A STUDY OF THE PLASTIC SURFACED MILK CARTONS

Thesis for the Degree of M. S.

MICHIGAN STATE UNIVERSITY

John C. Barnes

1960

71 ~~FEB 1 '81~~ 032

~~8 1981~~ 074

~~AUG 0 1 [illegible]~~

~~AUG 27 1990~~

~~SEPT 24 1990~~

~~OCT 23 1990~~

NOV 20 1990

A STUDY OF THE PLASTIC SURFACED MILK CARTONS

By

JOHN C. BARNES

AN ABSTRACT

Submitted to the College of Agriculture
Michigan State University of Agriculture and
Applied Science in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE

Department of Dairy

1960

Approved T. I. Hedrick

ABSTRACT JOHN C. BARNES

More than 50 percent of the market milk is packaged in paper cartons and nearly 90 percent of all milk sold in supermarkets is in single-service cartons. Most of these cartons are wax coated. The purpose of this investigation was to study, under commercial conditions, factors related to packaging, handling and merchandising milk in the plastic surfaced cartons.

In order to preform, sanitize, fill and seal cartons with the new plastic surface and an improved closure, a modified Pure-Pak packaging machine was used. The modifications consisted of heaters and pressure pads for sealing carton bottoms, a hot water sanitizing compartment and a heat sealing mechanism for carton-tops.

The flavor of milk, orange drink and cultured buttermilk was not affected by packaging and storing in these cartons. The flavor of milk that was frozen and defrosted in these cartons was not adversely affected. Plastic surfaced cartons did not prevent sunlight induced off-flavor when exposed to direct rays of sunshine for 2 hours.

Cold milk packaged in plastic surfaced cartons increased in temperature slightly more rapidly than milk in waxed cartons when placed in a warm room for 1 hour.

In general, the quart plastic surfaced cartons of milk, cultured buttermilk and orange drink tended to bulge very little during 3, 7 and 14 days of storage at 41° F. Cartons of milk had more bulge after freezing and thawing, but it was not excessive.

Durability tests designed to indicate the cartons' resistance to rough handling included the Drop, Incline-Impact, Combination and Hauling Tests. The carton top-seal was sufficiently durable to resist leaker development when subjected to the four durability tests. The plastic surfaced carton appeared to have several points of weakness compared to the wax coated cartons. Slow seepage and leaks appeared more frequently at the bottom-seal and corners, side-seam seal and shoulder-seal when subjected to the Drop, Incline-Impact, Combination and Hauling Tests. Improper application of sealing material or inadequate heat sealing may have contributed to the defects.

Consumer acceptance on retail milk routes was very favorable. In fact, most customers preferred plastic surfaced cartons over the wax coated cartons.

The operation of the modified packaging machine was satisfactory after several minor changes were made. The fact should be emphasized that the sealing mechanism did not compensate for most imperfections resulting from the lack of precision in the dies used for cutting cartons.

The temperature increase of the contents of quart cartons during the machine operation averaged between 2 and 3 degrees F.

ABSTRACT JOHN C. BARNES

The hot water (190° F.) immersion bath was very effective in sanitizing regular or seeded cartons. This was true when the seeding contamination consisted of common thermoduric organisms such as *Lactobacillus thermophilus* and *Micrococcus varians* as well as the less heat resistant types of *Escherichia coli* and *Pseudomonas fragi*. Standard plate and coliform counts on the new empty cartons that were not immersed in hot water averaged very low (15 organisms per carton) and were well within the maximum limits for milk containers.

This experimental work indicated that the dairy industry and the customers would readily accept these cartons for regular use providing the price would be economical.

A STUDY OF THE PLASTIC SURFACED MILK CARTONS

By

John C. Barnes

A Thesis

Submitted to the College of Agriculture
Michigan State University of Agriculture and
Applied Science in partial fulfillment of
the requirements for the degree of

Master of Science

Department of Dairy

1960

ACKNOWLEDGEMENTS

The author owes appreciation to many individuals for their cheerfulness, confidence and forbearance and to others for their willingness to help with the work. Sincere thanks and gratitude are especially extended to those who made this study possible:

Professor T. I. Hedrick for his attentive interest and guidance during the study and his major contribution of assistance in the preparation of this manuscript.

Professor L. G. Harmon for contributing guidance of research plus direction and help in the preparation of the microbiological parts of this manuscript.

Pure-Pak Division of the Ex-Cell-O Corporation for the financial support and materials.

Professor Carl W. Hall who provided an example of excellent teaching.

Mrs. Barnes, Robert, Allan and Patricia for their forbearance, inspiration and optimism.

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES

INTRODUCTION

The general trend shows an increase in packaging of milk in paper cartons since 1937. The consumer acceptance of milk in paper cartons increased very rapidly after the regulatory agencies publicly approved the sanitary condition of the cartons.

Currently, more than 50 percent of home-consumed milk is packaged in single-service containers. Most of these containers are wax coated. Rectangular cartons with a plastic coating are on the market (since 1949); but acceptance is limited by inherent problems. However, prospective advantages of polyethylene coated paperboard and its suitability for use stimulated the development of new plastic surfaced cartons as a replacement for wax coated cartons.

To solve problems associated with the "gable" type plastic surfaced cartons and the modified packaging machine, experimental work was performed in the Michigan State University Dairy Plant facilities, whose sales were commercially competitive but restricted to the University campus area.

This investigation was undertaken to study the use of the plastic surfaced cartons as containers for milk and other products. The problems that were studied included: product stability, durability of the cartons under common handling and transportation, customer acceptance of the cartons, microbiological condition of the cartons and adjustment of machine operations to the use of plastic surfaced cartons.

LITERATURE REVIEW

1. Product Stability in the Plastic Surfaced Cartons

Literature on the effect of plastic surfaces on the flavor of milk and other associated dairy products is meager. Burgess (1950) concluded that polyethylene caused less change in food products than other surfacing materials used on paperboard. He referred particularly to flavor inertness as well as to chemical inertness. Dahle and Josephson (1939) confirmed reports of Doan and Myers (1936) that milk in paper cartons developed less oxidised and sunshine flavor when exposed to the sun's rays than milk in glass bottles. Finely ground oat flour (Avenex) and an antioxidant (Avenol) were used in sprays on the carton interface and in mixtures with paraffin. This treatment of cartons did not prevent off-flavors induced by sunshine. However, Dahle and Josephson stated, "Cartons made from paperboard which had been sized with oat flour before paraffining aided in delaying the oxidised flavor induced by exposure to sunshine for 30 minutes."

Prucha and Tracy (1943) confirmed the work of Dahle and Josephson showing that milk in paper containers developed an off-flavor when exposed to sunlight.

2. Durability of Plastic Surfaced Cartons

Prucha and Tracy (1943) reported on paper containers that were tested for strength, bulge and leakage. On the basis of the results, they concluded that paper containers were practical for milk packaging.

Burgess (1950) stated that polyethylene had water and water vapor resistance at normal temperatures. The folding endurance and flexibility characteristics were excellent and rated highly during aging.

The use of polyethylene was advocated as a coating for paperboard because of important properties which included chemical inertness, light weight, toughness, tear strength, extensibility, flexibility at low temperatures, grease proofness, water and water vapor proofness and heat sealability (Anonymous (1950)). The plastic could also be colored by pigments and dyes for advertising purposes.

The polyethylene extrusion processes were accomplished by first melting polyethylene crystals at 500° to 600° F. (Anonymous (1950)). Then by use of a screw the hot liquid was forced through a tubular screen onto the applicator roller which applied the thin coating of polyethylene onto the paper sheet. The polyethylene was cooled immediately.

John and Stannett (1956) described four techniques for applying plastic to paper. They were tub sizing, saturation, coating and lamination.

Booth (1956) reported his survey of the coating methods by machines. He presented a line drawing of the coating application by using one furnish-roll (which picks up and applies liquid coating material on paperboard). The roll was partly submerged in a supply vessel. Another method was an offset gravure coater with two furnish-rolls partly submerged. A third system utilized one or two furnish-rolls with attached inclined-blades holding and spreading the supply of coating. The fourth method consisted of a supply between two counter running furnish-rolls. He stated that most of the methods of coating were developed by individual mills to fill specific needs.

The American Society for Testing Materials (ASTM) (1957) explained the use of vibrating equipment and tentative methods for simulating conditions of transportation. To determine the ability of a container to protect its contents and to withstand rough handling, cartons were subjected to the simulated conditions of rough handling. Transportation by truck had certain ranges of vibration frequencies that predominated at 70 to 200 cycles per second in combination with shock. Container failure occurred when the contents spilled, when predetermined damage occurred or if some contents were removed without further damage to the container.

A second method involved the controlled dropping of filled containers on the edges, corners or faces of the containers. Extent of damage was observed.

A third method outlined the Conbur tester (Incline-Impact) which subjected containers to impact stresses, such as rail car switching shocks. The tester consisted of an inclined track, dolly and rigid bumper. Containers of filled packages were allowed to slide down the slope against the bumper. Usually containers were subjected to the impact stresses on the four faces but sometimes were tested on edges and corners, depending on the handling conditions to be simulated.

Bickerman (1959) stated that adhesionable properties of polyethylene were improved by the removal of low molecular components. The improved processing eliminated the formation of objectionable surface films having low mechanical strength which sometimes existed on commercial polyethylenes.

3. Customer Acceptance

Paper cone bottles were used for milk containers (The Milk Dealer (1929)) and (Business Week (1932)).

Wheaton, Lueck and Tanner (1938) reported a general trend toward an increase in packaging of milk in single service paper containers. Paper containers were lighter in weight and needed no bottle deposit at stores. Bottle cleaning was eliminated.

Tracy (1938) stated that the advent of store selling of milk brought on the development of several paper containers. At the same price a slight majority of 221 customers polled preferred to buy milk in paper instead of glass containers. The customers believed sanitation was better in paper and few customers noted any difference in flavor. Less space was needed in refrigerators and cartons were preferred on picnics. Tracy's survey of comments from customers included favorable reports about paper cartons such as: no bottle washing, no bottle return, no breaking or chipping and more easily handled.
Prucha and Tracy (1943) conducted surveys which showed that 95 percent

of 136 customers who returned questionnaires preferred paper containers instead of glass bottles. The customers' opinions indicated that paper cartons were sanitary as well as practical for packaging fluid milk.

The paper carton was referred to as an outstanding innovation in the promotion for health and safety in manufacturing plants (Anonymous (1942)). Production time of workers was not lost through accidents due to broken bottles nor by returning empty bottles.

Pitman (1946) advocated that research workers measure the efficiency of packaging performance by using adverse as well as practical conditions involving time and temperature of storage, exposure to sunshine, gain or loss of moisture by the product or package, bacteria, appearance, product flavor and general palatability. He also suggested test marketing for customer acceptance, taste panels and comparison with competitors' packages.

Sealking plastic coated cartons gained favorable customer acceptance (Anonymous (1949)). Williamson (1955) wrote that Tetra-Pak had been used for the three previous years in Stockholm, Sweden. Based on information from the manager of a large dairy in Stockholm, Mr. Williamson stated that the reaction of customers was variable. Occasionally, a customer reacted strongly against the awkwardness in handling the tetrahedron container. Adverse reaction by consumers had diminished gradually. The manager found that it was necessary to have a separate filling machine for each size of Tetra-Pak packages. He also had difficulties if the seal was incomplete or the paperboard was of uneven quality.

4. Sanitary Condition of Plastic Surfaced Cartons

In order to show the sanitary condition of paper milk containers, Prucha (1938, 1939) stated that paperboard could be made practically free from bacteria and could be converted to paper milk cartons having a satisfactory microbiological condition. He stated that cartons paraffined at 185° F. for 30 seconds were practically sterile and were safe for use. Immersion water at 185° F. practically sterilized cartons in less time than paraffin at 185°.

To standardize the testing of the cartons, Wheaton, Lueck and Tanner (1938) suggested the use of 20 ml. rinses and plating of 10 ml. of rinse water. They found 80 percent of the cartons contained no bacteria and 20 percent had fewer than 5 colonies per carton. Tests for Escherichia coli on the waxed cartons were all negative.

Sanborn (1938, 1939, 1940, 1941 and 1942) stated that sanitation in the manufacture and use of paper containers involved: use of virgin pulp only; microbiological control at pulp and paper mills; protective packaging of the finished board; mechanical handling at conversion factories and milk plants; eliminating human contact with paperboard, adhesives, wax and the final containers; adequate protection from contamination, dirt, flushing water or insects and use of nontoxic germicidal substances which had no effect on milk. He stated that the bacteria count of paperboard should not exceed 500 colonies per gram.

In the preparation of sanitary standards for paper milk containers, the combined data from various studies on the containers were examined and used by Sanborn, Yale, Breed and others (1938). They presented the sanitary standards which were agreed upon by a group meeting sponsored by the International Association of Milk and Food Sanitarians. The following principles of sanitation for the manufacture and use of paper containers for milk were recommended for the industries. They involved:

1. Use virgin pulp free from dirt and slime and protected from contamination during processing.
2. Protect paperboard with sealed wrappers.
3. Convert rolls or sheets of paperboard into containers by sanitary means and mechanical handling, because containers must be clean and free from chemical reagents and foreign materials.
4. Use sterile adhesives of synthetic thermoplastic types.
5. Package finished cartons in sealed, suitable wrappers or shipping cases.
6. Use shipping cases having the ability to withstand rough handling and to protect the contents in transit.
7. Protect the shipping cases from contamination in the milk plants.
8. Avoid use (in carton manufacture or filling) of germicidal or bacteriostatic agents which would be toxic or have an effect on the product.
9. Handle paraffin by suitable, clean and sanitary means.

10. Use containers made from paperboard containing less than 500 colonies per gram (reduced to 250 in 1939).
11. Control average bacteria counts at 50 or fewer colonies per container.
12. Use shipping containers which are uninjured, neat and clean for filled cartons.
13. Use single service containers for milk deliveries to hospitals and quarantined residences caring for infectious diseases.

Twelve hundred containers tested for E. coli were negative when examined by Tanner (1938, 1939 and 1948). Over 90 percent of the containers had negative bacteria counts in the rinses. The average microbiological population recovered from paper containers was much lower than those reported from some glass bottles which usually contained less than 10 organisms per bottle. Special methods of making paperboard were necessary to have a large reduction in viable bacteria. Tanner also found that immersion of cartons in hot paraffin resulted in a further reduction in viable bacteria.

In 1939 data indicated that some mills consistantly made paperboard with not over 100 organisms per gram (Sanborn (1939)). The following year, Sanborn (1940) reported that 13 different mills made paperboard which contained few counts in excess of 500 per gram (2,879 analyses). Fifty percent of the counts were less than 10.

Huntley and Torrey (1940) stated that mills processing paperboard controlled the microbiological condition of paperboard by a chloramine process and cleaning methods. The drying operation was one of the most effective sterilizers. Water on the rolls was treated with chlorine.

The next year, Sanborn (1941) stated that 73 percent of the counts on paperboard were less than 10, and 99 percent were less than 100 per gram of paperboard. The Baltimore Health Department specified not more than 50 organisms per quart container and Boston permitted only 25 with a proportional standard for the other sizes of containers.

According to Rice (1942) there was a closer relationship between the degree of sterility of paper containers and the microbiological condition of paperboard from which the containers were made than there was between the degree of sterility and the supposedly germicidal effect of moisture proofing with paraffin at high temperatures (150° F. and above).

Preformed cartons were examined by Foord, Crane and Clark (1943). Tests showed that 78.5 percent of the cartons were sterile and the other 21.5 percent contained less than three organisms per carton. When 10 ml. of rinse was left in the cartons and agar was added, 87.5 percent were sterile.

Methods for the microbiological examination of various kinds of products in paperboard mills were reported by Appling (1945) and were incorporated into a suggested standard in the Technical Association of the Pulp and Paper Industry as T-449 sm 40. Because dairy products had been packaged in paper for many years, it was not surprising to find various methods of examination being used by research workers and technicians with the American Public Health Association.

Microbiological studies by Reed (1951) showed that mill systems had a problem with surviving sporeforming bacteria in paperboard. His summation of data indicated that organisms in paper containers were due to converting processes and other handling and processing methods, and were not due to the material from which the units were made.

PROCEDURES, RESULTS AND DISCUSSION

1. Product Stability in the Plastic Surfaced Cartons

Procedure

To determine how the plastic surfacing material would effect the flavor of dairy products and orange drink, cartons were filled with pasteurized homogenized whole milk (3.5 percent milk fat), cultured buttermilk or orange drink. These products were stored for periods in excess of commercial practice at refrigerator temperatures varying from 33° to 60° F. They were examined at specific intervals depending upon the product. Competent dairy product judges carefully performed organoleptic tests for possible changes of the products due to the plastic material.

Pasteurized homogenized whole milk packaged in quart plastic surfaced containers was frozen and stored at -15° F. from 15 to 34 weeks. The milk was defrosted for 4 days in a refrigerated room at 41° F. After mixing, each sample was examined for off-flavors induced by the polyethylene.

The protection provided by the plastic surfaced cartons against sunlight-induced off-flavors in pasteurized homogenized whole milk was investigated. Cartons of cold milk (39° F.) were exposed to direct sunlight for 1 to 2 hours. Immediately after exposure, the samples were placed in a 41° F. refrigerator for 24 to 48 hours before their flavor was evaluated by dairy product judges.

Liquid milk products have ample opportunity to change in temperature during handling, especially in the home. The rate of change is important in preserving freshness of flavor and in preventing microbiological growth. To ascertain the rate of temperature change in the contents of plastic surfaced cartons, water was packaged in the cartons and allowed to become uniform in temperature by storing in a refrigerated room at approximately 38° F., 44° F. or 51° F. for 5 days. Control samples (wax coated cartons) were handled in the same manner.

After the 5-day hold, cartons at each of the three temperatures were placed in a room for 55 to 68 minutes with 50 percent relative humidity at 73° F. The arrangement of the cartons on shelves allowed uniform exposure of air to all sides. After exposure the cartons were inverted six times, and the temperature of the contents was read to the nearest 0.5° F.

To observe the rate of cooling, cartons of water were held 5 days at 73° F. and then transferred to a 41° F. refrigerated room with 88 percent relative humidity. After holding for 55 to 68 minutes the cartons again were inverted six times and the temperature recorded to the nearest 0.5° F.

Results and Discussion

Data in Table 1 show the plastic surfaced material in contact with the milk did not cause an off-flavor when held 7 to 14 days at 33° F. or 41° F. Additional trials with milk samples held in storage at 50° and 60° F. for 4 and 7 days indicated sufficient microbiological growth to influence the flavor adversely. However, comparison with control samples showed that none of the changes could be attributed to the plastic surfaced material.

Results of the 16 trials in which quarts of cultured buttermilk were stored 4 and 7 days at 33° F. and 41° F. indicated no off-flavor was caused by the plastic surfaced carton. Thirteen trials on orange drink conducted under similar conditions also showed no off-flavor from the cartons. Results of the tests are presented in Table 2.

Table 3 presents the data on pasteurized homogenized milk scored for flavor after freezing, storing in the frozen state for 15 to 34 weeks and defrosting. The ten trials indicated a detectable off-flavor was not imparted to the milk in the plastic surfaced containers under these conditions.

The plastic surfaced cartons were not effective in the prevention of off-flavors induced by sunlight. Results are shown in Table 4. One hour of exposure caused only a small flavor deterioration or no detectable change, but 2 hours of exposure consistently caused a decrease in flavor score that was criticized as "slight oxidized" or "oxidized" in all trials. The oxidized off-flavor was characteristic of the flavor caused by sunlight.

Tables 5, 6 and 7 show the data for the trials conducted on temperature change of water in plastic surfaced cartons. Samples with a temperature of 38.5°, 44.0° or 51.5° F. were exposed for 55 to 68 minutes to air at 73° F. Twenty samples in plastic surfaced cartons with an initial temperature of 38.5° F. had an average increase of 10.90° F. The control samples (in wax coated cartons) under the same

TABLE 1--Effect of plastic surfaced cartons on flavor of whole milk (22 trials using plastic surfaced paperboard lot No. 909 and commercial wax coated cartons as controls)

Examination period	Wax coated cartons (control)		Plastic surfaced cartons	
	33° F.	41° F.	33° F.	41° F.
7 days	neg.*	neg.	neg.	neg.
14 days	neg.	neg.	neg.	neg.

*No off-flavor from cartons.

TABLE 2--Effect of plastic surfaced cartons on flavor of cultured buttermilk and orange drink (samples held 7 days in plastic surfaced paperboard lot No. 1568-2 and commercial wax coated cartons as controls)

Number of Trials	Buttermilk				Orange drink			
	Wax coated cartons (control)		Plastic surfaced cartons		Wax coated cartons (control)		Plastic surfaced cartons	
	33°F.	41°F.	33°F.	41°F.	33°F.	41°F.	33°F.	41°F.
4					neg.		neg.	
5	neg.*		neg.					
13						neg.		neg.
16		neg.		neg.				

*No off-flavor from cartons.

TABLE 3--Effect of plastic surfaced cartons on flavor of whole milk subsequent to freezing and storage at -15° F.

Trial number	Held frozen (weeks)	Plastic[1] surfaced	Control (wax coated)	Flavor score and comment after storage
1	34	negative[2]	no sample	37.0 slight stale
2	30	negative	no sample	37.0 slight stale
3	26	negative	no sample	37.0 slight stale
4	21	negative	no sample	38.5 slight feed
5	21	negative	negative	38.5 slight feed
6	18	negative	negative	39.0 very good
7	18	negative	negative	39.0 very good
8	16	negative	negative	38.5 slight feed
9	15	negative	negative	38.5 slight feed
10	15	negative	negative	39.0 very good

[1]Lot 1568-2
[2]No off-flavor from plastic surfaced cartons was detected.

TABLE 4—Effect of sunlight on flavor of homogenized milk in plastic surfaced cartons

Trial number	Control (no sunlight)	Sunlight (1 hour)	Sunlight (2 hours)
1	39.0 very slight feed	38.5 very slight oxidized	37.5 slight oxidized
2	39.0 very slight feed	38.5 very slight oxidized	37.5 slight oxidized
3	39.5 very slight cooked	39.5 very slight cooked	38.0 very slight oxidized
4	39.0 very slight cooked	38.0 very slight oxidized	37.5 slight oxidized
5	39.0 very slight feed	37.5 slight oxidized	36.0 oxidized
6	38.5 slight feed	37.5 slight oxidized	35.0 oxidized
7	39.0 very slight feed	37.5 slight oxidized	35.0 oxidized
8	38.0 feed	38.0 feed	37.5 slight oxidized
9	38.5	38.5 slight feed	37.5 slight oxidized

TABLE 5—Temperature increase of water at 38.5° F. in quart plastic surfaced cartons held at 73° F. for 55 to 68 minutes

Plastic surfaced[1]				Control (wax coated)			
Sample number	Initial temp. (degrees F.)	Ending temp. (degrees F.)	Diff.	Sample number	Initial temp. (degrees F.)	Ending temp. (degrees F.)	Diff.
1	38.5	48.0	9.5	21	38.5	47.5	9.0
2	38.5	48.0	9.5	22	38.5	47.5	9.0
3	38.5	48.5	10.0	23	38.5	47.5	9.0
4	38.5	48.5	10.0	24	38.5	47.5	9.0
5	38.5	48.5	10.0	25	38.5	48.0	9.5
6	38.5	48.5	10.0	26	38.5	48.0	9.5
7	38.5	48.5	10.0	27	38.5	48.0	9.5
8	38.5	48.5	10.0	28	38.5	48.0	9.5
9	38.5	48.5	10.0	29	38.5	48.0	9.5
10	38.5	48.5	10.0	30	38.5	48.0	9.5
11	38.5	48.5	10.0	31	38.5	48.5	10.0
12	38.5	49.0	10.5	32	38.5	48.5	10.0
13	38.5	49.0	10.5	33	38.5	48.5	10.0
14	38.5	49.0	10.5	34	38.5	49.0	10.5
15	38.5	49.5	11.0	35	38.5	49.5	11.0
16	38.5	50.5	12.0	36	38.5	50.0	11.5
17	38.5	51.0	12.5	37	38.5	51.5	13.0
18	38.5	52.5	14.0	38	38.5	51.0	12.5
19	38.5	51.5	13.0	39	38.5	53.0	14.5
20	38.5	53.5	15.0	40	38.5	53.5	15.0
		Average	10.90°			Average	10.55°

[1] Lot 5

TABLE 6—Temperature increase of water at 44° F. in quart plastic surfaced cartons held at 73° F. for 55 to 68 minutes

Plastic surfaced[1]				Control (wax coated)			
Sample number	Initial temp. (degrees F.)	Ending temp. (degrees F.)	Diff.	Sample number	Initial temp. (degrees F.)	Ending temp. (degrees F.)	Diff.
1	44.0	50.5	6.5	21	44.0	51.0	7.0
2	44.0	51.5	7.5	22	44.0	51.5	7.5
3	44.0	51.5	7.5	23	44.0	51.5	7.5
4	44.0	52.0	8.0	24	44.0	51.5	7.5
5	44.0	52.5	8.5	25	44.0	52.0	8.0
6	44.0	52.5	8.5	26	44.0	52.0	8.0
7	44.0	52.5	8.5	27	44.0	52.5	8.5
8	44.0	52.5	8.5	28	44.0	53.0	9.0
9	44.0	52.0	8.0	29	44.0	53.0	9.0
10	44.0	52.5	8.5	30	44.0	53.0	9.0
11	44.0	53.5	9.5	31	44.0	53.5	9.5
12	44.0	53.0	9.0	32	44.0	53.5	9.5
13	44.0	54.0	10.0	33	44.0	53.5	9.5
14	44.0	54.5	10.5	34	44.0	54.0	10.0
15	44.0	55.5	11.5	35	44.0	54.0	10.0
16	44.0	55.5	11.5	36	44.0	54.0	10.0
17	44.0	55.5	11.5	37	44.0	54.0	10.0
18	44.0	56.0	12.0	38	44.0	55.0	11.0
19	44.0	56.0	12.0	39	44.0	55.0	11.0
20	44.0	56.5	12.5	40	44.0	55.0	11.0
		Average	9.50°			Average	9.13°

[1]Lot 5

TABLE 7—Temperature increase of water at 51.5° F. in quart plastic surfaced cartons held at 73° F. for 55 to 68 minutes

Plastic surfaced[1]				Control (wax coated)			
Sample number	Initial temp. (degrees F.)	Ending temp. (degrees F.)	Diff.	Sample number	Initial temp. (degrees F.)	Ending temp. (degrees F.)	Diff.
1	51.5	58.0	6.5	21	51.5	57.5	6.0
2	51.5	58.5	7.0	22	51.5	57.5	6.0
3	51.5	58.5	7.0	23	51.5	57.5	6.0
4	51.5	58.5	7.0	24	51.5	58.0	6.5
5	51.5	58.5	7.0	25	51.5	58.0	6.5
6	51.5	58.5	7.0	26	51.5	58.0	6.5
7	51.5	59.0	7.5	27	51.5	58.0	6.5
8	51.5	59.0	7.5	28	51.5	58.5	7.0
9	51.5	59.0	7.5	29	51.5	59.0	7.5
10	51.5	59.0	7.5	30	51.5	59.0	7.5
11	51.5	59.0	7.5	31	51.5	59.0	7.5
12	51.5	59.0	7.5	32	51.5	59.0	7.5
13	51.5	59.0	7.5	33	51.5	59.0	7.5
14	51.5	59.5	8.0	34	51.5	59.0	7.5
15	51.5	59.5	8.0	35	51.5	59.5	8.0
16	51.5	60.0	8.5	36	51.5	59.5	8.0
17	51.5	60.0	8.5	37	51.5	59.5	8.0
18	51.5	60.0	8.5	38	51.5	60.0	8.5
19	51.5	60.5	9.0	39	51.5	60.0	8.5
20	51.5	61.0	9.5	40	51.5	60.0	8.5
		Average	7.70°			Average	7.28°

[1]Lot 5

conditions had an average increase of 10.55° F. or 0.35° F. less. Twenty samples of water in plastic surfaced cartons with an initial temperature of 44.0° F. increased an average of 9.50° F. and the control samples increased an average of 9.13° F. or 0.37° F. less. The temperature after 1 hour of exposure to warmer air was sufficiently high to permit rapid microbiological growth. Twenty samples in plastic surfaced cartons at 51.5° F. increased an average of 7.70° F. compared to the average of 7.28° F. for the contents of wax coated cartons. The average difference was 0.42° F.

The decrease in temperature of 20 samples with an initial temperature of 73° F. during a hold at 40° F. for 55 to 68 minutes is shown in Table 8. Plastic surfaced cartons had an increase of 10.95° F. with 11.12° F. for the wax coated cartons. The average difference was 0.17° F.

The average difference in temperature change between the contents of plastic surfaced and wax coated cartons was not considered large enough to be of practical importance. In the four sets of trials the average difference was less than 0.4° F. Consequently, the plastic surfacing material did not add materially to the insulation properties of the board when test results were compared with those of the wax coated board. The opinions expressed by customers that plastic surfaced cartons kept milk cooler when exposed to a warm atmospheric temperature were not verified. The suggestion by other customers that the reverse was true in comparison with wax coated cartons was not of sufficient magnitude to be of importance.

TABLE 8—Temperature decrease of water at 73° F. in quart plastic surfaced cartons held at 44.0° F. for 55 to 68 minutes

Plastic surfaced[1]				Control (wax coated)			
Sample number	Initial temp. (degrees F.)	Ending temp. (degrees F.)	Diff.	Sample number	Initial temp. (degrees F.)	Ending temp. (degrees F.)	Diff.
1	73.0	63.5	9.5	21	73.0	62.0	11.0
2	73.0	63.5	9.5	22	73.0	62.0	11.0
3	73.0	63.0	10.0	23	73.0	61.5	11.5
4	73.0	62.5	10.5	24	73.0	62.0	11.0
5	73.0	62.5	10.5	25	73.0	62.0	11.0
6	73.0	62.5	10.5	26	73.0	63.0	10.0
7	73.0	62.5	10.5	27	73.0	63.0	10.0
8	73.0	62.5	10.5	28	73.0	62.5	10.5
9	73.0	62.0	11.0	29	73.0	63.0	10.0
10	73.0	62.0	11.0	30	73.0	61.5	11.5
11	73.0	62.0	11.0	31	73.0	62.0	11.0
12	73.0	62.0	11.0	32	73.0	61.0	12.0
13	73.0	62.0	11.0	33	73.0	62.0	11.0
14	73.0	62.0	11.0	34	73.0	62.0	11.0
15	73.0	62.0	11.0	35	73.0	61.5	11.5
16	73.0	61.5	11.5	36	73.0	62.5	10.5
17	73.0	61.5	11.5	37	73.0	62.0	11.0
18	73.0	60.5	12.5	38	73.0	60.5	12.5
19	73.0	60.5	12.5	39	73.0	60.5	12.5
20	73.0	60.5	12.5	40	73.0	61.0	12.0
		Average	10.95°			Average	11.12°

[1]Lot 5.

2. Durability of Plastic Surfaced Cartons

Procedure

Freedom from leaks and maintenance of original shape are important qualities of a milk carton during handling from the filling process until consumption. No single laboratory test has been devised that will accurately measure the durability of the milk cartons during commercial handling. Several tests are commonly used to check the filled cartons for one or more properties that contribute to durability.

The Ex-Cell-O Corporation has developed procedures for measuring "bulge" of the filled carton and the carton's tendency to resist leakage after the shock of dropping.

For the Bulge Test quart milk cartons were measured with a cabinetmaker's rule which has two sliding squares. Measurements were taken in an area approximately midway between the top and bottom of the carton and between the two sides (the front represented the panel having the pouring lip). Measurements were read to the nearest 1/32 inch.

The cartons were filled and sealed with homogenized milk, cultured buttermilk or orange drink and held in refrigerated rooms at 33° F. or 41° F. Because of the compact fit, storage in the case tended to prevent bulging of the cartons. Therefore, the cartons were placed on shelving a sufficient distance apart to prevent contact.

The bulge measurement of each carton was obtained after 0, 3, 7 and 14 days of storage. Bulge was expressed in whole numbers which represented the numerator in thirty-seconds of an inch.

Freezing trials consisted of filling plastic surfaced cartons with whole milk, cultured buttermilk or orange drink and then storing them for 15 to 34 weeks in a -15° F. freezer. The cartons were placed on shelving with allowance for air circulation on all sides.

Thawing was accomplished by a transfer of the cartons to a 40° F. cooler and placement upon shelving which permitted air circulation around all sides of the carton. The bulge was checked after 7 days at 40° F. Each carton was also examined carefully for leaks.

The Drop Test equipment consists of a metal frame just large enough to allow a quart milk carton to fall freely. The bottom of the chute was constructed with four small raised corners. Upon impact the contact with the carton was limited to the raised areas. The carton containing 1 quart of product was dropped four times from a height of 7 inches. With each of the successive drops the carton was turned one-quarter clockwise. Cartons were then examined for damage, especially in the bottom area, and were placed on absorbent paper for detection of slow leaks that might have developed.

Another test of durability is the Conbur Test also known as Incline-Impact Test which consists of a frame with a carriage mounted on a 10-degree slope. Four times the case (wire or aluminum) of filled quart cartons was allowed to roll freely 30 inches down the slope and was brought to an abrupt stop. The case was given a one-quarter clockwise turn before each repeat. The cartons were inspected individually for damage, especially for leaks or seepage. In recording the data for this test, the side to the right of the pouring lip was considered the front of the carton.

After filling cases with milk cartons from the turntable of the Pure-Pak machine, they received a cold water rinse during their travel on the conveyor to the cooler. Wire cases allowed rapid, adequate drainage. The aluminum cases were of panel construction and tended to retain some moisture, especially in the bottom. This caused the base of cartons with both 0- and 3-day holds to be damp.

In the absence of a standard test to ascertain the overall durability of a milk carton during commercial handling, a method was developed for this study. It is referred to as the Combination Test. Quart cartons were filled by the machine with colored water, sealed and placed in wire or aluminum (solid wall) cases and held 0-day and 3 days. Durability was then tested by subjecting the cartons to the following handling:

1. Pairs of cartons were lifted 7 inches and then released to drop back into the case.

2. The case with cartons was lifted 2 inches and dropped a total of six times.

3. The case of cartons was fastened to a standard vibrator* and subjected to 2 minutes of vibration at 210 cycles per minute.

4. Cartons were examined individually for any evidence of damage which caused leaking.

The Hauling Test was also used to ascertain the durability of the plastic surfaced cartons. Aluminum and wire cases were filled with quart cartons of colored water. These cases were added to the load of

---

*Packaging Tester SNLVMCH 35, Type 400, L.A.B. Corporation.

a regular retail delivery truck and transported over the usual route which consisted mainly of paved streets but also included some rough dirt and gravel roads. The trial cases were taken on the route for 3 or 6 successive days. The cartons were inspected individually for leaks. A leak was considered to be any visual evidence of the colored water on the outside of cartons. The leakage ranged from very slight seepage to rapid dripping.

On warm summer days, the Icing Test was used to determine the ability of the plastic surfaced cartons to withstand snow ice and melted ice. Twenty trials were conducted using wire or aluminum cases with 20 plastic surfaced quart cartons of milk per case. The cartons were kept cool by the use of snow ice on top of them. The first four trials involved placing as much ice as would conveniently remain on top of the cartons. This, however, did not assure complete coverage of the tops. Thereafter sideboards were placed on the cases and the ice was added until cartons were covered to a depth of 2 or 3 inches. The cases were loaded on the truck with regular cases for the retail route delivery. The ice supply on trial cases was replenished during transportation to maintain constant coverage. After the route trip of approximately 10 miles (which took 5 hours), trial cases were returned to the cooler and held 2 or 3 hours. Remaining ice was removed and a careful visual inspection of each carton was made. Particular attention was given to damage of the top-seal, especially to damage caused by moisture from the melting ice.

Results and Discussion

Data on the bulge of cartons filled with milk are presented in Table 9. The weighted average bulge for 75 samples held for 3 days at 33° F. was 7.2. For 75 cartons held 7 days it was 8.2, and after 14 days it was 9.1. Seventy-five cartons held 3, 7 and 14 days at 41° F. showed weighted average bulges of 7.7, 9.0 and 11.2, respectively.

Data showing the results of bulges on cartons of cultured buttermilk are presented in Table 10. The weighted average bulges of cartons held 3, 7 and 14 days at 33° F. were 6.0, 8.0 and 10.3, respectively. Cartons stored for the same periods of time at 41° F. had average bulges of 6.7, 9.2 and 10.5, respectively. As would be anticipated, there was a slight increase in bulge tendency among cartons stored at the higher temperature.

Table 11 shows the bulge of cartons filled with orange drink. Sixty cartons held 3, 7 and 14 days at 33° F. had a weighted average bulge of 6.0, 6.1 and 7.8, respectively. Cartons held the same length of time at 41° F. had bulges of 6.3, 7.4 and 9.3, respectively.

The amount of bulge tolerated without customer objection is a matter of personal opinion. An arbitrary measurement of 8 was considered as the maximum. The aim should be to keep the bulge below 8.

Table 12 shows the bulge of plastic surfaced cartons of milk, cultured buttermilk and orange drink which were frozen immediately after filling and sealing. This table also presents the data on most of the same cartons after thawing by holding 7 days at 41° F.

TABLE 9—The bulge of plastic surfaced cartons[1] of milk during storage

Measurement (inches)	$3\frac{1}{32}$	$3\frac{2}{32}$	$3\frac{3}{32}$	$3\frac{4}{32}$	$3\frac{5}{32}$	$3\frac{6}{32}$	$3\frac{7}{32}$	$3\frac{8}{32}$	$3\frac{9}{32}$	Total	Total average bulge
Bulge (in terms of 1/32 inch above 2 28/32 inch)	5	6	7	8	9	10	11	12	13		
			3 days at 33° F.								
No. of cartons	0	15	32	26	2	0				75	
Percent	0	20.0	42.7	34.7	2.7	0				100.1	7.2
			7 days at 33° F.								
No. of cartons		0	14	35	24	2	0			75	
Percent		0	18.7	46.7	32.0	2.7	0			100.0	8.2
			14 days at 33° F.								
No. of cartons		0	1	23	21	27	3	0		75	
Percent		0	1.3	30.7	28.0	36.0	4.0	0		100.0	9.1
			3 days at 41° F.								
No. of cartons	2	7	16	42	6	2	0			75	
Percent	2.7	9.3	21.3	56.0	8.0	2.7	0			100.0	7.7
			7 days at 41° F.								
No. of cartons		0	4	19	28	21	3	0		75	
Percent		0	5.3	25.3	37.3	28.0	4.0	0		99.9	9.0
			14 days at 41° F.								
No. of cartons				0	2	8	41	20	4	75	
Percent				0	2.7	10.7	54.7	26.7	5.3	100.1	11.2

[1] Lot 1568-2.

TABLE 10—The bulge of plastic surfaced cartons[1] of buttermilk held in storage

Measurement (inches)	$3\frac{1}{32}$	$3\frac{2}{32}$	$3\frac{3}{32}$	$3\frac{4}{32}$	$3\frac{5}{32}$	$3\frac{6}{32}$	$3\frac{7}{32}$	$3\frac{8}{32}$	$3\frac{9}{32}$	$3\frac{10}{32}$	$3\frac{11}{32}$	$3\frac{12}{32}$	$3\frac{13}{32}$	$3\frac{14}{32}$	Total	Total average bulge
Bulge (in terms of 1/32 inch above 2 28/32 inch)	5	6	7	8	9	10	11	12	13	14	15	16	17	18		
					3 days at 33° F.											
No. of cartons	4	36	5	0											45	
Percent	8.9	80.0	11.1	0											100.0	6.0
					7 days at 33° F.											
No. of cartons	1	14	20	16	6	12	6	0							75	
Percent	1.3	18.7	26.7	21.3	8.0	16.0	8.0	0							100.0	8.0
					14 days at 33° F.											
No. of cartons			0	8	34	17	2	3	0	1	1	6	1	2	75	
Percent			0	10.7	45.3	22.7	2.7	4.0	0	1.3	1.3	8.0	1.3	2.7	100.0	10.3
					3 days at 41° F.											
No. of cartons	0	20	19	6	0										45	
Percent	0	44.4	42.2	13.3	0										99.9	6.7
					7 days at 41° F.											
No. of cartons	0	3	4	19	21	12	9	3	2	0					73	
Percent	0	4.1	5.5	26.0	28.8	16.4	12.3	4.1	2.7	0					99.9	9.2
					14 days at 41° F.											
No. of cartons			0	6	13	16	16	21	0						72	
Percent			0	8.3	18.1	22.2	22.2	29.2	0						100.0	10.5

[1]Lot 1568-2.

TABLE 11—The bulge of plastic surfaced cartons[1] of orange drink held in storage

Measurement (inches)	$3\frac{1}{32}$	$3\frac{2}{32}$	$3\frac{3}{32}$	$3\frac{4}{32}$	$3\frac{5}{32}$	$3\frac{6}{32}$	$3\frac{7}{32}$	$3\frac{8}{32}$	Total	Total average bulge
Bulge (in terms of 1/32 inch above 2 28/32 inch)	5	6	7	8	9	10	11	12		
3 days at 33° F.										
No. of cartons	9	44	7	0					60	
Percent	15.0	73.3	11.7	0					100.0	6.0
7 days at 33° F.										
No. of cartons	7	41	12	0					60	
Percent	11.7	68.3	20.0	0					100.0	6.1
14 days at 33° F.										
No. of cartons	0	12	23	7	4	13	1	0	60	
Percent	0	20.0	38.3	11.7	6.7	21.7	1.7	0	100.1	7.8
3 days at 41° F.										
No. of cartons	10	30	15	5	0				60	
Percent	16.7	50.0	25.0	8.3	0				100.0	6.3
7 days at 41° F.										
No. of cartons	1	4	28	20	6	0			59	
Percent	1.7	6.8	47.5	33.9	10.2	0			100.1	7.4
14 days at 41° F.										
No. of cartons	0	2	11	3	17	10	15	2	60	
Percent	0	3.3	18.3	5.0	28.3	16.7	25.0	3.3	99.9	9.3

[1]Lot 1568-2.

TABLE 12—The bulge of plastic surfaced cartons[1] after freezing and thawing

Measurement (inches)	$3\frac{1}{32}$	$3\frac{2}{32}$	$3\frac{3}{32}$	$3\frac{4}{32}$	$3\frac{5}{32}$	$3\frac{6}{32}$	$3\frac{7}{32}$	$3\frac{8}{32}$	$3\frac{9}{32}$	$3\frac{10}{32}$	Total	Total average bulge
Bulge (in terms of 1/32 inch above 2 28/32 inch)	5	6	7	8	9	10	11	12	13	14		
Cartons of milk												
No. of cartons (frozen)	3	39	31	10	7	0					90	
Percent	3.3	43.3	34.4	11.1	7.8	0					99.9	6.8
No. of cartons (7 days at 41° F. after thawing)	0	2	17	34	29	2	0				84	
Percent	0	2.4	20.2	40.5	34.5	2.4	0				100.0	9.1
Cartons of cultured buttermilk												
No. of cartons (frozen)			0	8	5	13	8	13	5	5	57	
Percent			0	14.0	8.8	22.0	14.0	22.0	8.8	8.8	100.0	10.8
No. of cartons (7 days at 41° F. after thawing)					0	8	12	25	8	0	53	
Percent					0	15.1	22.7	47.2	15.1	0	100.1	11.6
Cartons of orange drink												
No. of cartons (frozen)	0	2	31	12	0						45	
Percent	0	4.4	68.9	26.7	0						100.0	7.2
No. of cartons (7 days at 41° F. after thawing)				0	16	11	7	4	7	0	45	
Percent				0	35.6	24.4	15.6	8.9	15.6	0	100.1	10.0

[1] Lot 1568-2.

The cartons of milk, when frozen solid, had a range in bulge from 5 to 9 with a weighted average of 6.8. The range was 6 to 10 on the cartons after melting the contents by holding 7 days at 41° F. None of these cartons leaked as a result of freezing and thawing.

While frozen, the cartons of cultured buttermilk had a weighted average bulge of 10.8. The range was 8 to 14. After defrosting 7 days at 41° F., the range was 10 to 13 with an average being 11.6. One carton out of 60 developed a rupture of the side-seam during freezing. Six more acquired leaks during the 7 days of storage.

The cartons of frozen orange drink showed an average bulge of 7.2 with a range of 6 to 8. After thawing and a storage period of 7 days at 41° F., the average bulge increased to 10.0 with a range from 9 to 13. None of the 45 quart cartons showed leaks from the effects of freezing orange drink.

The freezing of milk, orange drink and cultured buttermilk caused some side-expansion of the cartons. The increase was in the following order: milk, orange drink and cultured buttermilk. Undoubtedly the freezing action weakened the carton, causing pronounced bulging during the subsequent 7-day hold at 41° F. The cartons of cultured buttermilk, with acidities ranging from 0.75 to 0.80 percent, tended to show greater bulge than milk or orange drink.

The results of the Drop Test are presented in Table 13. After subjection to the Drop Test, one leak appeared from 100 cartons tested on 0-day. Twenty-one leaks appeared from a second group of 100 cartons tested after being held for 3 days. The 3-day hold allowed water to

TABLE 13—Leak development in cartons subjected to the Drop Test

Cartons	Plastic surfaced[1]		Control (wax coated)	
Held (days)	0	3	0	3
Location of leaks	Number of leaks			
Chipped edge of waxed carton	-	-	0	0
Bottom board	0	0	0	0
Front left bottom corner	0	0	1	0
Front right bottom corner	0	7	1	0
Back right bottom corner	1	2	0	5
Back left bottom corner	0	0	2	0
Bottom side seam	0	0	0	0
Front bottom butt joint	0	9[2]	0	0
Bottom center seal	0	0	0	0
Vertical side seam	0	0	0	0
Shoulder side seam	0	0	0	0
Top side seam	0	3	0	0
Top pour side	0	0	0	0
Total leaks in cartons	1	21	4	5
Total cartons with leaks	1	21	4	5
Total cartons tested	100	100	100	100

[1]Lot 1568-2.
[2]Few leaked on third day before being drop-tested.

soften the board. A few of the 21 leaks actually occurred before the second set was tested, and 15 of the 21 appeared to have been caused by inadequate glue along the side seam.

The Drop Test was a convenient means of checking the ability of the cartons to withstand a mild jolt. Recent additional trials, using cartons made from paperboard Lot 56 and the modified Q machine for filling and sealing, indicated that the plastic surfaced cartons were able to withstand this test with little visible damage. They were comparable to the wax coated cartons in this respect.

The standard quart carton had a distance of 2 28/32 inches between the two side panels. Immediately after filling, the cartons ranged from 3 1/32 to 3 5/32 inches. The arithmetic average of 120 cartons was 3 5/64 inches, or an increase of 13/64 inch.

The severity of the Incline-Impact Test is shown by the data presented in Table 14. The results indicate that plastic surfaced cartons were much less likely to develop leaks after the 0-day hold than after the 3-day hold. Seventeen leaks occurred in cartons at 0-day compared to a total of 86 leaks in cartons after 3 days. Results of the control (wax coated) cartons showed 69 leaks at 0-day and 71 after 3-day holds, indicating little difference at the 3-day hold period.

Despite the snug fit of plastic and wax coated cartons in aluminum cases, the total number of leaks (0- and 3-day) was 138 compared to 105 from cartons in the loose fitting wire cases. Generally, from the Incline-Impact Test, the plastic surfaced cartons developed

TABLE 14—Leak development in cartons subjected to Incline-Impact Test

Carton	Control (wax coated)				Plastic surfaced[3]			
Days held	0	3	0	3	0	3	0	3
Case description[1]	Wire	Wire	Al.	Al.	Wire	Wire	Al.	Al.
Location of leaks	Number of leaks				Number of leaks			
Bottom board	0	0	0	0	1	0	0	0
Case damage	6	0	0	0	0	0	0	0
Front[2] left bottom cor.	0	0	0	0	1	2	2	3
Front right bottom cor.	0	0	0	0	2	10	2	15
Back right bottom cor.	0	0	0	0	1	3	2	3
Back left bottom cor.	0	0	1	1	0	0	1	0
Bottom side seam	0	0	0	0	0	1	0	3
Front bottom butt joint	0	0	0	0	1	4	0	2
Bottom center seal	0	0	0	0	0	0	0	1
Vertical side seam	0	0	0	0	0	3	0	7
Shoulder side seam	0	0	0	0	0	0	0	0
Top side seam	0	0	0	2	3	8	1	6
Top pour side	0	0	0	2	0	5	0	3
Top seal open	0	0	1	0	0	0	0	7
Top fold of waxed	15	16	12	25	-	-	-	-
Top wire pulled	12	11	22	14	-	-	-	-
Total leaks in cartons	33	27	36	44	9	36	8	50
Total cartons with leaks	30	27	36	44	9	23	8	38
Total cartons tested	100	100	100	100	100	100	100	100

[1]Bottom of cartons in wire cases were dry and in aluminum were damp.
[2]Front is right of pour side.
[3]Lot 1568-2.

the most leaks in the bottom and the wax coated cartons developed the largest percentage of leaks in the top.

The Incline-Impact Test is more severe than the handling that normally occurs in a plant and therefore is too rigorous to be of much practical value for most purposes.

The Combination Test proved to be rough on milk cartons as demonstrated by the results given in Table 15. Three hundred eighteen individual leaks developed in 400 plastic surfaced cartons while the same treatment caused 66 leaks in 400 wax coated cartons. The plastic surfaced cartons with a snug fit in aluminum cases had approximately one-third as many leaks as occurred in the wire cases. Most of the damage which caused leaks took place in the bottom and bottom corners of the cartons. Control cartons (wax coated) had less damage with most occurring also in the bottom areas. Cartons in the wire cases were most often damaged. The loose fit of cartons in wire cases probably allowed the damage to occur.

The test is more severe than handling in common plant practice. However, it demonstrated that compactness of cartons in the cases could prevent unnecessary damage which caused leakage in the bottom areas of the cartons.

The results of the Hauling Test applied to plastic surfaced cartons made from board lots 3, 4, 5, 10 and 20 are presented in Table 16. None of these lots showed satisfactory results. The range of cartons with leaks varied from 100 percent in lot 20, to 30 percent in lot 10. Seventy-four and five-tenths percent or 566 of the 760 cartons developed

TABLE 15—Leak development in cartons subjected to combination test

Carton	Control (wax coated)				Plastic surfaced			
Days held	0	3	0	3	0	3	0	3
Case description	Wire	Wire	Al.	Al.	Wire	Wire	Al.	Al.
Location of leaks	Number of leaks				Number of leaks			
Bottom board	2	0	0	0	20	27	2	1
Case damage	27	19	3	6	18	0	0	0
Front left bottom cor.	0	0	0	0	16	16	7	11
Front right bottom cor.	0	0	1	0	12	24	8	19
Back right bottom cor.	0	0	0	0	16	32	10	18
Back left bottom cor.	0	0	1	0	8	8	3	4
Bottom side seam	0	0	0	0	16	11	0	3
Front bottom butt joint	0	0	1	0	1	3	1	1
Bottom center seal	1	0	0	0	2	0	0	0
Vertical side seam	0	0	0	0	0	0	0	0
Shoulder side seam	0	0	0	0	0	0	0	0
Top side seam	0	0	0	0	0	0	0	0
Top pour side	0	0	0	0	0	0	0	0
Top seal open	0	0	0	0	0	0	0	0
Top fold of waxed	2	3	0	0	-	-	-	-
Top wire pulled	0	0	0	0	-	-	-	-
Total leaks in cartons	32	22	6	6	109	121	31	57
Total cartons	100	100	100	100	100	100	100	100

[1]Lot 1568-2.

TABLE 16—Leak development in plastic cartons subjected to Hauling Test

Location of leaks	Plastic surfaced cartons: Walled Lake die[1] lot 3, 3 trips, Al.	Wire	Philadelphia die[2] lot 4, 3 trips, Al.	Wire	6 trips, Al.	Wire	Philadelphia die[2] lot 5, 3 trips, Al.	Wire	6 trips, Al.	Wire	Philadelphia die[2] lot 10, 3 trips, Al.	Wire	Remodeled Walled Lake die[1] lot 20, 3 trips, Al.	Wire	Total	Control cartons (wax coated): Stock cartons, 3 trips, Al.	Wire	6 trips, Al.	Wire	Total
Bottom board	0	1	0	1	0	1	0	0	0	0	0	0	0	0	6	0	0	0	0	0
Bottom front left corner	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bottom front right corner	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bottom back right corner	0	0	2	0	3	2	0	1	1	1	0	0	0	0	10	0	0	0	0	0
Bottom back left corner	0	0	0	0	2	3	0	0	1	0	0	0	0	0	6	0	0	0	0	0
Bottom at side seam	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bottom front side butt joint	0	0	0	6	6	6	24	18	7	5	8	5	0	0	85	0	0	0	0	0
Bottom center seal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Side seam	0	0	1	0	2	2	1	0	0	1	0	1	0	0	8	0	0	0	0	0
Side seam at shoulder	64	45	21	25	22	26	48	49	26	25	1	3	12	6	373	0	0	0	0	0
Top side seam, upper 1/4 inch	73	67	11	16	12	25	53	62	12	9	6	7	19	20	392	0	0	0	0	0
Top pour side seal	10	12	3	1	3	2	5	10	2	2	4	3	20	11	88	0	0	0	0	0
Top seal open	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Top fold (wax cartons only)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	0	0	1
Total leaks in cartons	147	125	38	49	50	67	131	140	49	46	19	19	51	37	968	1	0	0	0	1
Total cartons with leaks	73	69	26	32	31	35	75	89	32	34	18	12	20	20	566	1	0	0	0	1
Percent of cartons with leaks	90	86	65	80	77	87	62	74	80	85	45	30	100	100	70.4	1	0	0	0	0.3
Total cartons	80	80	40	40	40	40	120	120	40	40	40	40	20	20	760	100	100	80	80	360

[1]The Walled Lake and the remodeled Walled Lake dies cut cartons of a dimension which closed the channel at the butt joint.

[2]The Philadelphia die cut cartons of a dimension which did not close the channel at the butt joint.

one or more leaks during hauling. Only one wax coated carton out of 360 or 0.3 percent had a leak after the same hauling conditions.

Nearly all of the leaks were of the slow seepage type. Three hundred ninety-two leaks, the largest number occurring in an area, were found at the top 1/4 inch of the side-seam, 373 were in the side-seam at the shoulder, 88 in the top-seal on the pouring side and 85 in the bottom at the channel formed by the butt joint.

When the pressure pads of the machine were equipped with special pins properly located, the extra pressure seemed to close the seepage channel in the butt joint. Data shown in Table 16 indicate a significant difference in the die that was used for cutting the cartons. Other factors closely related to forming the bottoms may have been of influence. Cartons cut by the die in the Walled Lake plant and by a successive model were practically free from seepage at the bottom.

Seepage from the top was frequently caused by a horizontal wicking action along the raw edges adjacent to the area forming the top-seal. Splashing action of the contents in the carton during transportation increased the seepage.

Machine formation of the shoulder of the cartons seemed to weaken the side-seam seal in the immediate area, thus frequently allowing seepage to occur during the activity associated with normal truck travel.

The Hauling Test proved useful in locating weaknesses of the plastic surfaced carton in the bottom, top and side-seam areas. Test results suggested the need of the investigation of methods which would prevent leakage.

A preliminary trial using one case of cartons cooled with crushed ice showed much damage to the top-seal during retail route deliveries. Several carton tops became unsealed completely. Subsequent trials using 400 cartons cooled by ice had no top-seal failures. Water from melting ice appeared to have penetrated the top raw edge to a depth of 1/8 inch on some cartons. The moisture caused a slight softness, but the seal remained unaffected.

Cartons in wire cases had more nicks and dents from jagged pieces of ice than those in aluminum cases. However none of the dents developed into leaks.

The cause of the detrimental effect of the moisture on the top-seal of the cartons in the preliminary trial was not determined. The most probable causes were inferior heat-sealing by the equipment or unsatisfactory sealing material of the carton.

3. Customer Acceptance of the Plastic Surfaced Cartons

Procedure

Retail route customers who had been receiving milk in paper cartons were informed by a letter (Appendix 1) that half of their homogenized milk order would be supplied in the plastic surfaced cartons and the remainder in the usual wax coated cartons. The letter also said that a questionnaire would be sent to them to obtain their preference in carton coatings.

These customers were staff members and married students at Michigan State University who were living in apartments on the campus.

Cooperation was excellent as everyone was willing to try the plastic surfaced cartons.

One month later a questionnaire (Appendices 2 and 3) was prepared and given to each customer with the promise of a free quart of milk when the questionnaire was returned. After the survey a note of appreciation (Appendix 4) was given to each participating customer.

Results and Discussion

A total of 464 retail route customers received the trial cartons. Of these, 415 questionnaires (89.44 percent) were completed and returned by mail or through the driver salesman. Table 17 presents a summary of the results.

TABLE 17—Summary of customers' preference between plastic surfaced and wax coated milk cartons

	Customers' preference			
Factor	Plastic[1]	Wax	None	Failed to choose
Appearance	387	2	26	0
Feel in your hands	393	6	16	0
On table	353	1	56	5
In refrigerator	369	3	41	2
Ease in opening and closing	364	19	30	2
Pouring	310	28	70	7
Apparent tendency to bulge	191	150	68	6
Leaking	200	124	76	15
Uses for empty containers	181	5	212	17

[1]Lot 1568-2.

Ninety-three and three-tenths percent of the customers who were questioned preferred the appearance of the plastic surfaced cartons and 0.5 percent the wax coated cartons. The other 6.2 percent had no preferance. A few of the favorable comments for plastic were "sharper", "cleaner looking", and "brighter in appearance". These comments resulted because the wax tended to dull the colored design on the cartons.

The "feel" of the plastic surfaced cartons was preferred by 94.7 percent of the participants. They explained their choice by saying that the cartons with plastic were "smoother and had no residue".

For table use 85.1 percent preferred plastic to wax coatings. According to remarks on the questionnaires, freedom from wax soiling influenced the preference for the plastic surfaced cartons.

A higher percentage (88.9 percent) chose plastic in answer to the question referring to refrigerator storage. The same reason, "no wax residue on the refrigerator shelves", was expressed.

The new closure design of the plastic surfaced cartons which eliminated overlapping proved desirable. Eighty-seven and seven-tenths percent preferred the new closure. The most common comment was that these cartons were easier to open. Adverse comments were that reclosing after use was less effective. The overlapping top of the waxed cartons aided in maintaining a closed top after use.

Seventy-four and seven-tenths percent indicated their approval of the plastic pouring lip but gave no reason for their choice. The investigators believe that the lack of comments about choice suggests that customers favoring plastic had been influenced by other factors as appearance. Limited trials under controlled conditions indicated that the plastic and wax cartons should be judged alike in pouring.

The choice for "apparent tendency to bulge" was 46.0 percent in favor of plastic compared to 36.1 percent for wax cartons, with the remainder expressing no choice, or abstaining. Improved wording which would have read "least bulging" could have brought more response, as a few participants considered the question ambiguous. Since no remarks were included with the replies, the investigators question the motives for the choice of plastic surfaced cartons.

Two hundred customers (or 48.2 percent of those in the survey) favored plastic surfaced cartons on the matter of leakage, 91 had no choice or abstained which left 124 who selected the wax coated cartons. Reasons were not given but according to the comments and personal interviews by the salesmen very few customers received a leaking carton of milk with either the wax or plastic surface during the test period. Leaking cartons of both types were never knowingly delivered to a customer. This practice is in accordance with usual commercial procedure. Consequently, the "no choice" percentage should have been very high.

Preferences for the "uses for empty containers" showed: 43.6 percent preferred plastic, 1.2 percent preferred wax, 51.1 percent had no preference and 4.1 percent abstained. Among the remarks of those choosing empty plastic surfaced cartons were: "safer for the children to play with" and "can use for food storage in refrigerator or freezer without wax contamination".

A summary of customer remarks on the questionnaires is presented in Appendix 5.

4. Pure-Pak Machine Operation with Plastic Surfaced Cartons

Procedure

A junior model machine was electrically re-engineered and rebuilt to provide sealing heat. The practical features of the machine for plastic cartons which differed from the machine for wax cartons were the hot water immersion compartment, the fold and bottom-seal and top-seal facilities. The top-seal of the carton was without an overlap.

The specific purpose of the machine was to shape the flat blanks into cartons, form and seal the bottoms, sanitize the cartons by immersion in water at 190°-194° F., fill the cartons and form and seal the tops. The process required steam, vacuum, compressed air, alternating current (115 volts), soft water and refrigerated water.

Generally, the machine was operated 3 days each week for the duration of the project. During each run 200 to 2500 quarts of homogenized whole milk were packaged. The usual number of cartons was approximately 800. Cultured buttermilk and orange drink were packaged by the machine only when they were needed for trials.

Water in the immersion compartment was heated with steam at 15 psi. The overflow water was regulated to a very small stream (4 to 6 pounds per minute).

The influence of machine-induced operational heat upon the contents of the cartons was observed by two series of trials. Quart samples of water were held in refrigerated rooms until equilibrium was reached at 40° F. for one group, 46° F. for the second group and 50° F. for a third group.

In the first series, the effect of the top-sealing was studied. The machine formed the cartons at room temperature. Cartons were removed, placed on the conveyor ahead of the top-sealer and filled immediately with a quart of water from one of the three temperature groups. Soon after the sealing step the cartons were inverted three times to insure uniform temperature and were opened. The temperature of the water was recorded to the nearest 0.1° F. The temperature increase was attributed to electrical heat from the sealer.

In the second test the cartons were processed in the regular manner except the cooling step was omitted. A quart of cold water from one of the three temperature groups was poured into each carton at the filling stage. Principal sources of heat during the operation were: (1) the electric bottom-seal, (2) the hot water immersion and (3) the electric top-seal. The temperature of each quart of cool water was taken just before it was poured into a trial carton prior to sealing. After top-sealing, the cartons were discharged onto the turntable. Immediately, each carton was inverted three times to assure uniform temperature of the contents and then opened. The temperature was taken with a thermometer that read to the nearest 0.1° F. The increase in temperature of the contents of the carton was attributed to the heat-producing steps during machine operation.

Results and Discussion

During the 18-month trial period many problems became evident in obtaining satisfactory machine operation and satisfactory sealing of the plastic surfaced cartons. These problems were gradually solved.

The machine was equipped with stops which controlled the uniformity of the distance that the cartons were pushed onto the mandrels. The design of the stops was altered to reduce or eliminate "spring back" which caused an incorrect position of the cartons in which the bottoms could not be folded precisely.

A change in electric heaters was made to distribute the heat more evenly and improve the seal on the bottoms of the cartons. The heater was engineered to move away from the cartons positioned on mandrels when the machine was not in operation. This prevented charring of cartons.

A modified tucking shoe proved to be beneficial in forming a more leak-proof seal in one step of the bottom-fold. Protruding pins 1/8 inch in diameter were useful in spot pressing the bottom to assure a better seal in the areas most susceptible to seepage along the channel formed by the butt joint. This resulted in a noticeable reduction of cartons with seepage.

After a few days of operation it became apparent that the immersion water for sanitation required attention. The temperature ranged from 185° F. to 190° F. or slightly higher. Addition of a preheater helped maintain a fairly constant temperature of the immersion water. The tests on thermoduric bacteria proved the necessity of maintaining the water temperature at 190° F. or higher.

The use of soft water was necessary to prevent excessive scale formation and to minimize accumulation of sediment in the immersion water. Other precautions were to install a filter for continuous filtering of immersion water and a rinse for preflushing the cartons during machine operation. Each day good maintenance required draining of the immersion water and cleaning of the immersion mechanisms by use of an acid detergent followed by a rinse.

Difficulty was encountered in properly sealing the top of the cartons. An improved heater which replaced the original gave more effective heat-sealing results. The replacement heat-sealer, which would retract from the cartons whenever the machine was stopped, proved satisfactory for preventing carton damage by excessive heat. However top-leaks and seepage were not entirely prevented with the improved sealer.

Even perfect machine operation cannot compensate for: lack of precision in die-cutting of the dimensions of the cartons, inferior heat-sealing films of polyethylene, sloppy application of glue on the side-seam, misplaced tabs on the pouring lip, or presence of nonadhesionable films on pouring lips. It was not always possible to pinpoint the cause of leakage as the result of faulty machine operation, carton deficiency or both.

The heat from the top-sealing operation of plastic surfaced quart cartons caused the contents with an initial temperature of approximately 40° F. to increase an average of 1.48° F. during the 20 trials. The range was 0.9° F. to 2.0° F. for this group. Data are shown in Table 18. The group with an initial temperature of approximately 45° F. had an increase of 1.1° to 1.6° and an average of 1.35° F. The third group of 20 cartons had an initial temperature of

TABLE 18—Temperature increase of quarts of water during the top-sealing operation

Trial number	Initial degrees	After sealing	° F. Diff.	Initial degrees	After sealing	° F. Diff.	Initial degrees	After sealing	° F. Diff.
1	39.0	40.5	1.5	45.2	46.5	1.3	49.0	50.5	1.5
2	39.0	40.5	1.5	45.4	46.9	1.5	49.0	50.1	1.1
3	39.0	40.5	1.5	45.4	46.5	1.1	49.0	50.5	1.5
4	39.0	40.5	1.5	45.5	47.1	1.6	49.1	50.5	1.4
5	39.2	41.0	1.8	45.5	47.0	1.5	49.4	50.8	1.4
6	39.2	40.6	1.4	45.5	46.6	1.1	49.4	50.5	1.1
7	39.5	41.5	2.0	45.5	46.8	1.3	49.5	50.5	1.0
8	39.5	41.2	1.7	45.5	47.0	1.5	49.5	51.0	1.5
9	39.5	41.0	1.5	45.6	47.0	1.4	49.5	50.6	1.1
10	39.6	41.2	1.6	45.7	46.9	1.2	49.5	51.1	1.6
11	39.8	41.0	1.2	45.7	47.0	1.3	49.6	51.0	1.4
12	40.0	41.5	1.5	45.7	47.0	1.3	49.6	51.0	1.4
13	40.0	41.3	1.3	45.8	47.0	1.2	49.6	51.0	1.4
14	40.0	41.5	1.5	45.9	47.5	1.6	49.7	51.1	1.4
15	40.0	41.5	1.5	46.0	47.2	1.2	49.9	51.1	1.2
16	40.1	41.8	1.7	46.0	47.5	1.5	50.0	51.1	1.1
17	41.5	43.0	1.5	46.2	47.5	1.3	50.2	51.4	1.2
18	41.5	42.5	1.0	46.5	47.9	1.4	50.5	51.6	1.1
19	41.6	42.5	0.9	46.7	47.9	1.2	50.5	51.6	1.1
20	42.0	43.5	1.5	47.0	48.5	1.5	51.5	52.8	1.3
°F. Average	39.95	41.43	1.48	45.82	47.17	1.35	49.70	50.99	1.29

approximately 50° F. The increase varied from 1.0° to 1.6° F. and averaged 1.29° F.

The increase in the temperature of the contents of the cartons, attributable to the sealing operation, did not exceed 2.0° F. and was usually less with the quart volume. This was not considered to be serious although any increase in temperature is undesirable.

Table 19 presents data on the total temperature increase of quart containers during the regular machine operation. The cartons with an initial temperature of approximately 40° F. showed an average increase of 2.44° F. The range was 2.0° F. to 2.9° F. The range was 2.0° to 3.0° F. with an average of 2.38° F. for the 20 cartons with an initial temperature of approximately 45° F. The third group with an initial temperature of approximately 50° F. increased an average of 2.07° F. with the range from 1.7° to 2.5° F.

The total heat effect from machine operation should be taken into consideration when thought is given to the temperature desired for the packaged milk. The milk should be cooled 2° to 3° F. colder to compensate for heat transfer into the plastic surfaced cartons during packaging.

The increase of 2° F. and more in quart containers suggests that heat transfer into one-half-pint containers might be serious. After the heating elements are standardized for normal operation of the machine, one-half-pint cartons should be checked and temperature difference recorded in various locations within the cartons, especially at the top.

TABLE 19--Temperature increase of quarts of water during machine operation

Trial number	Temperature in degrees F.								
	Initial	After packaging	Diff.	Initial	After packaging	Diff.	Initial	After packaging	Diff.
1	40.2	43.0	2.8	43.5	46.0	2.5	50.5	53.0	2.5
2	39.5	42.0	2.5	43.5	45.8	2.3	49.5	51.7	2.2
3	40.0	42.2	2.2	43.5	46.5	3.0	50.4	52.2	1.8
4	41.1	43.6	2.5	43.5	46.0	2.5	50.5	52.5	2.0
5	39.0	41.3	2.3	44.2	47.0	2.8	50.6	52.7	2.1
6	40.0	42.6	2.6	45.0	47.0	2.0	50.5	52.5	2.0
7	37.7	40.2	2.5	45.5	48.0	2.5	51.1	53.5	2.4
8	39.8	42.0	2.2	44.8	47.2	2.4	50.6	52.7	2.1
9	37.2	39.7	2.5	45.2	47.5	2.3	49.6	51.5	1.9
10	37.3	40.2	2.9	45.5	48.0	2.5	50.5	52.6	2.1
11	38.5	40.5	2.0	46.0	48.1	2.1	48.4	50.5	2.1
12	38.0	40.5	2.5	46.0	48.5	2.5	49.0	51.1	2.1
13	40.5	43.0	2.5	46.0	48.0	2.0	49.0	51.0	2.0
14	39.5	42.0	2.5	45.5	48.0	2.5	49.0	51.3	2.3
15	41.9	44.0	2.1	46.0	48.0	2.0	49.4	51.3	1.9
16	41.2	43.5	2.3	47.0	49.0	2.0	49.0	51.0	2.0
17	43.4	45.5	2.1	46.0	48.5	2.5	49.0	51.1	2.1
18	42.3	44.8	2.5	46.0	48.5	2.5	50.6	52.6	2.0
19	42.2	45.0	2.8	46.5	49.0	2.5	51.0	52.7	1.7
20	44.5	47.0	2.5	47.0	49.2	2.2	49.5	51.5	2.0
°F. Average	40.19	42.63	2.44	45.31	47.69	2.38	49.89	51.95	2.07

Additional problems may occur with long operations and with the use of cartons in sizes other than quarts. In general there were no problems which could not be worked out satisfactorily for larger operations under commercial conditions.

5. Sanitary Condition of Plastic Surfaced Milk Cartons

Milk cartons must be in good sanitary condition and sufficiently durable to protect the milk during handling, holding and distribution. The modified Pure-Pak machine which forms and fills these cartons had a compartment in which the cartons were submerged in water at approximately 190° F. for 8 seconds.

The purpose of this study was to determine the sanitary condition of the plastic surfaced milk cartons with and without immersion in the hot water before filling. Investigators were also interested in the bacteriological condition of specifically contaminated cartons and immersion water.

Procedure

Preliminary testing. In preliminary work four trials were performed in which cartons were sanitized by submersion in hot water and then were removed from the machine immediately after passing through the hot water tank. Twenty ml. of sterile buffered rinse solution were added to each carton. The tops were closed and covered with aluminum foil held in place with clamps. Total and coliform counts were performed on rinses from the cartons according to Standard Methods (1953) using 10 ml. portions divided among three plates. Also several trials were made in which skimmilk was packaged and similar counts were performed.

Testing the commercial operation. After procedures for commercial operation were established, about 1,000 quarts of homogenized whole milk were packaged each operating day. Total and coliform counts were completed before the milk was sold. One empty carton and one carton of milk were removed from the processing line during the fore, middle and latter periods of packaging. Milk samples and rinse solutions from the empty cartons were plated as later described. Frequently during carton forming operations, samples of water were removed from the hot water tank and plated to determine the number of total and thermoduric organisms present. In addition to counts made by Standard Methods (1953), some samples of milk were plated with trypticase soy agar and incubated at 89.6° F.

Bacteria counts were made on control cartons formed in the machine and processed as indicated below:

(a) Cartons not immersed in water (subsequently referred to as "dry formed" cartons).

(b) Cartons which were removed from the machine immediately after passing through the hot water.

(c) Cartons which were passed through the hot water and sealed.

Bacteria counts were also performed on samples of hot water taken from the rinse compartment after the control cartons had passed through.

Testing contaminated cartons and immersion water. In an attempt to determine the sanitary efficiency of the machine, cartons and immersion waters were contaminated with five different organisms commonly found in a dairy plant. The organisms used were *Micrococcus varians* (M.S. 102), *Microbacterium lacticum*, *Lactobacillus thermophilus*, *Escherichia coli* and *Pseudomonas fragi*.

Lactobacillus thermophilus was propagated in nutrient broth containing 0.5 percent proteose peptone and was plated in tomato juice agar. The incubation temperature was 127° to 131° F. The other four organisms were propagated in nutrient broth at 89.6° F.* Ten ml. of each culture was added to 90 ml. of sterile buffered water. After mixing for 1 minute in a dilution bottle, the contents were then uniformly blended with 5.9 liters of sterile buffered water. The flat, unformed cartons were contaminated by submerging 10 at a time for 30 seconds in the 6 liters of contaminated buffered water. The water was poured into the hot water rinse compartment of the machine after the contaminated cartons were processed through the machine.

Bacteria counts were made on rinses from contaminated cartons formed and sealed in the machine and processed as indicated below:

(a) Cartons which were conveyed through the empty hot water compartment receiving no rinse.

(b) Cartons which were conveyed through lukewarm rinse water at 90° to 100° F.

---

*The organism, tentatively classified as *Pseudomonas fragi* and used in this work, grew satisfactorily at 89.6° F.

Bacteria counts were also performed on:

(a) Inoculated buffered water used to contaminate the cartons;

(b) Hot water from the rinse compartment after the contaminated cartons had passed through;

(c) Hot water from the rinse compartment after the inoculated buffered water had been added, and

(d) Cartons which had not received the contaminating treatment and were formed, passed through the contaminated hot water and sealed in the machine.

Sanitary condition of cartons and the hot water tank. Total bacteria counts were performed on representative noncontaminated cartons which were formed and:

(a) Passed through hot water at 190° F. and removed before being sealed.

(b) Passed through the empty hot water compartment (received no rinse) and removed before being sealed.

Immediately after the cartons indicated under (a) immediately above were processed, samples of hot water were removed from the tank and plated to determine whether thermoduric organisms were present.

Sanitary condition of "dry formed" cartons affected by cleaning methods. In order to determine the relationship between the sanitary condition of the mandrels which were given a cold water spray and the total bacteria count of "dry formed" cartons, three methods of cleaning were used on the mandrels and the hub. The first method employed a hot water rinse once a week on the mandrels and the hub. The second method employed a daily hot water rinse of the mandrels and hub. The third method involved a hot water rinse, a chlorine solution rinse and another hot water rinse. After each of the three cleaning procedures, the mandrels were occasionally coated sparingly with a silicone compound.

Contaminated ice. Ice cubes containing *Escherichia coli* were prepared by adding 30 ml. of nutrient broth culture of *E. coli* to water containing 5 percent glycerin, 1 percent sucrose and 1 percent nonfat dry milk solids. After 200 pounds of the solution was frozen into cubes, it was stored at -8° F. Coliform counts were performed on the inoculated solution prior to freezing and on a composite sample of the melted ice.

A randomly selected case lot of milk (20 quarts) in plastic surfaced cartons was taken during normal operation and was stored overnight at 34° to 36° F. Controls were removed from the conveyor line immediately before and after filling each random case.

The next morning the case of milk being used in the trial was covered to a depth of 2 to 3 inches with contaminated ice cubes, held in place by paperboard supports. The cartons in the case were then transported for 4 to 5 hours over about 10 miles of retail routes. The samples were then replaced in storage until early afternoon when the slush ice was removed. The cartons were rinsed with tap water, wiped dry and taken to the laboratory along with the control samples which had not been iced. The slush ice was promptly examined for coliform population.

The procedure was repeated eight times using plastic surfaced cartons and two times using wax coated cartons.

Coliform counts on milk from non-iced and iced cartons. The cartons were opened in the normal manner. Two samples were removed from each carton. First, 10 ml. of milk was removed carefully with a pipette without contacting the pouring spout; then 50 ml. of milk was poured from each carton into a sterile flask.

Coliform counts were performed according to Standard Methods (1953) by using 10 ml. of milk. The milk was divided into three plates which were covered with violet red bile agar. The plates were incubated at 95° F.

Results and Discussion

Sanitary condition of cartons. The coliform counts on eight samples of skimmilk from plastic surfaced cartons were all less than 0.1 per ml. and total bacteria counts varied from 200 to 800 organisms per ml. Coliform counts from eight empty cartons were all less than 1.0 per carton. These results suggested that there was little, if any, contamination from the cartons.

After cartons passed through the immersion water, the cartons were tipped by the machine to permit drainage. Some water absorbed into the inside raw edges and visible droplets were apparent on the inside surfaces. By holding and shaking the cartons against a horizontal surface, most of the water was collected in a bottom corner of the carton. A maximum of 0.7 ml. of water was recovered from any one carton. The average recovered from 20 cartons was 0.46 ml. This is a little less than remains in quart glass bottles.

The arithmetic average of total coliform counts on 71 samples of milk in plastic surfaced cartons was 1,200 organisms per ml. Total counts on 54 of the 71 samples ranged from 240 to 1,000 per ml.; 14 varied from 1,100 to 1,800 per ml., and 3 ranged from 8,500 to 11,000 per ml.

Twenty-one of the 71 samples of milk were plated in both standard plate count agar and trypticase soy agar and were incubated at 89.6° F. The arithmetic averages of total counts were 840 per ml. on plate count agar and 1,000 per ml. on trypticase soy agar.

The 71 milk samples contained an arithmetic average of 0.6 coliform per ml. Forty-nine of the 71 milk samples contained less than 0.1 coliform per ml. and 16 contained 1.0 per ml. The coliform count of 6 samples ranged from 2 to 15 per ml. Rinses from 71 empty cartons all showed less than 1.0 coliform organism per carton.

The arithmetic average of total counts on rinses from 39 empty cartons immersed in hot water was 2.0 organisms per carton. Thirty-five of the 39 cartons contained less than 1.0 organism per carton, and 4 varied from 10 to 30 organisms per carton. All cartons contained less than 0.1 organism per ml. of milk.

Control cartons not submerged in contaminated water. Data in Table 20 show the arithmetic average of total counts on rinses from

TABLE 20—Standard plate counts obtained on noncontaminated plastic surfaced cartons[1] and hot water

	Five trials with the bacteria count of 8 cartons averaged in each trial				
	Trial no.				
	I	II	III	IV	V
40 cartons not immersed in water ("dry formed" cartons)					
a. Average count per carton	44	4,000	1,400	85	5.4
b. Range of counts per carton	<1.0 to 420	<1.0 to 80,000	<1.0 to 23,000	<1.0 to TNTC	<1.0 to 22
c. Number of cartons containing one or more organism(s) per ml. of capacity	0	3	3	2	0
40 cartons removed from the machine immediately after passing through immersion water at 190° F.					
a. Average count per carton	1.8	2.2	5.0	<1.0	3.3
b. Range of counts per carton	<1.0 to 6.0	<1.0 to 8.0	<1.0 to 200	<1.0	<1.0 to 16
c. Number of cartons containing one or more organism(s) per ml. of capacity	0	0	0	0	0
40 cartons passed through immersion water at 190° F. and continued through the sealing mechanism					
a. Average count per carton	5.1	3.6	<1.0	<1.0	2.6
b. Range of counts per carton	<1.0 to 78	<1.0 to 20	<1.0 to 2.0	<1.0	<1.0 to 8.0
c. Number of cartons containing one or more organism(s) per ml. of capacity	0	0	0	0	0
Hot immersion water before any cartons were passed through					
a. Average count	0.2	0.2	<0.1	<0.1	0.8
b. Range of counts	<0.1 to 0.4	<0.1 to 0.5	<0.1 to 2.0	<0.1	<0.1 to 3.2

[1] Lot 1568-2.

groups of 40 cartons which were formed on the machine. The cartons were conveyed through the empty hot water compartment (not immersed). The counts ranged from 5.4 to 4,000 organisms per carton. High counts were recorded for some individual cartons which could have been contaminated during the forming process on the mandrels. Also, some contamination could have occurred while the cartons were being cut, printed and glued. The fact must be emphasized that the cartons were essentially "hand made" and handled individually at least eight times. In normal production, cartons are "bunch handled" by hand only about three times and are handled in ways to minimize contamination.

The arithmetic averages of total counts on groups of 40 control cartons which were removed from the machine immediately after passing through the hot water varied from less than 1.0 to 5 organisms per carton (Table 20).

The arithmetic averages of total counts on groups of 40 control cartons which were passed through the hot water and sealed in the machine varied from less than 1.0 to 5.1 organisms per carton (Table 20).

Total counts on samples of hot water varied from less than 0.1 to 3.2 organisms per ml. (Table 20). Intermittently, thermoduric populations were determined in water taken from the hot water compartment and varied from less than 0.1 to 12 per ml.

<u>Contaminated cartons and immersion water</u>. The contaminated water in which the flat cartons were submerged contained from 3,000 to

7,500,000 organisms per ml. (Table 21). The groups of 40 contaminated cartons which were passed through the empty compartment had total arithmetic averages of 400 to 59,000 per carton. The data also show that the arithmetic averages of total counts of groups of corresponding cartons which passed through water at 90° to 100° F. ranged from 3 to 3,700 organisms per carton. The arithmetic averages of total counts of 40 contaminated cartons which passed through hot immersion water at 189° to 190° F. ranged from less than 1.0 to 4.2 organisms per carton.

Data in Table 21 also show that total counts of samples of hot water taken immediately after the passage of contaminated cartons varied from less than 0.1 to 0.7 organism per ml. Total counts of samples of hot water, taken immediately after the 6 liters of contaminated water was added to the hot water compartment and after the temperature had returned to 189° to 190° F., ranged from less than 0.1 to 0.4 organism per ml.

The data show that the arithmetic average of total counts of noncontaminated cartons which passed through contaminated hot water varied from less than 1.0 to 8 organisms per carton.

In connection with this work, bacteria counts were performed on 600 contaminated cartons and 200 noncontaminated cartons. Data indicate that cartons submerged in hot water at 189° to 190° F. for 8 seconds consistently complied with requirements published in the Milk Ordinance and Code (1953), which state that "a milk package shall

TABLE 21--Standard plate counts on immersion water and plastic surfaced cartons[1] contaminated with organisms

	Cartons contaminated as indicated				
	Micrococcus varians	*Microbacterium lacticum*	*Lactobacillus thermophilus*	*Escherichia coli*	*Pseudomonas fragi*
Average count of 40 contaminated cartons not immersed in water					
a. Average count per carton	28,000	13,000	400	9,100	59,000
b. Range of counts per carton	200 to 47,000	1,700 to 47,000	<1.0 to 1,100	<1.0 to 54,000	6,400 to 170,000
c. Number of cartons containing one or more organism(s) per ml. of capacity	36	40	1	19	40
Average count of 40 contaminated cartons immersed in water at 90 to 100° F.					
a. Average count per carton	860	1,800	5.0	3.0	3,700
b. Range of counts per carton	1.0 to 4,000	100 to 10,000	<1.0 to 60	<1.0 to 100	200 to 39,000
c. Number of cartons containing one or more organism(s) per ml. of capacity	11	18	0	0	19
Average count of 40 contaminated cartons passed through immersion water at 190° F.					
a. Average count per carton	4.2	2.6	<1.0	<1.0	2.5
b. Range of counts per carton	<1.0 to 24	<1.0 to 10	<1.0 to 2.0	<1.0	<1.0 to 12
c. Number of cartons containing one or more organism(s) per ml. of capacity	0	0	0	0	0
Average count of 40 cartons immersed in contaminated water at 190° F.					
a. Average count per carton	6.3	4.3	<1.0	<1.0	8.0
b. Range of counts per carton	<1.0 to 54	<1.0 to 22	<1.0	<1.0	<1.0 to 250
c. Number of cartons containing one or more organism(s) per ml. of capacity	0	0	0	0	0

[1]Lot 1568-2.

TABLE 21—Continued

	Total counts per ml. of (1) contaminating medium, (2) hot water after contaminated cartons had passed through, and (3) hot water after contaminating medium had been added (four samples in each group)				
	Micrococcus varians	*Microbacterium lacticum*	*Lactobacillus thermophilus*	*Escherichia coli*	*Pseudomonas fragi*
Contaminating medium					
a. Average count per sample	140,000	2,000,000	31,000	350,000	680,000
Hot immersion water after contaminated cartons passed through					
a. Average count per sample	0.3	0.1	<0.1	<0.1	<0.1
b. Range of counts per sample	0.1 to 0.7	<0.1 to 0.3	<0.1	<0.1	<0.1 to 0.2
Hot water after contaminating medium was added					
a. Average count per sample	0.2	0.2	0.1	<0.1	<0.1
b. Range of counts per sample	<0.1 to 0.4	<0.1 to 0.3	<0.1 to 0.2	<0.1 to 0.3	<0.1 to 0.1

not have more than one organism per ml. of capacity when determined by rinse and swab tests".

Additional bacteria counts on cartons and hot water. Data in Table 22 show that the total counts on control cartons removed from the machine immediately after passing through the hot water varied from less than 1.0 to 10 organisms per carton. The thermoduric population in the hot water through which the above cartons passed ranged from less than 0.1 to 12 organisms per ml.

Total counts on rinses from "dry formed" cartons which passed through the empty compartment varied from less than 1.0 to 900 organisms per carton and less than 0.1 to 0.9 organism per ml. of capacity.

Cold water was employed to cool the mandrels. During operation some water migrated back and forth between the mandrels and the hub. Some of this water probably was retained in the cartons and represented a contamination hazard to cartons which were not subsequently passed through hot water.

The effect of three cleaning methods used on the mandrels and hub. In the regular cleaning procedure (Method I) the mandrels and hub received only one hot water rinse each week. Intermittently swabs from the surface of the hub showed a range of total counts of 200,000,000 to 1,000,000,000 organisms per 8 sq. in. of hub. area.

When using cleaning Method I, the total counts performed on 54 "dry formed" cartons ranged from less than 1.0 to 8,400 organisms per carton. Coliform counts from 47 cartons were less than 1.0 organism

TABLE 22--Standard plate counts obtained from: (a) control cartons immersed in hot water (b) "dry formed" cartons and (c) thermoduric counts on immersion water

Description of sample	Arithmetic average of total counts per carton (6 trials on different days)	Range of total counts per carton
a. 36 control cartons removed immediately after passing through water at 190° F. (six cartons in each trial)	1.6	<1.0 to 10
b. 36 "dry formed" cartons not immersed in water and removed immediately after passing through the empty water compartment (six cartons in each trial)	30.0	<1.0 to 900
	Arithmetic average of thermoduric count per ml. on immersion water at 190° F. (6 trials on different days)	Range of thermoduric count per ml.
c. Immersion water at 190° F. after cartons had passed through (one sample in each trial)	5.0	<0.1 to 12

per carton, and 7 cartons varied in coliform population from 2 to 12 per carton (Table 23).

When using cleaning Method II which included a daily hot water rinse on the mandrels and hub, the total counts on 18 "dry formed" cartons ranged from less than 1.0 to 48 organisms per carton (Table 23). Seventeen of the cartons contained less than 1.0 coliform and one contained 44 coliforms.

When using cleaning Method III which employed a hot water rinse, a chlorine solution rinse and another hot water rinse, the total counts on 54 "dry formed" cartons ranged from less than 1.0 to 150 organisms per carton. Coliform counts were all less than 1.0 per carton (Table 23).

Obviously the mandrels and the hub must be properly cleaned immediately before each operation. As a result an internal cooling system for the mandrels was installed which eliminated this source of contamination.

The effect of covering cartons with contaminated ice. The coliform count on a composite sample of the contaminated solution before freezing was 1,100,000 per g. Immediately after the solution was frozen and stored, the coliform count was 450,000 per g. The coliform count of samples of slush ice which covered the cartons during transportation varied from 60,000 to 500,000 per g. (Table 24).

Analysis showed that milk in the non-iced plastic surfaced and wax coated cartons contained less than 1.0 coliform organism per 10 ml. (Table 24).

TABLE 23--Standard plate and coliform counts on "dry formed" plastic surfaced cartons as affected by the sanitary conditions of the mandrels and hub. (Six trials with nine cartons in each trial or 54 cartons in each group)

Method of cleaning	Carton lot number	Arithmetic average of total count per carton	Range of total count per carton	Arithmetic average of coliform count per carton	Range of coliform count per carton
I. Hot water rinse once each week.	2027	69	2 to 650	<1.0	<1.0
	10	480	7 to 1,200	1.6	<1.0 to 12
	10	2,500	10 to 8,400	<1.0	<1.0 to 6
	20	68	12 to 120	<1.0	<1.0 to 6
	20	400	8 to 2,100	1.1	<1.0 to 6
	20	870	<1.0 to 3,600	<1.0	<1.0
II. Hot water rinse before each trial	1880	<1.0	<1.0 to 6	<1.0	<1.0
	1880	16	<1.0 to 48	4.9	<1.0 to 44
III. Hot water rinse followed by chlorine solution rinse, and another hot water rinse before each trial	1880	29	4 to 102	<1.0	<1.0
	1880	17	2 to 92	<1.0	<1.0
	2027	6.2	2 to 32	<1.0	<1.0
	909	14	<1.0 to 32	<1.0	<1.0
	2027	21	2 to 150	<1.0	<1.0
	10	6.0	2 to 8	<1.0	<1.0

TABLE 24--Coliform population in milk packaged in non-iced cartons and in cartons covered with contaminated ice

Description of sample	Cartons covered with contatаminated ice (20 cartons in each trial)							
	Plastic surfaced (six trials)						Wax coated (two trials)	
	I	II	III	IV	V	VI	I	II
1. *Escherichia coli* per gram of ice	500,000	250,000	60,000	76,000	160,000	145,000	140,000	86,000
2. Milk in iced cartons:								
a. Average per ml.	<0.1	0.6	14*	0.4	1.1	0.2	<0.1	<0.1
b. Range of count per ml.	<0.1 to 0.2	<0.1 to 8.1	<0.1 to TNTC	<0.1 to 2.5	<0.1 to 12	<0.1 to 3.6	<0.1 to 0.3	<0.1 to 0.1
c. Number of samples containing one or more organism(s) per ml.	0	3	5	4	2	1	0	0
3. Milk poured from iced cartons:								
a. Average count per ml.	<0.1	0.5	14*	0.4	1.1	0.3	0.1	<0.1
b. Range of count per ml.	<0.1 to 0.5	<0.1 to 5.7	<0.1 to TNTC	<0.1 to 2.0	<0.1 to 12	<0.1 to 4.8	<0.1 to 0.3	<0.1
c. Number of samples containing one or more organism(s) per ml.	0	2	3	5	2	1	0	0
	Non-iced cartons (two cartons in each trial)							
4. Control samples of milk	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

*Estimated (TNTC averaged as 900 coliforms per 10 ml.)

One hundred and twenty samples of milk which were packaged in plastic surfaced cartons, covered with contaminated ice and transported varied from less than 0.1 to more than 90 coliforms per ml. of milk. Only 15 of the 120 samples contained more than 1.0 coliform per ml. Coliform counts on 19 of the 120 samples ranged from more than 0.1 to 1.0 organism per ml., 30 samples contained 0.1 coliform per ml. and the remaining 56 samples contained less than 0.1 coliform per ml.

Apparently, the samples of milk poured from cartons contained about the same coliform population as the pipetted samples (Table 24). The data indicate that there was little (if any) contamination in the samples of milk in wax coated cartons which were covered with contaminated ice cubes and transported. Presumably, the melted ice containing E. coli did not pass into the wax coated cartons.

Since the termination of this thesis study a limited survey has indicated that the sanitary condition of the plastic surfaced carton will meet regulatory requirements without the germicidal treatment affected by immersion in hot water. An additional study would be helpful in establishing the precautions necessary to assure a sanitary carton when the germicidal treatment is omitted.

SUMMARY AND CONCLUSIONS

This study involved an investigation of the suitability of plastic surfaced cartons for use under commercial conditions. The cartons were preformed, sanitized, filled and closed by the modified junior model Pure-Pak machine. The experimental results showed that the cartons were practical as well as sanitary for commercial use in the market milk operation at the Michigan State University Dairy Plant. The results are summarized as follows:

1. Plastic surfaced cartons did not cause off-flavors in milk, cultured buttermilk or orange drink during storage at 33° F. or 41° F. for 7 days.
2. Plastic surfaced cartons caused no off-flavors in milk that was frozen 15 to 34 weeks at -15° F. and thawed 4 days at 41° F.
3. Neither plastic surfaced cartons nor wax coated cartons were effective in the preventing of sunlight off-flavors.
4. The average increase in temperature of milk was slightly higher in plastic surfaced cartons than in wax coated cartons upon holding 1 hour at room temperature.
5. The average bulge of quart cartons of milk held 3, 7 and 14 days at 41° F. was 7.7, 9.0 and 11.2, respectively. The average of cultured buttermilk was 6.7, 9.2 and 10.5, respectively, while cartons of orange drink had an average bulge of 6.3, 7.4 and 9.3, respectively. The average bulge after freezing and thawing

cartons of milk, buttermilk, and orange drink was 9.1, 11.6 and 10.0, respectively.

6. Drop, Incline-Impact, Combination and Hauling Tests demonstrated greater damage which resulted in a higher percentage of leaks in plastic surfaced cartons than in wax coated cartons.
7. General consumer preference on retail routes was much greater for plastic surfaced cartons of milk than for wax coated cartons.
8. The rebuilt junior model Pure-Pak machine required changes and improvements to perfect the bottom-seal, the top-seal and the immersion bath.
9. Heat from the top-sealing mechanism increased the temperature in the contents of quart cartons an average of 1.48°, 1.35° and 1.29° F., with approximate initial temperatures of 40°, 45° and 50° F., respectively.
10. The increase in temperature of quart cartons of milk passing through the machine averaged 2.44°, 2.38° and 2.07° F. when the initial temperatures were 40°, 45° and 50° F., respectively.
11. A standard plate count on plastic surfaced cartons which were processed through 190° F. water in the Pure-Pak machine varied from less than 1 to 200 organisms per carton, and averaged less than 3 per carton.
12. Standard plate counts and thermoduric counts on noncontaminated hot water at 190° F. ranged from less than 0.1 to 12 organisms per ml.

13. Standard plate counts on plastic surfaced cartons, contaminated with Micrococcus varians and passed through immersion water at 190° F., varied from less than 1 to 24 organisms and averaged 4.2. The standard plate count on all cartons contaminated with Lactobacillus thermophilus or Escherichia coli varied from less than 1 to 2 organisms per carton. Counts on cartons contaminated with Microbacterium lacticum ranged from less than 1 to 10 organisms per carton with an average of 2.6 while cartons with Pseudomonas fragi varied from less than 1 to 12 organisms and averaged 2.5.

14. Standard plate counts on contaminated immersion water at 190° F. showed less than 0.1 organism per ml. The water was contaminated on different days by using Micrococcus varians, Microbacterium lacticum, Lactobacillus thermophilus, Escherichia coli and Pseudomonas fragi.

15. Standard plate counts and coliform counts indicate that the mandrels and hub of the Pure-Pak machine should be sanitized daily if cooled externally by water.

16. Products in plastic surfaced cartons may become contaminated from ice melting over the tops of cartons.

17. Data indicate standard plate counts and coliform counts on "dry formed" plastic surfaced cartons were well within the limit of 1 organism per ml. capacity when the machine was maintained in sanitary condition. Consequently with adequate precautions,

consideration may be given to eliminating the immersion of cartons in hot water in the Pure-Pak machine.

In conclusion the plastic surfaced cartons of quart size proved satisfactory as milk containers during limited commercial operations. These containers were preferred by most of the customers in a comparison with the wax coated cartons.

LITERATURE CITED

American Public Health Association, Inc. (1953). Standard Methods for the Examination of Dairy Products. 10th ed. Amer. Pub. Health Assoc., Inc., New York. 345 pp.

American Society for Testing Materials (1957). ASTM Standards on Paper and Paper Products and Shipping Containers. Amer. Soc. for Testing Materials, Philadelphia. 408 pp.

Anonymous (1929). Fifty thousand quarts of milk delivered in paper cones. The Milk Dealer 18(4): 58-59.

________ (1932). Chain will sell milk in paper cones. Business Week, April 27. pp. 10, 13.

________ (1942). One less bottleneck. Safety Engin. 84(2): 8.

________ (1949). Sealking milk packaging process now available to large dairies. Milk Plant Monthly 38(11): 91.

________ (1950). Polyethylene on paper. Mod. Plastics 28(4): 67-71.

Appling, J. W. (1945). The bacteriological examination of paper. Paper Trade Jour. 120(6): 34-40.

Bickerman, J. J. (1959). Making polyethylene adhesionable. Adhesive Age 2(2): 23-24.

Booth, G. L. (1956). A survey of machine coating methods. Tech. Assoc. of the Pulp and Paper Indus. (TAPPI) 39(12): 846-850.

Burgess, L. M. (1950). Uses of polyethylene as a paper coating. Paper Trade Jour. 130(25): 31, 38.

Dahle, C. D., and D. V. Josephson (1939). Treatment of paper milk bottles to delay or prevent oxidized flavor of milk. The Milk Dealer 28(11): 39, 66, 68, 69.

Doan, F. J., and C. H. Myers (1936). Effect of sunlight on milk and cream products. The Milk Dealer 26(1): 76, 78, 80, 82, 84-87.

Foord, D. C., C. L. Crane and B. S. Clark (1943). Significance of adequate controls in absolute sterility determinations. Food Res. 8(4): 489-495.

Huntley, R. F., and R. H. Torrey (1940). Promoting satisfactory bacteriological conditions in the paper mill. Paper Trade Jour. 110(8): 108-110.

John, E. C., and V. T. Stannet (1956). Plastic-paper combinations. Soc. Plastic Eng. 12(1): 32-34, 56.

Pitman, A. L. (1946). How processors can test and improve their own packages. Food Indus. 18(7): 104-106, 228.

Prucha, M. J. (1938). Sanitary aspects of paper milk containers. Jour. Milk Technol. 1(2): 4-9.

__________ (1939). Are paper milk containers sanitary? Milk Plant Monthly 28(5): 27-28.

__________ and P. H. Tracy (1943). Bacteriological and practical aspects of paper containers for milk. Ill. Agr. Expt. Sta. Bul. 495. pp. 415-472.

Reed, E. (1951). Microbiology of certain paper food containers. TAPPI 34(11): 524-525.

Rice, J. W. (1942). The bacterial population of paper milk containers in relation to methods of moisture proofing. N. Y. (Geneva) Agr. Expt. Sta. Tech. Bul. 263. pp. 3-29.

Sanborn, J. R. (1938). Proposed standards for paper milk containers. Jour. Milk Technol. 1(2): 41-45.

__________ (1939). Sanitary condition of paper containers for retail packaging of perishable foods. Amer. Jour. Pub. Health 29(5): 439-442.

__________ (1940). Microbiological content of paperboard used in the packaging of foods. Amer. Jour. Pub. Health 30(3): 247-255.

__________ (1941). Single-service containers for distribution of fluid milk. Amer. Vet. Med. Assoc. Jour. 99(774): 223-224.

__________ (1942a). Public health compliance of manufacturers of paper and packaging perishable foods. Jour. Milk Technol. 5(2): 88-93.

__________ (1942b). Single-service containers for distribution of fluid milk. Amer. Vet. Med. Assoc. Jour. 101(789): 477-480.

__________, M. W. Yale, R. S. Breed et al. (1938). Paper containers for milk and principles of sanitation to be observed in their manufacture and use. Jour. Milk Technol. 1(5): 50-53.

Tanner, F. W. (1938). Microbial flora of paper containers. Amer. Jour. Pub. Health 28(5): 587-592.

__________ (1939). The present status of the paper milk container. Jour. Milk Technol. 2(1): 4-15.

__________ (1948). Paperboard and paper food containers--an analysis of literature and appraisal of their sanitary condition. Jour. Milk and Food Technol. 11(6): 334-345.

Tracy, P. H. (1938). Certain practical aspects of the use of paper milk containers. Jour. Milk Technol. 1(3): 40-42.

Wheaton, E., R. H. Lueck and F. W. Tanner (1938). Observations on problems relating to the paper milk bottle. Jour. Milk Technol. 1(3): 11-15.

Williamson, G. E. (1955). Report from Sweden: the progress of Tetra-Pak. Milk Plant Monthly 44(2): 38-40.

APPENDIX

APPENDIX 1

MICHIGAN STATE UNIVERSITY

OF AGRICULTURE AND APPLIED SCIENCE • EAST LANSING

College of Agriculture • Department of Dairy • Food Technology Program

Dear Mr. and Mrs. Milk Customer:

For you, we have two kinds of quart-sized paper milk containers, one with a wax coating and one with a plastic surface. Today we have left half your order in our waxed container and your other half in our container with a plastic surface. After several deliveries you will receive a short questionnaire. Your choice of wax or plastic will create further developments and will help us determine the type of container preferred.

As you use the two kinds of containers, please try to form personal opinions about your preference. Both wax and plastic equally protect the milk and cost the same.

Earnestly, we need a report from you about how you like the milk containers and which you prefer. We realize that when you buy milk you want the best milk in the best milk container you can buy. Your ideas will literally spark newer action as there is room for packaging improvement. We will appreciate your thought by assisting in this evaluation survey.

Sincerely,

M.S.U. Dairy Plant Milkman

APPENDIX 2

MICHIGAN STATE UNIVERSITY

OF AGRICULTURE AND APPLIED SCIENCE • EAST LANSING

College of Agriculture • Department of Dairy • Food Technology Program

Dear Mr. and Mrs. Milk Customer:

A free quart of homogenized milk will be delivered to you when this questionnaire is filled out and returned to this office. Your opinions are important.

Thank you for accepting and using the two kinds of quart-sized milk containers, one with wax and one with plastic.

Check your choice:

	Wax	Plastic	Don't Care
Appearance	( )	( )	( )
Feel in your hands	( )	( )	( )
On table	( )	( )	( )
In refrigerator	( )	( )	( )
Ease in opening and closing	( )	( )	( )
Pouring	( )	( )	( )
Apparent tendency to bulge	( )	( )	( )
Leaking	( )	( )	( )
Uses of empty containers	( )	( )	( )

Comments about "room for improvement" may be placed on the back side of this paper.

Earnestly, we need your opinions because your cooperation will help us determine the type of container preferred. Thank you for your time. The enclosed envelope is stamped for your reply.

Sincerely,

M.S.U. Dairy Plant Milkman

APPENDIX 3

MICHIGAN STATE UNIVERSITY

OF AGRICULTURE AND APPLIED SCIENCE • EAST LANSING

College of Agriculture • Department of Dairy • Food Technology Program

Dear Mr. and Mrs. Milk Customer:

A free quart of homogenized milk will be delivered to you when this questionnaire is filled out and returned to this office. Your opinions are important.

Thank you for accepting and using the two kinds of quart-sized milk containers, one with wax and one with plastic.

Check your choice:

	Plastic	Wax	Don't Care
Appearance	( )	( )	( )
Feel in your hands	( )	( )	( )
On table	( )	( )	( )
In refrigerator	( )	( )	( )
Ease in opening and closing	( )	( )	( )
Pouring	( )	( )	( )
Apparent tendency to bulge	( )	( )	( )
Leaking	( )	( )	( )
Uses of empty containers	( )	( )	( )

Comments about "room for improvement" may be placed on the back side of this paper.

Earnestly, we need your opinions, because your cooperation will help us determine the type of container preferred. Thank you for your time. The enclosed envelope is stamped for your reply.

Sincerely,

M.S.U. Dairy Plant Milkman

APPENDIX 4

MICHIGAN STATE UNIVERSITY

OF AGRICULTURE AND APPLIED SCIENCE • EAST LANSING

College of Agriculture • Department of Dairy •
Food Technology Program

Dear Mr. and Mrs. Milk Customer:

Today, we have delivered to you a FREE QUART OF MILK in our new plastic surfaced container. Thank you for mailing the questionnaire to us.

Several months or longer will be required to complete our research work and to increase our plant production progressively up to 100% of plastic surfaced containers.

You are among the first milk consumers in the United States to receive milk in the plastic surfaced container of this type.

It is our aim to satisfy as many consumers as possible and your comments on the questionnaire will be used to guide our future package and sales program.

Sincerely,

M.S.U. Dairy Plant Milkman

APPENDIX 5—Customer comment about "room for improvement" of plastic surfaced and wax coated milk cartons

Comments on plastic surfaced cartons ("plastic")	Comments on wax coated cartons ("wax")
Product stability in cartons	
1. Without a refrigerator, milk keeps longer in "plastic".	1. Wax plugs the nipple on the baby's bottle.
2. Milk in "plastic" has a different taste after storage for 3 or more days in my refrigerator.	2. Wax gets into the baby's formula.
3. Milk is not so waxy tasting.	3. The child should not eat chipped wax.
4. "Plastic" keeps the milk colder.	4. For our kids, we strain milk from "wax" cartons.
5. Milk seems warmer in "plastic".	5. Wax tastes like heck in milk.
6. "Plastic" has felt warmer.	6. I don't like wax in my mouth.
7. The "plastic" feels a bit warmer.	7. Milk seems colder in "wax".
8. A pleasure not to have wax in my mouth.	8. Wax feels colder. Is it the temperature?
9. No wax floats in the milk.	9. Wax is in the glasses.
10. No wax is in the milk.	10. Wax is on the lip of glasses.
11. I have no wax in my coffee.	11. Wax mixes with the milk.
	12. Wax is in our milk.
	13. Wax floats on the milk.
	14. Eight other customers commented; we do not like wax in our milk.

APPENDIX 5 (Continued)

Comments on plastic surfaced cartons ("plastic")	Comments on wax coated cartons ("wax")
Durability of cartons	
1. Plastic does not get on my dress.	1. Wax breaks off onto my hands and dresses.
2. Plastic is not on the table tops.	2. Wax chips off into the refrigerator. Two other customers stated that wax is shedded onto the refrigerator shelves.
3. Plastic is not in my refrigerator (three customers comment).	3. Wax gets all over.
4. Plastic is not messy to handle.	4. Wax falls on the carpet.
5. The "plastic" does not leak.	5. Wax falls on the polished kitchen floor.
6. Did not leak.	6. Wax flakes off.
7. No leaking from plastic.	7. Wax rubs off onto the kitchen table.
8. "Plastic" is sturdier and stays nicer in storage.	8. Wax is messy to handle.
9. "Plastic" adds strength and firmness.	9. No leaks from "wax".
10. "Plastic" is nice to open and close.	10. Messy wax to contend with.
11. "Plastic" opens a little too easy.	11. The "wax" are more rigid for kids to handle.
12. "Plastic" seems to gap at the top after opening.	12. "Wax" are more difficult to open.

APPENDIX 5 (Contimued)

Comments on plastic surfaced cartons ("plastic")	Comments on wax coated cartons ("wax")
Durability of cartons	
13. The "plastic" does not stay closed after opened.	
14. "Plastic" top-seal leaks.	
15. What do you mean, tendency to bulge?	
16. Excellent for freezing foods.	
17. "Plastic" are more practical for freezing foods.	
18. "Plastic" is slippery to hold.	
19. The "plastic" is somewhat slippery in my hands.	
20. "Plastic" is slippery when wet.	
21. "Plastic" makes "chewable" toys.	
Acceptance of cartons	
1. When are you going to have half gallons?	1. "We don't like wax" was most frequent comment.
2. A best improvement would be a 2 quart "plastic".	2. Wax is messy.
3. Improvement is 100 percent.	3. "Wax" are easier to pour from.
4. The "plastic" is superior.	

APPENDIX 5 (Continued)

Comments on plastic surfaced cartons ("plastic")	Comments on wax coated cartons ("wax")
Acceptance of cartons	
5. I like the plastic better.	
6. The "plastic" is neater and not messy.	
7. Please put the milk in the "plastic" cartons from now on	
8. "Plastic" has a cleaner and whiter look.	
9. "Plastic" is far the best.	
10. "Plastic" are better in every way, sharper.	
11. "Plastic" are definitely superior.	
12. Our neighbors and friends prefer the "plastic".	
13. In the future, I hope all our milk will be in plastic.	
14. Can we have the plastic?	
15. Had "plastic" before and prefer it.	
16. An outstanding improvement.	
17. Use "plastic" all the time.	
18. Deliver "plastic" to us.	
19. I will quit if you do not give me "plastic".	

APPENDIX 5 (Continued)

Comments on plastic surfaced cartons ("plastic")	Comments on wax coated cartons ("wax")

Acceptance of cartons

20. Am learning how to pour from "plastic".

21. Milk flies all-over when opening "plastic".

22. Great improvement.

23. Enjoy the plastic, 100 percent.

24. One hundred percent better.

25. Far superior.

Sanitary condition of cartons

1. Only one comment:

   Just keep the milk safe to drink. Who cares what the carton is lined with.*

*Comment about sanitation was meager. Customers apparently believed that the milk in both cartons was of satisfactory microbiological condition.