EFFECT OF FLUORESCENT LIGHT ON THE FLAVOR AND SELECTED NUTRIENTS OF HOMOGENIZED MILK HELD IN CONVENTIONAL CONTAINERS[1]

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ABSTRACT

Homogenized milk packaged in three conventional half-gallon containers, unprinted fiberboard, blown mold plastic, and clear flint glass, was held in a sliding door display case with fluorescent light exposure of 100 ft-c for 144 hr. The fiberboard container afforded protection from the light activated flavor up to 48 hr, whereas milk in plastic and glass containers developed the off-flavor following only 12 hr of exposure. No differences in organoleptic response could be demonstrated between milk held in glass and plastic half gallon containers. Similarly riboflavin destruction in plastic and glass was not significantly different and amounted to approximately 10-17% loss following 72 hr of exposure. No significant loss in riboflavin could be demonstrated in milk held in fiberboard as compared to the control. Ascorbic acid losses were evident in all milk samples independent of container material, however losses of this vitamin in milk held in plastic and glass were much more rapid than in milk held in fiberboard, decreasing to a minimum level after 48 hr exposure. The TBA values did not parallel the organoleptic response demonstrating that the activated flavor associated with light exposure is differentiated from flavors caused by lipid oxidation.

Exposure of milk in all three containers tested to light had no effect on the amino acid composition as compared to the control milk held in the dark. These studies reinforce present thinking that protection of milk from light during marketing is necessary to assure flavor quality and to a lesser extent nutrient value.

Acceptance of fluid milk by the consumer is determined to a great extent by such quality measures as flavor, shelf life, and nutritional value. Changes in marketing channels have lengthened the time between processing and consumption; for example, it is common for fluorescent lights to illuminate display cases of milk 24 hr per day. It has been realized for some time that milk undergoes flavor deterioration when exposed to light. Much of the work in this area has been concerned with sunlight exposure to milk with the resulting off-flavor classified as "sunlight," "oxidized," or "activated" *(16)*. Another detrimental effect of light exposure is the compositional change which may have importance relative to the nutritional quality of the product. Several investigations have demonstrated the loss in ascorbic acid and riboflavin upon exposure to sunlight as well as artificial light *(2, 7, 12)*. Analysis of the protein fraction of low density lipoproteins of milk by Finley and Shipe *(6)* indicated a loss in the amino acids methionine, tryptophan, tyrosine, cysteine, and lysine due to photodegradation. The type of container and its capability of reducing light filtration can greatly reduce the off-flavor associated with light exposure *(3, 4, 5)*.

This investigation was initiated as a result of a flavor survey *(3)* which demonstrated that the percentage of commercial milk samples rated in the good to excellent category declined from 1967 to 1970 with an increase in the incidence of oxidized off-flavors. The objectives of this study were to evaluate three conventional half-gallon containers, fiberboard, plastic, and glass under controlled conditions of fluorescent light exposure to compare the flavor changes as well as riboflavin, ascorbic acid, and amino acid destruction in homogenized milk.

MATERIALS AND METHODS

Samples and treatment description

Mixed herd milk routinely supplied to the University Creamery was used in this study. The raw milk (up to 2 days old) was pasteurized at 74 C for 16 sec, homogenized at 2500 psig, cooled to 6 C, and transferred directly into 5-gal stainless steel dispenser cans. The milk containers were immediately filled by hand and placed into a commercial double sliding door display case held at 7 ± 1 C. One each of three types of containers was examined for flavor and chemical changes after exposure to fluorescent light for 3, 6, 12, 24, 48, 72, 120, and 144 hr. The milk was not agitated during storage. An unexposed sample from the same lot of milk designated as control was held at the same temperature in a 5-gal stainless steel can. At each time interval a control sample was obtained for analyses. The display case was illuminated by cool white fluorescent lamps (F 40 CW) mounted parallel to the shelves at a distance of 45.7 cm from the containers. Illumination averaged 100 ft-c perpendicular to the light source at the mid-point of the exposed container vertical surface. All light measurements were conducted with a Weston illumination meter (Model 756).

Three conventional half-gallon milk containers were used in this study. The commercial fiberboard container was an

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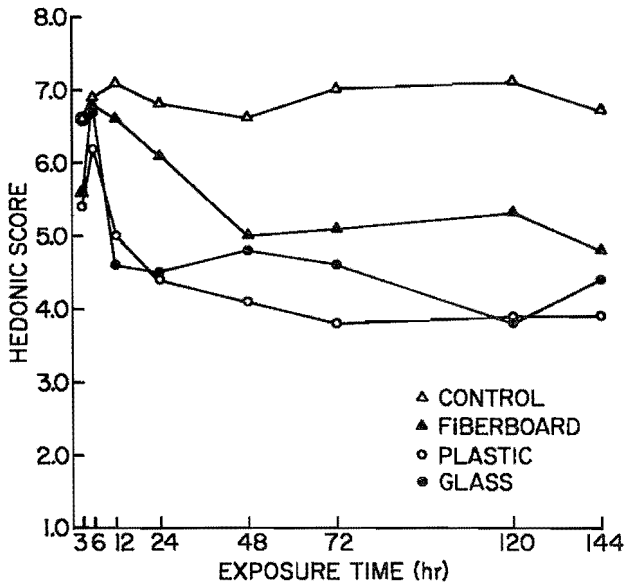

Figure 1. Mean hedonic flavor scores from trained panel for milk exposed to fluorescent light in various containers for 144 hr at 7 ± 1 C.

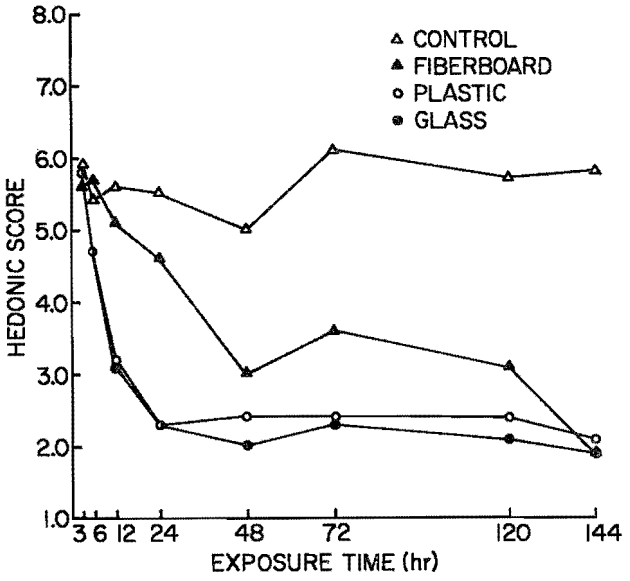

Figure 2. Mean hedonic flavor scores from expert panel for milk exposed to fluorescent light in various containers for 144 hr at 7 ± 1 C.

unprinted olefin coated paper of 0.58 mm thickness. The blown mold 55 g plastic container had a thickness of 0.52 mm and the clear flint glass bottle was 2.5 mm thick. The average light transmission of the three container materials was 2.8% for fiberboard, 69.2% for plastic, and 90.7% for glass. Surface area exposed to the light was approximately the same (185-190 cm^2) for all three containers.

Flavor panel procedures

At each exposure time the containers were removed from the display case, mixed by inversion, and aliquots were transferred to 30-ml medicine cups in dim light. All samples were transferred and presented to the panel members within 15 min. Two types of taste panels were employed; a trained panel and an expert panel.

The trained taste panel consisted of 12 women from a pool of 19, all of whom had from 2 to 5 yr experience in organoleptic evaluations with numerous food products. These women ranged in age from 23 to 45 years. Preference evaluation was obtained by using a 9-point hedonic scale (1, dislike extremely; 9, like extremely) and a multiple comparison test using the control sample as reference *(9)*.

The expert panel was composed of 5 to 7 members of the Dairy Science faculty who were familiar with dairy product flavor evaluations. Coded samples were submitted to the expert panel for preference using a 9-point hedonic scale.

Chemical analyses

Ascorbic acid was determined in triplicate by the 2, 6-dichlorophenolindophenol visual titration method *(1)* and riboflavin was determined in duplicate by the fluorometric method *(1)*. The thiobarbituric acid (TBA) method employed for milk was that reported by King *(8)*. The ascorbic acid, riboflavin, and TBA studies were conducted in duplicate.

Hydrolysis of proteins for total amino acid analysis was accomplished by heating (110 ± 2 C) 0.25 ml milk with 5 ml 6 N HCl in sealed ampules for 24 hr *(13)*. Free amino acids were extracted from homogenized milk by the picric acid method *(13)*. A quantitative internal standard, norleucine, was added to the milk before hydrolysis and free amino acid extraction for computing the amino acid concentrations. Analyses were done with a Beckman Model 120C automatic analyzer.

Analysis of variance and Duncan's multiple range statistical techniques *(11)* were used to analyze the chemical and taste panel data.

Results and Discussion

Results of the trained panel evaluation of homogenized milk from the three containers and the control are in Fig. 1. After 12 hr of exposure to fluorescent light milk samples held in all containers were rated lower in acceptance than control milk held in the dark in stainless steel. The flavor of milk held in plastic and glass was comparable and decreased

Table 1. Effect of container on organoleptic response of the panel members to homogenized milk exposed to fluorescent light up to 144 hr.

	Type of panel		
	Expert	Trained	
Container	Hedonic value[a] n=72	Hedonic value[a] n=96	Multiple comparison[b] n=192
	$(\bar{x})$	$(\bar{x})$	$(\bar{x})$
Control	5.61 A[c]	6.83 A	5.10 A
Fiberboard	4.06 B	5.67 B	4.66 B
Glass	3.11 C	4.99 C	3.86 C
Plastic	3.00 C	4.60 C	3.83 C

[a]Hedonic scores from 1, dislike extremely; to 9, like extremely.

[b]Reference sample was control sample at each exposure time period.

[c]Means within each measurement represented by the same letter are not significantly different, $P < 0.01$.

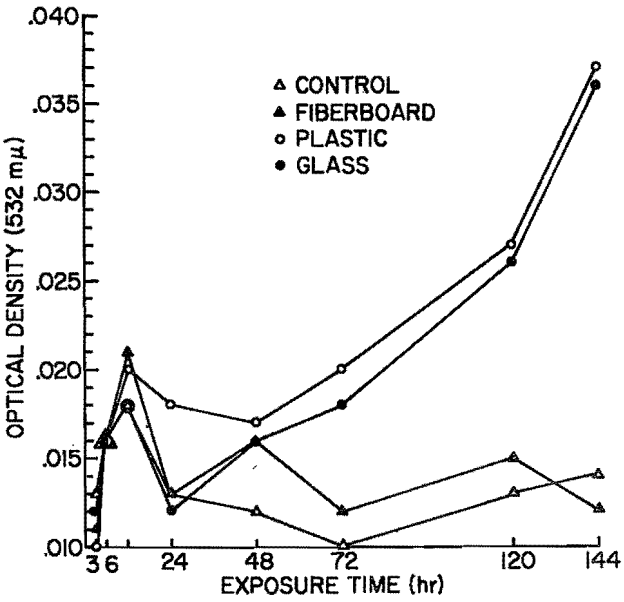

Figure 3. Mean TBA values for milk exposed to fluorescent light in various containers for 144 hr at 7 ± 1 C.

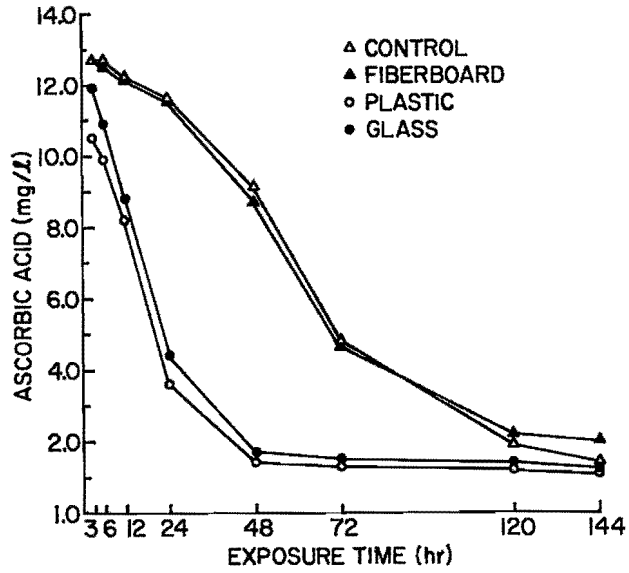

Figure 4. Mean ascorbic acid contents for milk exposed to fluorescent light in various containers for 144 at 7 ± 1 C.

rapidly at 12 and 24 hr exposure, whereas milk in fiberboard took 48 hr to reach similar hedonic values. Data in Table 1 illustrate that there were no significant differences in flavor responses (hedonic and multiple comparison testing) between milks held in glass and plastic throughout the experimental period. A significant difference in preference was evident between control milk and that stored in fiberboard and that stored in glass and plastic.

The flavor evaluations by the expert panel (Fig. 2 and Table 1) were similar in direction and significance; however the expert panel members were more critical of the milk held in the three container materials as seen by the lower hedonic scores. The expert panel members rated the milk in glass and plastic at about 2.0 (dislike very much) after 24 hr exposure, whereas the trained panel members rated the same samples about 4.0 (dislike slightly). The off-flavor associated with exposed milk developed within 48 hr and remained consistent over time throughout the remainder of the experimental period. It is interesting, however, that a measure of oxidative flavor changes by the thiobarbituric acid method demonstrated that values increased with milk in plastic and glass after 48 hr exposure (Fig. 3). The exposure of light had no significant effect (Table 2) on TBA values in fiberboard as compared to the control over time. These data confirm previous investigations *(2)* in that the activated flavor associated with light exposure is differentiated from flavors caused by lipid oxidation.

TABLE 2. EFFECT OF CONTAINER ON TBA VALUES, ASCORBIC ACID AND RIBOFLAVIN IN HOMOGENIZED MILK EXPOSED TO FLUORESCENT LIGHT UP TO 144 HR

Container	TBA values n=48	Ascorbic acid n=48	Riboflavin n=32
	(OD)	(mg/l)	(mg/l)
Control	0.014 A[a]	8.30 A	2.99 A
Fiberboard	0.014 A	8.28 A	2.98 A
Glass	0.019 C	5.21 C	2.78 B
Plastic	0.021 B	4.63 B	2.77 B

[a]Means within each measurement represented by the same letter are not significantly different, P <0.01.

TABLE 3. TOTAL AMINO ACID COMPOSITION OF HOMOGENIZED MILK IN VARIOUS CONTAINERS EXPOSED TO FLUORESCENT LIGHT UP TO 144 HR[a]

Amino acid	Container			
	Control	Fiberboard	Glass	Plastic
	(mg%)			
Lysine	6.8	7.4	7.5	7.5
Histidine	2.1	2.5	2.4	2.5
Arginine	2.5	2.8	2.8	2.8
Aspartic acid	8.1	7.8	7.8	7.8
Threonine	4.4	4.3	4.4	4.4
Serine	5.1	5.0	5.0	5.1
Glutamic acid	22.2	21.7	21.8	21.8
Proline	9.3	9.0	9.2	9.0
Glycine	1.8	1.8	1.8	1.8
Alanine	3.2	3.1	3.1	3.2
Half Cystine	0.6	0.7	0.6	0.5
Valine	6.4	6.3	6.3	6.2
Methionine	2.3	2.4	2.3	2.4
Isoleucine	5.4	5.4	5.4	5.4
Leucine	9.8	9.8	9.8	9.8
Tyrosine	4.8	4.8	4.8	4.8
Phenylalanine	5.1	5.1	5.2	5.2

[a]Number of observations = 8. No significant difference (P < 0.05) between containers over time.

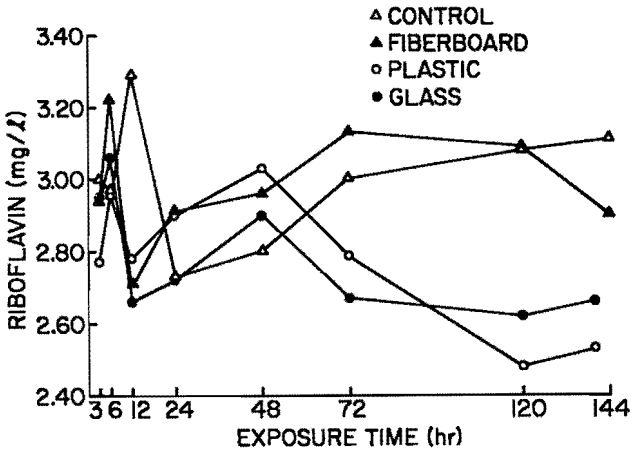

Figure 5. Mean riboflavin contents for milk exposed to fluorescent light in various containers for 144 hr at 7 ± 1 C.

Destruction of ascorbic acid and riboflavin upon exposure to light and their relationship to oxidized flavor in milk has been studied *(2, 5, 7, 12, 16)*. Even though fluid milk is not recognized as an adequate source of vitamin C, destruction of this compound in milk may be used as a criterion for oxidative stability. A rapid decrease in ascorbic acid (Fig. 4) was evident in the milk stored in glass and plastic up to 48 hr, thereafter remaining at approximately 10% of the original concentration through 144 hr. The ascorbic acid concentration in the fiberboard paralleled that of the unexposed milk through storage decreasing to 16% of the original at 144 hr. No significant difference in the ascorbic acid content was apparent in the milk held in fiberboard when compared to the unexposed control (Table 2). Therefore it appears that loss of this vitamin in milk stored in fiberboard is an autoxidative rather than a photooxidative reaction. From these data it is also apparent that prolonged storage of milk without exposure to light destroys vitamin C, which may be attributed to the dissolved oxygen present in the product.

The concentration of riboflavin in milk exposed in fiberboard paralleled that of the control (Fig. 5) while the riboflavin content of milk stored in glass and plastic decreased after 48 hr of exposure. There was a significant difference in riboflavin content of milks stored over time between the control and fiberboard and that stored in the glass and plastic (Table 2). The greatest loss in riboflavin was noted in milks stored in plastic following 120 hr exposure and amounted to 17% based on the control mean value; however, the nutritional implications of this loss are only speculative. The rate of destruction of riboflavin and ascorbic acid was not directly proportional to the light exposure as reported by others *(5, 7)*. This could be attributed to the long exposure times and the complex nature and relationship of the photo-oxidative reactions.

The activated flavor due to light exposure has been attributed to protein degradation *(16)* and more specifically to the Strecker reaction *(10)*. Table 3 compares the amino acid composition of the total protein in homogenized milk following exposure to fluorescent light in the various containers. These results demonstrate that there was no significant difference in the total amino acid composition due to container material over time of exposure. The free amino acids, which amounted to 0.2% of the total protein, also did not vary with container over time. These data indicate that amino acid destruction is insignificant in conventionally packaged milk, independent of the three container materials used in this study. It must be pointed out however, that the amino acid tryptophan decreases when milk is exposed to direct sunlight in glass *(2)*; and photodegradation of isolated milk protein fractions *(15)* and model systems of amino acids *(14)* in the presence of photosensitizers demonstrates the loss of histidine, methionine, tryptophan, and tyrosine. Based on the present study, the alteration in protein composition due to fluorescent light exposure does not appear to influence the amino acid content, and more importantly the essential amino acids of milk in half-gallon containers.

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TABLE 4. EFFECT OF CONTAINER ON ESSENTIAL AMINO ACID LEVEL IN HOMOGENIZED MILK EXPOSED TO FLUORESCENT LIGHT UP TO 144 HR

Container	Essential amino acids[a] Total protein n=8	Free amino acids n=8
	(mg%)	
Control	42.3 A[b]	16.1 A
Fiberboard	43.2 A	17.3 A
Glass	43.1 A	15.7 A
Plastic	43.3 A	18.4 A

[a]Lys, His, Thr, Val, Met, Isoleu, Leu, Phe.
[b]Means within each measurement represented by the same letter are not significantly different, $P < 0.05$.

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