases (Hansen et al., 1975). Senyk and Shipe (1981) demonstrated a reduction in the vitamin A contents of whole milk, reduced fat, low fat, and nonfat milk exposed to 2000 lx for 4 h. Further, packaging type and size influences vitamin A loss and reduction of flavor quality. Of milk packaged in polyethylene terephthalate (PET; green or clear), PET with a UV blocker, low-density polyethylene (LDPE) or high-density polyethylene (HDPE), products in HDPE had the largest vitamin A losses (Cladman et al., 1998). The majority of US fluid milk products currently are packaged in containers made of paperboard or HDPE plastic. Paperboard does offer protection from light exposure, but HDPE containers transmit light.

Federal regulations require low fat (21 CFR 131.135) and nonfat milk (21 CFR 131.143) fortification with vitamin A. Targeted vitamin A fortification levels are between 2000 and 3000 IU per quart. As vitamin A in fluid products may degrade from light exposure in a retail dairy case, an exposed product may not be in label compliance at the time of purchase. In this study, we examined vitamin and flavor stability in fluid milk products of various fat levels that have been exposed to light for different time periods. Vitamin A concentrations and light-oxidized flavor intensities were measured in whole, reduced fat (2%) and nonfat milks packaged in HDPE that had been exposed to 1000 or 2000 lx for 2, 4, 8, or 16 h.

MATERIALS AND METHODS

To select appropriate light parameters for this study, light intensities in stocked dairy cases of five supermarkets and three convenience stores were measured. Multiple readings were taken in each dairy case, and the maximal and minimal attainable readings were recorded for each. Light intensities ranged from 215 to 6460 lx, with an approximate mean of 2000 lx, which was selected to be the light treatment dose in the first experiment. A low-intensity exposure of 1000 lx was used in a second experiment to compare the light treatment dose response.

Nonfat, reduced fat, and whole milk in gallon plastic containers were taken directly from the production line of a dairy plant and placed in heavy-duty corrugated cardboard cases to protect the milk from light exposure
prior to the study. The milk samples were exposed to fluorescent lighting (400 to 700 nm) at 1000 and 2000 lx ± 5% for 0, 2, 4, 8, and 16 h inside a light box located in a 6°C walk-in cooler. Control samples were kept in closed cases in the same walk-in cooler. Light intensity was measured with a digital light meter (Dickson #D102, Universal Enterprises Inc., Beaverton, OR). Milk samples were positioned in the light box to achieve the desired light intensity readings (1000 or 2000 lx) on the closest exposed flat surface of each gallon container. For each experiment, milk samples were exposed to light for the appropriate period and then allowed to stand in the dark at 6°C for 24 h before analysis. Vitamin A levels were determined in duplicate by HPLC according to the method described by Murphy et al. (2001). Vitamin A concentrations in control samples of each type were determined simultaneously with those of the experimental samples. All-trans retinol palmitate (Sigma Chemical Corp., St. Louis, MO) was used as the primary standard.

The samples described above were also presented to sensory panelists. Twenty-one panelists had attended three training sessions on identifying light-oxidized flavor defects in milk before the start of this study, and at least 17 panelists participated in each session. The sessions were designed not only to train panelists in identification of light-oxidized flavor defects but also to evaluate the intensity of those flavors. Control and reference milk samples were used to develop light-oxidized flavor detection skills among the panelists during the training sessions.

For this study, panelists were asked to rank the samples in ascending order of light-oxidized flavor intensity and then to assign an intensity rating from a range of “same as” to “extremely different” from the reference sample, which was never exposed to light. The design of this plan incorporated a blind control sample. The Compusense five (Compusense Inc., Guelph, Canada) computerized data collection system was used to determine the order of presentation of the samples using the Williams-Balanced plan (Williams, 1949), as well as for sensory questionnaire development and data collection. To encourage panelists to complete each experimental trial, monetary incentives were provided.

Before presentation, the samples were mixed by inversion and prepared in dim light, according to procedures previously described by Chapman et al. (1998). The milk samples were allowed to warm to room temperature (∼25°C) before they were served. Unsalted crackers and spring water were provided to cleanse the palate. Panelists evaluated the samples according to the procedures of Chapman et al. (1998). The expert panel rated the samples using the sensory method of rank-rating (Kim and O’Mahony, 1998). The rank-rating method reduces discrimination errors by allowing the panelists to retaste samples until certain of the characteristics. During each session panelists were presented with two sets of samples for each type of milk and each light treatment. Each sample set contained a reference, plus 5 samples; the second set was a duplicate of the first set. Panelists were asked to rate the light-oxidized flavor compared to a control on an 11-point rating scale, with 0 = “same as” to 10 = “extremely different” from the reference. To reduce carryover effects of the light-oxidized flavor, panelists were required to take a 5-min rest break between the two sample sets. Testing was conducted over a 6-d period, with presentation of only one type of milk from one light treatment on any single day. The milk samples that were exposed to 2000 lx were presented to the panelists first, followed by the milk samples of the same fat type that were exposed to 1000 lx on the following day.

Data were analyzed using Minitab ver. 13. Analysis of variance (ANOVA) was performed using a randomized block design for balanced data to determine whether there was a significant difference between samples exposed to different light treatments, hours of exposure or milk types. Linear regressions were performed to determine the rates of vitamin A loss and the increase in light oxidized flavor.

**RESULTS AND DISCUSSION**

Reduced fat and skim milk products exposed to 2000 lx had measurable vitamin A losses and light-oxidized flavor development after 2 h of exposure. Vitamin A loss was directly influenced by the length and intensity of light exposure and inversely influenced by the fat content of the milk. To illustrate, after 16 h, vitamin A content was reduced by 29% in reduced fat milk and by 49% in nonfat milk. Figure 1 shows the percentage of vitamin A loss relative to the control at the end of the experiment for the various exposure times for all types of milk exposed to 2000 lx. Reduced fat and nonfat milk samples exhibited a linear increase in vitamin A loss relative to the exposure time to the fluorescent light. The vitamin A concentration of nonfat milk was reduced at 3 times the rate of that in the reduced fat milk and at ~3.5 times the rate of that whole milk. Similar trends in vitamin A loss were observed following exposure to 1000 lx, although overall vitamin losses were reduced at the lower intensity. Specifically, after 16 h of exposure to 1000 lx, vitamin A content of whole milk, reduced fat milk, and nonfat milk were reduced by 0, 24, and 32%, respectively. These results provide further evidence that the presence of milk fat protects against the loss of vitamin A in fluid milk samples.
exposed to light (Senyk and Shipe, 1981; Gaylord et al., 1986).

Mean relative light-oxidized flavor intensities for milk products exposed to 2000 lx are shown in Figure 2. For milk exposed to 2000 lx the ANOVA for the light-oxidized flavor score, with hours of exposure and fat type as fixed factors, shows that the hours of exposure, fat type, and the interaction of the hours of exposure and fat type all have a significant effect on the detectable presence of light-oxidized flavor. The P-value for relative light oxidized flavor for hours of exposure to 2000 lx is <0.001, for fat type is 0.043, and for the interaction of hours of exposure and fat type is 0.001. In contrast, for milk exposed to 1000 lx, the ANOVA shows that fat type does not have a significant effect on the detectable presence of light-oxidized flavor. However, the hours of exposure and the interaction of hours of exposure and fat type do significantly affect the development and detection of light-oxidized flavor. The P-value for hours of exposure to 1000 lx is <0.001, for fat type is 0.111, and for the interaction of hours of exposure and fat type is 0.014.

In contrast to results from the vitamin assays, light-oxidized flavor development was least pronounced in nonfat milk. Of the three milk types, nonfat milk was least affected by either length or intensity of light exposure, showing no difference between the light treatments. The nonfat milk was rated as having a moderate light-oxidized flavor after 16 h for both treatments, with a rating of 4.4 for 2000 lx and 4.3 for 1000 lx. Reduced fat and whole milk were rated as having slight off-flavors after 4 h (rating = 3.5 for both) and strong off-flavors after 16 h of exposure to 2000 lx with a rating of 6.9 and 6.5, respectively. In contrast, after 16 h of exposure to 1000 lx, the reduced fat and whole milks had only moderate off-flavors, with ratings of 4.7 and 5.3, respectively. Regardless of milk type, relative light-oxidized flavor development increased linearly with increased exposure to 2000 lx fluorescent light over the 16 h. Whole milk and reduced fat milk exhibited the greatest rates of increase in relative light oxidized flavor development; both 2 times that of detectable defects in nonfat milk. Relative light-oxidized flavor ratings in whole milk exposed to 1000 lx increased linearly, but at 0.75 the rate of the increase in defects detectable at 2000 lx. Relative light-oxidized flavor ratings in reduced fat and nonfat milk exposed to 1000 lx increased linearly over 8 h of exposure but did not exceed intensities of 5 and 4, respectively, which had been attained by 8 h. The relative off flavor intensity for the reduced fat milk increased slightly faster than the nonfat milk ratings when exposed to 1000 lx.

Clearly, even with minimal light exposure (2 h at 2000 lx) milk loses nutritional value and flavor quality. The presence of milk fat appears to reduce vitamin A degradation, but adversely affects the flavor quality of milk after exposure to light. To protect the delicate flavor and nutritional value of fluid milk products, milk products should be protected from exposure to light.

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REFERENCES


