THE RELATIONSHIP BETWEEN LIGHT INTENSITIES FOUND IN DAIRY CASES AND THE FLAVOR OF MILK PACKAGED IN TWO CONTAINER TYPES

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ABSTRACT

THE RELATIONSHIP BETWEEN LIGHT INTENSITIES FOUND IN DAIRY CASES AND THE FLAVOR OF MILK PACKAGED IN TWO CONTAINER TYPES

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A survey of dairy case lighting systems in area retail stores was conducted. The type of lighting employed and the distance from the light source to the milk packages was noted. The approximate foot-candle intensities at point of contact were then calculated. These ranged from 8.0 to over 3,000 foot-candles.

From this data a high and low intensity level was selected for the experimental work. Fresh milk packaged in half gallon blow molded polyethylene bottles and quart polyethylene coated paperboard cartons was evaluated for light induced activated flavor at given exposure time intervals.

It was found that activated flavor could be detected in the blow molded bottle at 12 hours of exposure to high intensity lighting and at 36 hours under low intensity lighting.

The paperboard carton showed a slight activated flavor at 96 hours of high intensity exposure. No activated flavor was detected through 96 hours of exposure to the low intensity lighting system.

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INTRODUCTION

Two types of flavor have been mentioned with respect to milk exposed to light. The first, described as sunlight, sunlight activated, or simply activated flavor, has been associated with the degradation of protein. The second flavor type, termed oxidized flavor, is caused by the oxidation of the lipids present in milk.

Protein degradation involves a complex of riboflavin and protein components (3). This loosely bound complex is capable of absorbing light which results in the conversion of the complex to an excited state. Further reaction produces an oxidized protein substance which is responsible for the sunlight flavor. The flavor is said to be that of burnt feathers.

The lipid oxidation process occurs at a slower rate. This oxidation yields a different flavor characteristic which has been described as "cardboardy or tallowy."

The flavor characteristic evaluated in this project was of the sunlight activated type. This flavor type is referred to as activated flavor throughout the remainder of this report.

The effects of light on packaged milk have become increasingly important since World War II. This was the beginning of the shift from the home delivery to the sale of milk at retail stores. The trend continued to the point now where most milk is sold through retail outlets rather than by home delivery.

In order to properly identify the dairy case in the retail store a well lighted display case has been used. This well lighted case, portrayed as a tool which increases sales, is not without fault. The light intensities in some of these dairy cases are often sufficient to cause a light activated flavor in the packaged milk prior to being sold. This light activated flavor is often mistaken for "sour" milk.

One approach to solving this problem has been to search for a container which will prevent light penetration. Some success has been realized with this approach. A foil lined paperboard will prevent light activated flavor but such a container is approximately 55 percent more expensive than the standard polyethylene coated paperboard now used. This increased cost is seen by the dairy industry as being prohibitive.

The approach used in this study was to establish a light intensity which would be satisfactory for use in dairy cases displaying packaged milk. The project was divided into two parts. The first part consisted of a survey of dairy case lighting systems to obtain the approximate foot-candle intensities at contact with the milk containers.

The second part consisted of subjecting two milk packages to light intensities approximating the high and low ranges found in the lighting survey of part one. This was attempted to determine if lowering the intensity of the lighting used would delay the onset of light activated flavor in milk stored under such a system.

LITERATURE REVIEW

The deleterious effect of light on the flavor of milk has been established. Various approaches to reducing or eliminating this effect in packaged milk have been taken.

Hendrickx and Moor (6) studied the influence of fluorescent lamps on light activated flavor and the level of ascorbic acid in milk. They utilized white, yellow, and green lights at varying intensities. In addition, they evaluated the effects of these lights on clear glass, amber glass, and a paper carton.

Hendrickx and Moor (7) also evaluated clear glass, amber glass, waxed cartons, polyethylene containers (clear and colored) and light protected Tetra-Paks (black liner coating) when exposed to high intensity lighting for a short period of time.

Findings in these studies indicated that the light activated flavor of milk is dependent on the amount of light penetrating the container. The clear container showed evidence of light activated flavor sooner than those containers which possess light barrier properties.

An article appearing in Packaging (2) described an experiment in which five containers were subjected to light and subsequently assayed for ascorbic acid content and also evaluated for activated flavor. The containers used were (1) clear glass, (2) white polyethylene bag, (3) yellow polyethylene bag, (4) paperboard package, and (5) bag with a ply of black polyethylene. A control was run in darkness. It was found that a close relationship existed between the ascorbic acid content and the light activated flavor. The white polyethylene bag, yellow polyethylene bag, and the clear glass lost 87 to 89 percent of the initial ascorbic acid content during the test period. The paperboard package lost 34 percent and the black polyethylene lost 5 percent. The dark control also lost only 5 percent. A corresponding degree of activated flavor was also noted, those losing the most ascorbic acid having a higher degree of activated flavor.

Bradfield and Duthie (4) of the University of Vermont conducted a series of experiments in which they evaluated various packages with respect to protection from light of a given intensity. Initially solid color cartons with no ink, red ink, blue ink, black ink, and green ink were used. A double tube fluorescent light which produced a 400 foot-candle light intensity at the carton surface was used.

It was found that the green carton afforded the greatest amount of protection and the plain carton with no ink provided the least amount of protection. Light transmission studies conducted on these containers also showed the green container had the greatest light barrier properties and the plain container had the least.

A second experiment was conducted using paper cartons varying the top portion of the container. The tops utilized were (1) aluminum foil laminate, (2) green and white printing, (3) metallic ink, and (4) plain (no ink). This experiment indicated the aluminum foil top to be the best and the plain top to be least effective in preventing the formation of activated flavor in milk exposed to 200-250 foot-candles of light intensity.

The experiments by Bradfield and Duthie gave the time of onset for oxidized flavor as being 12 to 54 hours. The time of onset was dependent on the containers used and the light intensity used.

Also in this series of experiments a study of the movement of milk in supermarket dairy cases was made. The results of this study demonstrated that 84 percent of the milk was exposed to 12 hours or less of light and 91 percent was exposed to 18 hours or less. It was also found that some of the remaining containers received at least 50 hours of light exposure.

The third study in the series by Bradfield and Duthie was conducted to compare various carton colors and lining combinations with clear glass, amber glass, and also a gallon blown polyethylene bottle containing two percent titanium dioxide pigment. This study showed very little difference between the clear glass and the pigmented white polyethylene bottle. Also, as in the previous experiment, the aluminum foil top container proved to be the most satisfactory.

An article in Food and Drug Packaging (1) gave a review of three university studies of the light activated flavor problem. These studies indicated that the best container for milk was a paperboard container with an aluminum foil laminate as part of the top. Also these studies indicated that the blow molded polyethylene container was unsatisfactory for the protection of milk from light.

DAIRY CASE LIGHTING SURVEY

Dairy case lighting systems in fourteen retail stores in the East Lansing-Lansing area were evaluated. Data obtained in this study included the type of lighting used and the distance from the light source to the nearest milk container. The information concerning the lighting used was taken as that information printed on the bulb itself.

The distance from the light source to the nearest milk container was measured in inches. For the blow molded polyethylene bottle the point of light contact was taken at a point approximately two inches from the top of the cap. For the gabled paperboard cartons the point of contact was measured as the junction between the gable portion and the vertical side walls. A flat paperboard container was measured as having a point of contact at the top or flat portion of the container.

From the data obtained in the above survey and the average initial lumen output for each lamp used as given in the I.E.S. Lighting Handbook* the approximate illumination intensity in foot-candles at the point of contact

*From figures 8-67, 8-93, through 8-95, pages 8-70 through 8-75, I.E.S. Lighting Handbook.

was determined for each dairy case observed. The following formula was used to convert the data into foot-candle illuminations (5).

$$\text{Foot-candle Illumination} = \frac{\text{Lamp Lumen Output}}{10 \cdot (\text{distance in feet})^2}$$

The data obtained in this survey is given in Table 1.

Table 1.--Dairy case lighting data.

Store Number	Lightbulb Used*	Distance in inches	Average Initial Lumen Output in Lumens	Foot-candles at the point of contact
1	F72-T12 CWX	44	11,100	82.5
2	F40 CWX deluxe cool white	24	2,220	55.5
3	F96-T12 CW H.O.	40	15,300	138.0
4	F30-T8 CW	18	2,080	92.5
5	F30-T8 CW	6	2,080	832.0
6	F40 CWX deluxe cool white	6	2,220	888.0
7	F40 SW	6	2,000	800.0
8	F30-T8 CW	6	2,080	832.0
9	F15-T8 CW	2	830	2900.0
10	F40 CWX deluxe cool white	3	2,220	3550.0
11	F40 CWX deluxe cool white	15	2,220	142.0
12	F40 CWX deluxe cool white	9	2,220	400.0
13	F48 PG17-CW power groove	18	6,900	306.0
14	60 watt frosted	36	722	8.0

*Stores 1 through 13 utilized fluorescent lights.
Stores 14 utilized incandescent lighting.

EXPERIMENTAL EVALUATION OF MILK PACKAGES

Container Description

The containers evaluated in this study were a blow molded half gallon high density polyethylene bottle and a quart polyethylene coated paperboard carton. Both of these containers are widely used in the area stores surveyed.

The blow molded polyethylene bottle employed a silk screen label of red ink covering approximately four square inches on each of two sides. Another side contained a silk screen label of red ink bearing only the dairy name and the type of milk. The fourth side of the container was blank. The label was considered to have no effect on the light barrier properties of the container due to the small area covered by the label.

The one quart polyethylene coated paperboard carton was labeled in two colors. Red ink covered approximately 6.5 square inches of each side. Blue ink covered approximately 2.5 square inches of each side. Each side had an area of approximately 22 square inches. The container utilized a flat top labeled in red ink which covered over 80 percent of the top surface.

Experiment One

An initial trial study was undertaken to determine the length of time required to produce activated flavor in milk exposed to a high illumination level. A 40 watt warm white fluorescent bulb was used. Four of these buls were placed end to end in a display case shelf. The bulbs were placed end to end so that the product being tested would be exposed to the light from only one bulb.

Milk in half gallon blow molded polyethylene bottles was purchased from Heatherwood Farms dairy. The milk samples purchased were taken directly from the filling line. The milk was transferred from the dairy to a dark refrigerator in a double walled corrugated container to avoid contact with light prior to initiating the tests.

To maintain a cool temperature throughout the test period the milk was placed in an ice bath. This bath was changed every six to eight hours. The milk containers were placed in the ice bath and then arranged on a shelf below the light source so that the distance from the light source to a point approximately two inches below the top of the container was seven inches. Another series of samples was placed at the back of the shelf giving a distance from light to container of nine inches.

The resulting light intensities were 865 foot-candles on the samples at the front of the shelf and 525 foot-candles on the samples at the back of the shelf.

One sample was retained in a dark refrigerator to act as a control. Also a sample was placed in a dark area of the shelf being used. It was also packed in ice. This was to act as a control for comparison with the refrigerated control.

Samples were removed from the lighted shelf and placed in a dark refrigerator at intervals of one, four, eleven, twenty-four and forty-eight hours. Within a forty-eight hour period the samples were removed from the refrigerator, placed in a corrugated container, and allowed to stand for two to three hours before tasting.

The test samples were tasted by a four member panel with experience in evaluating light activated flavor in milk. The results of the taste evaluation are given in Table 2.

It can be seen that the milk was oxidized sufficiently at eleven hours to give a slight activated flavor. Exposure for twenty-four hours resulted in a product which would be considered objectionable by the consumer or purchaser of such a product.

It is also noted from this experiment that no difference was observed between the samples at seven inches and those at nine inches.

TABLE 2.--Flavor scores of milk exposed in polyethylene bottles.

Exposure Distance in inches	Exposure Time in Hours	Score*	Degree of Oxidation
refrigerated control	0	39	None
dark control	0	39	None
7	1	39	None
9	1	39	None
7	4	39	None
9	4	39	None
7	11	35	Slight
9	11	35	Slight
7	24	32	Definite
9	24	32	Definite
7	48	32	Definite
9	48	32	Definite

*Milk scoring system used was that recommended by the American Dairy Science Association and is in common use in the dairy industry.

Experiment Two

The next step in the experimental procedure was to evaluate the difference between the blow molded polyethylene and polyethylene coated paperboard carton.

The containers used were the blow molded half gallon polyethylene bottle used in the first experiment and a one quart polyethylene coated paperboard carton. The one quart polyethylene coated paperboard carton was used because the dairy from which we purchased the milk did not utilize a half gallon polyethylene coated paperboard carton.

The test containers were placed in an ice bath to maintain a low temperature. The ice bath was changed every six to eight hours. The containers were arranged so that they were seven inches from the light source used. This distance was measured at a point 2 inches from the top of the blow molded half gallon bottle. Also the quart polyethylene coated paperboard containers were placed in the ice bath at an angle of approximately 30° so that the light struck the sides of the container rather than the top of the container. The distance in this case was measured from the light source to a point approximately two inches below the top of the container.

The light source for this experiment was a 48 inch 40 watt cool white fluorescent lamp. The lumen output of this lamp is approximately the same as that for the warm white bulb used in the initial experiment. The resulting foot-candle intensity at point of contact was 880 foot-candles.

One sample, a quart paperboard container, was placed in a dark refrigerator to act as a control.

Samples were removed from the light condition and placed in the dark refrigerator at 6, 12, and 24 hours. Within forty-eight hours after the test was completed the samples were tasted by the four member panel mentioned in the initial experimental work. The results of this taste evaluation are given in Table 3.

This experiment demonstrated that the polyethylene coated paperboard container was superior to the blow molded polyethylene container in preventing the development of activated flavor in milk when exposed to a high illumination light source of approximately 900 foot-candles.

Experiment Three

The third phase of the experimental procedure was to evaluate the two containers under a low illumination environment for a longer period of time. This was conducted using a constant temperature cabinet fitted with a fluorescent light fixture. The distance from the test containers was increased from 7 inches to 40 inches. This increased distance gave an illumination of approximately 25 foot-condles at the point of contact. The point of contact was measured in the same manner as the previous two experiments.

TABLE 3.--Flavor scores of milk exposed to high intensity light.

Exposure Time in Hours	Container Type*	Score	Degree of Oxidation
0 control	carton	39	None
6	bottle	39	None
6	carton	39	None
12	bottle	32-33	Definite
12	carton	39	None
24	bottle	32-33	Definite
24	carton	39	None

*Carton refers to the polyethylene coated paperboard carton used; bottle refers to the blow molded polyethylene bottle used.

Again, as in previous experiments the milk was purchased directly from the dairy and held in darkness until the start of the experiment.

It was also decided to further evaluate the polyethylene coated paperboard container at the high illumination level to determine at what exposure time an activated flavor would develop in milk stored in this container.

The constant temperature cabinet was maintained at 35-37°F throughout the experiment. The samples were placed in the cabinet so that six blow molded polyethylene and six polyethylene coated paperboard containers were 40 inches from the light source. In addition six polyethylene coated paperboard containers were placed at a distance of 7 inches from the light source.

Samples were removed from the light source and placed in a corrugated board container with two thicknesses of corrugated board on top to prevent light penetration. This box was placed in an area of the constant temperature cabinet away from the light source to further reduce the possibility of light penetration. The control sample, a polyethylene coated paperboard container, was retained in this container throughout the experiment. Samples were withdrawn from the light source at 12, 24, 36, 48, 72 and 96 hours.

The samples were evaluated by the taste panel within 48 hours of the conclusion of the tasting. The results of these tests are given in Table 4.

TABLE 4.--Flavor scores of milk exposed for longer duration.

Distance in Inches	Exposure Time in Hours	Container Type*	Score	Degree of Oxidation
control	0	carton	39	None
40	12	carton	39	None
40	12	bottle	39	None
40	24	carton	39	None
40	24	bottle	37	None (slight flat taste)
40	36	carton	39	None
40	36	bottle	35	Slight
40	48	carton	39	None
40	48	bottle	32	Definite
40	72	carton	38	None
40	72	bottle	32	Definite
40	96	carton	38	None
40	96	bottle	32	Definite
7	12	carton	39	None
7	24	carton	39	None
7	36	carton	39	None
7	48	carton	39	None
7	72	carton	39	None
7	96	carton	36	Slight

*Carton refers to the polyethylene coated paperboard carton used; bottle refers to the blow molded polyethylene bottle used.

It can be seen from this experiment that decreasing the illumination does increase the time required for an activated flavor to appear in milk stored in blow molded polyethylene bottles. However it does indicate that milk exposed for 36 to 48 hours may be objectionable to the consumer.

This experiment also demonstrated that the polyethylene coated paperboard carton provided adequate protection for the milk through four days of exposure to both high and low intensity illumination.

DISCUSSION

A review of the literature indicated that the basic approach to the problem of light induced activated flavor to this point had been the search for a container that would be impervious to light. While this has met with success from a technical point of view in the form of an aluminum foil laminate paperboard carton the costs of producing such a package for use by the dairy industry have been termed prohibitive.

The approach taken in this project was to determine the relationship between the time required to produce a light activated flavor in milk and the intensity of the light at contact with the container being tested. The problem was divided in two parts.

The initial step was to determine the light intensities in local dairy cases. This was accomplished by recording the lighting used and the distance from light source to container. The light intensities at contact were then calculated.

The second step included the experimental evaluation of two containers under two light intensity levels. A high and low level of light intensity was selected from the survey in the initial phase of the project. Then the two test containers were subjected to the two levels of lighting for varying periods of time. The exposure time interval at which activated flavor was detected and the time at which it became objectionable from a consumer standpoint were determined.

The dairy case lighting systems surveyed varied from approximately 8.0 foot-candles to over 3,000 foot-candles at the point of contact with the milk containers.

The low intensity level selected for the experimental work was approximately 25 foot-candles. The high intensity level selected was approximately 900 foot-candles.

Samples were kept cold and removed from the light source at preselected time intervals. The samples were retained at refrigerated temperatures until the actual taste testing.

The results of these experiments showed that the blow molded polyethylene bottle could not protect milk from the high intensity lighting for more than 12 hours exposure time. Using a low intensity lighting system it was found that the milk would be unsatisfactory for the consumer after 48 hours of exposure with the activated flavor being detected at 36 hours exposure.

The polyethylene coated paperboard container was found to be satisfactory through 96 hours of exposure to low intensity lighting with no activated flavor being detected at that point. Under exposure to the high intensity lighting system only a slight trace of activated flavor was noted through 96 hours of exposure. This was not objectionable.

CONCLUSIONS AND RECOMMENDATIONS

Through a survey of dairy case lighting systems in local retail stores it was found that no standard system was used. This point was supported by the fact that the calculated illuminations of dairy cases varied from 8.0 foot-candles to over 3,000 foot-candles at point of contact with the nearest milk container.

The subsequent experiments using two lighting intensities showed the polyethylene coated paperboard container to be satisfactory through 96 hours of exposure to the low intensity lighting used. Only a slight activated flavor was produced after 96 hours of exposure to the high intensity lighting used. This was not considered objectionable.

On the other hand the milk packaged in the blow molded polyethylene bottle was unsatisfactory after 48 hours of exposure to the low intensity lighting. It was considered unsatisfactory after only 12 hours of exposure to the high intensity lighting system.

From this study it is concluded that milk packaged in blow molded polyethylene bottles should be stored in a darkened dairy case. This type of storage facility may have a deficiency in the marketability of milk because of the low light intensity which would be used.

It is recommended that two additional areas of this problem of activated flavor in packaged milk be explored.

The first area of recommended study is that of altering the dairy case lighting systems now in use. A market evaluation of a darkened dairy case system for the sale of milk should be conducted. As a possible solution to the problem of identification of the dairy case in the retail outlet under these circumstances I would suggest that the dairy case be identified through the use of identifying graphics and display above the actual case itself. The lighting would then be directed to the overhead area rather than the milk packages themselves. Investigation of the use of reflected lighting should also be considered.

The second area of recommended study is that of container modification. The use of ultraviolet light absorbers in the polyethylene should be considered. Well controlled studies using an opaque polyethylene container should also be considered.

The fact that the blow molded polyethylene bottle is used for a variety of products packaged at local dairies should encourage further research into the modification of this bottle or its storage environment. This should be done to make this package more acceptable for all products packaged in it including the light susceptible product originally packaged by these dairies--milk.

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APPENDIX

TABLE 5.--Stores used in lighting survey.

Store Number	Name and Address	Type of Store
1	Shop Rite Super Food Market 940 Trowbridge Road East Lansing, Michigan	Supermarket
2	Big E Thrif-T Mart 3301 East Michigan East Lansing, Michigan	Supermarket
3	Wrigley Supermarket 600 Frandor Shopping Center Lansing, Michigan	Supermarket
4	The Kroger Company Frandor Shopping Center Lansing, Michigan	Supermarket
5	The Kroger Company Yankee Stadium Center East Lansing, Michigan	Supermarket
6	Schimdt's Super Food Markets Grand River Okemos, Michigan	Supermarket
7	Hamady Brothers, Inc. Meridian Mall Okemos, Michigan	Supermarket
8	Larry's Shop Rite 1109 East Grand River East Lansing, Michigan	Convenience
9	A & P Food Store 305 North Clippert Lansing, Michigan	Supermarket
10	A & P Food Store 1908 East Michigan East Lansing, Michigan	Supermarket
11	K Mart Discount Stores West Grand River Okemos, Michigan	Supermarket

TABLE 5.--Continued.

Store Number	Name and Address	Type of Store
12	Min-A-Mart Food Stores 2168 West Grand River Okemos, Michigan	Small Convenience
13	Meijer Thrifty Acres 2055 West Grand River Okemos, Michigan	Supermarket
14	Quality Dairy Company 1201 East Grand River East Lansing, Michigan	Small Convenience