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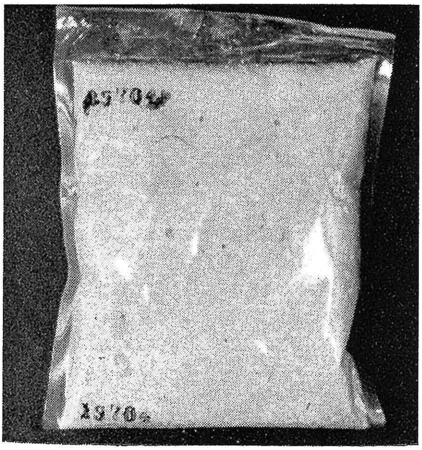

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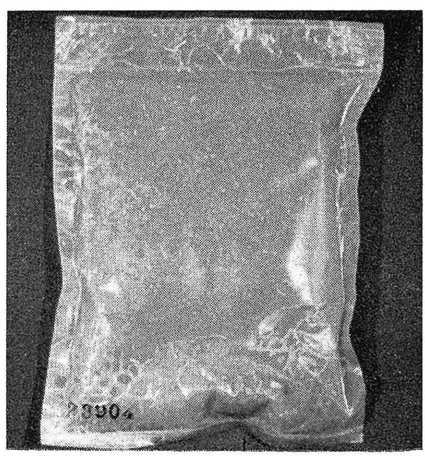

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HEAT PROCESSING OF VEGETABLES IN FLEXIBLE FILMS

W. A. Gould, J. R. Geisman, H. H. Weiser, W. D. Bash, W. H. Moore, R. H. Salzer, and F. E. Long[1]

Suitable containers for the preservation and packaging of man's food is a problem which dates back to the Fifteenth Century B. C. when Egyptians used earthen crocks to store food. However, until 1810, there was no way to preserve food in a container and thus spread the harvest abundance through lean periods. In the early 1900's, technical advances and mechanization made the widespread use of preserved or canned foods possible. Recently, flexible materials have been developed which will withstand the temperatures necessary for sterilization of food products.

Flexible packaging materials offer many advantages over both glass and tin containers. These are: portion control, low container cost, low shipping cost, less inventory storage space, consumer preparation of several products in the same heating vessel and little or no container disposal problem. Further, new techniques for vacuum sealing foods in flexible containers make mass production possible.

This study was undertaken to establish sterilization processes to permit room temperature storage of food products packaged in flexible films. A further objective was to evaluate the acceptability and shelf-life of food products packaged in flexible film by organoleptic, physical, and microbiological examinations. The third objective was to determine the limitations and uses of new pouch structures and flexible packages for selected foods of known processing characteristics.

Review of Literature

The idea of heat processing foods in flexible films was proposed as early as 1940. Since that time there have been few published results on the processing of low acid foods and on the storage of these foods after processing. The review of literature directly related to this study is presented under the following categories.

1. Characteristics of films for heat processing.
2. Biological determination of safe process levels.

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A. W. N. Brown, M. W. Austin, Joe Lovering, Gary Korn, Robert Cowley, Don Yingst, and Don Streets of the Ohio Agricultural Experiment Station and the Ohio State University.
B. Fred B. Shaw, Flexible Packaging Division, Continental Can Company.

This study was initiated in 1960 as a contract project between the Flexible Packaging Division, Continental Can Company, and the Ohio Agricultural Experiment Station.

3. Problems encountered with flexible films for heat processing.
4. Effect of heat processing in flexible films on food quality.

Characteristics of films for heat processing:

For many years the value and convenience of flexible films has been realized in different phases of the food industry. These materials were first used as over-wraps and containers for fresh commodities, such as bread and lettuce. When used in this capacity, the films were required only to contain the product, keep the product clean, and reduce to a significant degree the vapor loss of the product. These products were items that moved from the retail store shelves rapidly and required little or no unusual processing or storage facilities. Thus, the films employed were not required to withstand extreme physical conditions.

The frozen cook-in-pouch utilized flexible films as food containers for processed food for the first time (6). With this type of operation, the product was frozen in the pouch and then heated in the same pouch prior to serving. These pouches were often made from polyester film, polyethylene film, aluminum foil, or laminated combinations of these or several other less important films (6). For this type of product, flexible films which maintained their physical properties at both freezing temperatures and boiling temperatures were required since the product was frozen and stored in this condition until placed in boiling water in preparation for serving (2, 6). In addition, flexible films that could be fabricated and sealed into pouches with satisfactory results were needed for this type of commercial operation. Films were available which had the necessary properties of moisture-vapor transfer, oxygen permeability, heat stability, cold resistance, flexibility, sealability, and fabrication (4, 6, 22).

This present study was concerned with a problem that was yet one step more complex than the cook-in-pouch method, that is, a flexible film container filled with a food product, hermatically sealed, heat processed to obtain sterilization, and stored at room temperature or above. There were two main differences between the cook-in-pouch and the flexible film pouch for heat processed foods. These were:

1. The films used for heat processed pouches must withstand retorting at temperatures above 212° F.
2. The films must provide adequate protection for the food product during a suitable storage period at room temperature.

As pointed out by Hu in 1955 (14), there were only seven films that could withstand heat processing at 250° F.: (1) Saran, (2) Cellophane, (3) Trithene, (4) Teflon, (5) Polyvinyl Chloride film for blood pack, (6) Tygon S22.2, and (7) Mylar Polyester. Of these seven films that have melting points above 250° F., several were undesirable for food processing due to other lacking qualities (11, 12, 14, 16, 17). Cellophane was undesirable because of physical deterioration when heated in live steam at 250° F. for thirty minutes. Tygon, vinyl blood pack, and saran were eliminated because they imparted an undesirable flavor and a turbidity to boiling water, and teflon was undesirable due to lack of satisfactory methods for heat sealing. In addition to the seven named films, aluminum foil also had resistance to melting at temperatures above 250° F. as well as other properties which made it a desirable material to be used in laminated films for heat processed foods (1, 6).

Biological determination of safe process levels:

A method of calculating thermal processes for sealed containers of food was developed in 1928 by Ball (7). In this method he used the straight line curves of the thermal death times. He used two symbols which described these curves:

F_0 — The number of minutes required to destroy the organism (in any specific medium) at 250° F.

z — The shape of the thermal death time curve expressed as degrees F. (the temperature interval required for the line to pass through one log cycle on semi-log paper).

In applying a biological method to determine a safe process level for canned foods, the need arose for an organism of uniform heat resistance. Townsend, Esty, and Baselt (23) found that it was difficult to produce spore crops of *Clostridium botulinum* with a high, or even a medium, heat resistance. Also, the danger of contaminating a food processing plant with this organism existed. They, therefore, tested an organism isolated by Cameron (9) in 1927 from spoiled, canned corn and designated as P. A. 3679. They found that the z values for this organism were slightly lower than those for *Clostridium botulinum* in neutral phosphate, but that it was higher in food substrates. They also discovered that the F_0 value of P. A. 3679 was always higher than that of *Clostridium botulinum.* Typical F values obtained in their studies were:

	ORGANISM:	P.A. 3679	Cl. bot. 62A	Cl. bot. 213B
Substrate	Neut. PO_4	4.00	1.70	2.00
Asparagus		3.30	0.39	0.39
Peas		3.00	0.30	1.40
Spinach		2.60	0.65	0.68

Further tests on the thermal death nature of *Clostridium botulinum* and P. A. 3679 were performed in 1952 by Reynolds, *et al.,* (20). These workers obtained essentially the same results as did Townsend, Esty, and Baselt (23). They found that all foods had an inhibitory effect, to some extent, on the germination of the spores of P. A. 3679. They concluded that for practical purposes it was safe to assume that a process calculated for z=16 and providing F_0 values equivalent to the observed F values for the destruction of P. A. 3679 spores in an unmodified vegetable substrate would yield an adequate sterilization process with respect to *Clostridium botulinum.*

Problems encountered with flexible films for heat processing:

Davis (13) pointed out that heat processing food in flexible films presented problems not encountered when containers were of conventional materials. Following are six areas that Davis listed as possible sources of trouble for flexible packaging materials:

"1. Permeability of films to gases and vapors and the effect of processing temperatures on these properties.
2. Possibility of extraction of film components into the food product during processing.
3. Effect of transmitted light on the food product.
4. Essential inertness of plastics. This may create additional problems. For example, tin and the special linings used in metal cans may react with food components or their breakdown products; such reactions are frequently beneficial to the appearance and flavor of the product.
5. Effect of processing temperature on the strength of films and heat seals.
6. Internal pressure-volume relation in film packages during processing."

Since the production of a sterile product was the primary objective of this study, retorting operations and their effect on the flexible containers were of utmost importance. There are three important physical factors in retorting flexible films:

1. The amount of heat.
2. The amount of pressure maintained.
3. The length of process.

All three of the above mentioned factors affect the pressure-volume relation in flexible packages during heat processing. Davis (13) indicated that the pressure which developed inside the sealed containers during heat processing arose from:

1. Increase in the vapor pressure of the water in the processed food with increasing temperature.
2. Increase in the pressure of air in the headspace with increasing temperature.
3. Release of additional air from the product, due to a decrease in gas solubility, with increasing temperature.
4. Thermal expansion of the food product itself.

This increase in pressure during the heating cycle and initial phase of the cooling cycle in the processing operation became quite acute when working with a product like cream style corn, where it was desirable to process under high temperature short time conditions (250° F. for 65 minutes in #303 size tin can) (5) in order to maintain high quality.

During the initial stages of heat-processing, the value of the differential pressure was relatively small and may even be negative if the product to be processed was filled into the pouches hot or if the head space was evacuated with steam. When the product reached retort temperature and the internal bag pressure attained maximum volume, the vapor pressure of the water in the container should have been equal to the retort pressure. The differential or increased pressure was due entirely to expansion of the product and the expansion of the enclosed air.

The maximum differential pressure occurred during the cooling period because the retort temperature and pressure fell more rapidly than the temperature and pressure inside the container (12). Davis also indicated that to minimize the resulting strain on containers during the cooling cycle, retorts were generally cooled under superimposed air pressure. Keller (15) carried this point further by stating: "If head-space air is not substantially removed from the package, a commercial pressure water cook (similar to a process for glass) with pressure cooling must be used: this requires a superimposed air pressure to prevent expansion and possible bursting of the packages and to insure proper heat transfer."

There were varied reports in the literature concerning the proper amount of over-riding air pressure to be maintained during processing. When processing at 250° F., 15 p.s.i. was required and the suggested superimposed air pressure required to prevent bursting of the pouches and insuring proper heat transfer varied from a 10 to 15 p.s.i. additional. This would give a total gauge pressure of 25 to 30 p.s.i.

Davis (13) found that, generally, the higher temperatures required less internal pressure to burst the filled pouches. Also, the majority of pouch failures occurred at the heat seals or areas immediately adjacent to the heat seals, either as leaks or as long tears.

Nelson (19) supported Keller's (15) reasons for using superimposed air pressure during the heat processing period. He indicated that heat transfer was undoubtedly improved when a superimposed air pressure was maintained, especially in viscous food products such as cream style corn. He indicated heat transfer was improved because the miniature gas and vapor bubbles that were present were kept from expanding through the product. Such expansion would greatly reduce heat transfer by interfering with the heat conduction and convection.

In addition to the superimposed air pressure there are two other precautions that should be taken in order to reduce or eliminate the damage caused to a pouch by high internal pressure during processing. First, the air space (head space) should be reduced to a minimum. Tests conducted by Wallenburg (24) established that there was a maximum ratio between the enclosed air volume and the surface of the package. Second, the product, especially a viscous product like cream style corn, should be filled into the pouches at an elevated temperature. This aids in reducing the amount of entrapped air in the product (13, 19).

Effect of heat processing in flexible films on food quality:

As pointed out by Nelson *et al* (19), heat processing of acid foods at the temperature of boiling water or lower, depending upon the nature of the product and the type of processing operation, was possible.

Keller (15) studied the use of flexible packages using color sensitive foods and found that packages made from single films including polyethylene up to 4 mil, 6 mil polypropylene, and 2 mil polyester showed objectionable discoloration within three weeks when stored at room temperature. In contrast, laminates, including foil, did not show objectionable discoloration after six months.

Commercially, low acid foods were processed in a pressure cooker or retort at above 250° F. for a definite length of time. Therefore, it appeared that testing films to show the effect on quality of foods processed at 250° F. would yield information regarding the suitability of these materials for packaging heat processed foods.

Materials and Methods:

This study was divided into two phases. These were (1) retort operation and (2) quality storage studies. Quality storage studies were further divided into two phases. The first was a six-month storage period conducted during the winter months and the second was a ten-month storage period initiated in the summer months. The materials and methods utilized in both phases will be discussed in chronological order from acquisition of raw materials to analysis of finished products.

Acquisition of Raw Materials:

Snap beans and sweet corn were obtained during the winter months from Joe Hatton, Inc., Pahokee, Florida. These commodities were shipped by refrigerated truck to The Ohio State University, Department of Horticulture, Division of Horticultural Products Pilot Plant, at Columbus, Ohio. The raw material arrived at Columbus in excellent condition; however, it should be noted that neither the snap beans nor the sweet corn were of a variety that was highly recommended for processing.

Earligreen, Slenderwhite, and Slendergreen varieties of snap beans and Deep Gold variety of sweet corn were grown according to accepted commercial practices during the summer months on The Ohio State University Farm, Columbus, Ohio. Each variety of snap beans or corn was harvested at least three times. The commodities were brought to the Horticultural Products Pilot Plant and then prepared for processing.

Flexible Materials:

Seven pouch materials were supplied by the Flexible Packaging Division, Continental Can Company. These materials were evaluated for appearance after retorting, ability to withstand retorting, and durability during storage. The materials are listed in Table 1.

Table 1—Flexible Materials Used for Retort Processing of Various Foods.

Continental Can Company Designation	Films
8346-1	Polyester-intermediate density polyethylene
8346-2	Polyester-polypropylene
8346-3	Polyester-foil-vinyl
8546-1	Polyester-foil-vinyl
8546-2	Polyester-foil-vinyl
8546-3	Polyester-foil-polypropylene
8546-4	Polyester-polypropylene

As shown in Table 1, there seemed to be several laminants of the same films; however, this was not the case since different laminating materials and different films of the same type were used. Only films 8346-3 and 8546-1 were duplicates, since the films with the 8346 designation were used in the preliminary stage (six-month storage) of the study. Further, films designated 8546 were made from improved materials based on the performance of the 8346 films.

Analysis of Raw Materials:

The Agtron "F" instrument was used to determine the color of the snap beans and sweet corn. For interpretive purposes, the higher the Agtron "F" readings, the lighter the color of the product. The Agtron "F" was standardized at 30 on the gray standard for snap beans and at 70 for sweet corn. Before being placed on the instrument, snap beans were ground for two minutes with the aid of a Waring Blendor, and cream style corn was ground for thirty seconds.

The fiber content of snap beans was determined by the sodium hydroxide digestion method of the Food and Drug Administration.

Specific gravity of sweet corn was determined by weighing the cut corn in air and in water. A nomogram was used to determine true specific gravity and this value was then the basis for the amount of water to add to each batch of cream style corn (10).

The Alcohol Insoluble Solids (AIS) of the sweet corn was determined according to the Official Method of Analysis (3). The percent pericarp was determined by grinding a 25 gram sample of corn in water in a Waring Blendor for three minutes. The mixture was then washed through a tared 30 mesh monel screen. It was dried for two hours at 100° F. and reweighed.

Preparation and Processing:

The snap beans were prepared as follows (see Figure 1): snipping was done mechanically using a Chisholm-Ryder bean snipper. The beans were cut into 1½ inch lengths with an Urschel Model 30 snap bean cutter. They were then blanched for three minutes in a continuous live steam blancher and immediately water cooled. They were filled by hand, eight ounces into each of the pouches and covered with boiling distilled water. The pouches were exhausted by injection of live steam into the pouches immediately prior to sealing. For the six-month storage study, pouches were placed in stainless steel baskets for processing; however, for the ten-month phase, the pouches were placed in the specially constructed rack which will be discussed in the retorting section.

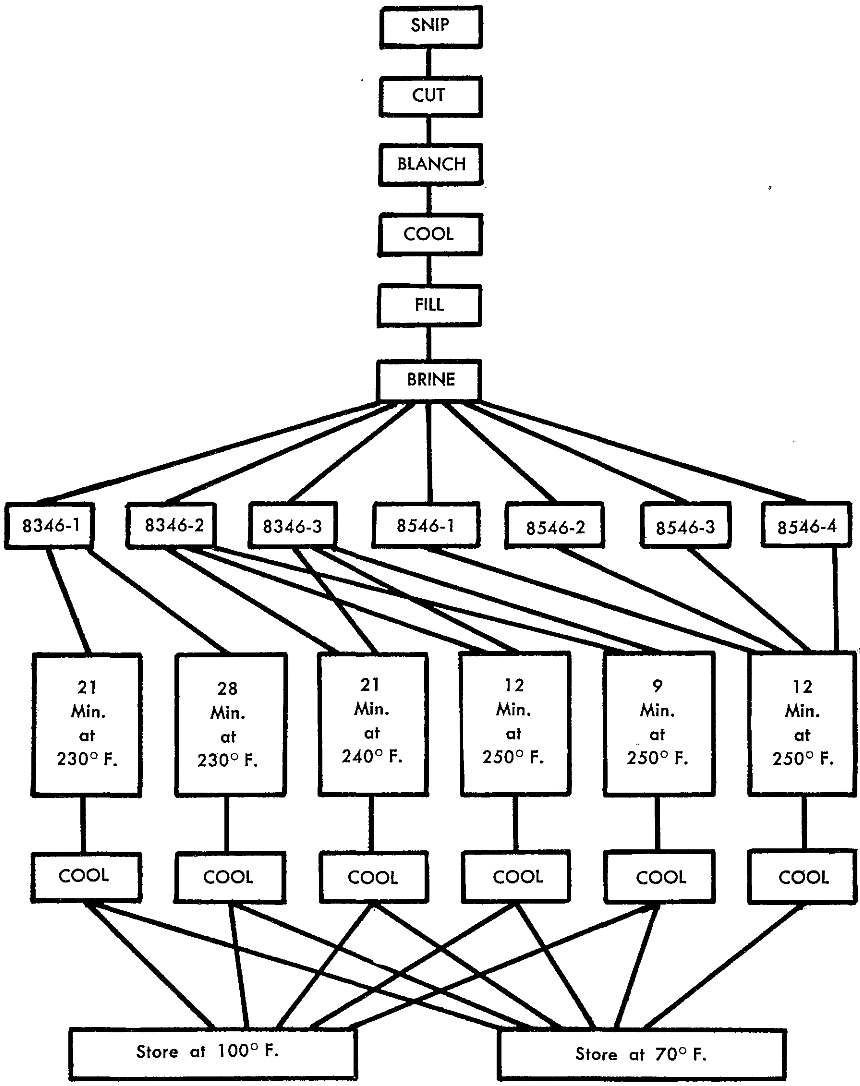
Sweet corn was prepared as follows (see Figure 2). The corn was husked with the aid of an FMC husker and the ears were transferred to a soak tank where they were trimmed and washed. Using a roller conveyor, the ears were conveyed under a high-pressure spray rinse (150 p.s.i.) and then to an FMC corn cutter. The kernels were capped about $\frac{3}{16}$ inch deep and the remaining kernel was scraped from the cob. For each fifty pounds of corn, 3.5 pounds of sugar and 0.35 pounds of salt were added. Water was also added depending upon the specific gravity of the corn.

Live steam was introduced into the corn mixture and preheated until the batch reached 190° F. Then 100 grams of starch were added and the batch was mixed for five more minutes. One pound of the cream style corn was filled directly into each pouch. These were heat sealed and were placed into the retort in the same manner as described for snap beans.

Both commodities were also filled into tin cans to serve as a control lot. Further, samples of both commodities packed in all films were frozen for comparison of product quality.

FIGURE 1

FLOW DIAGRAM FOR SNAP BEANS



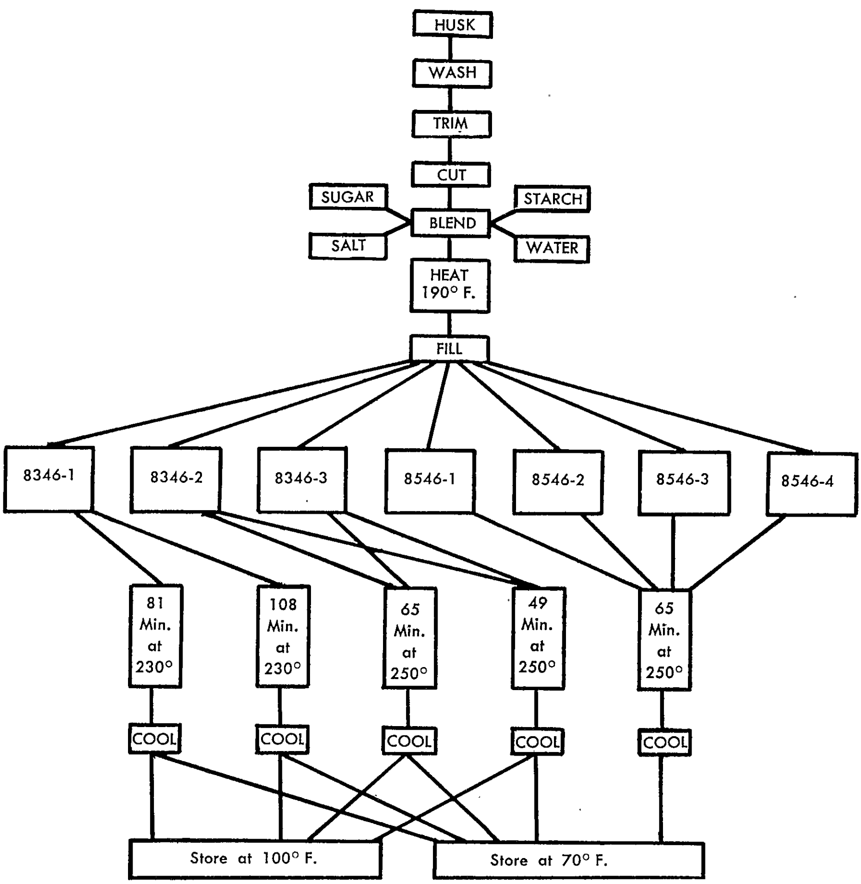
Heat Penetration:

In order to obtain heat penetration data, thermocouple probes were inserted into sample pouches. The lead entered the pouch wall through a specially designed nut and washer screw clamp. Before filling the pouch, the thermocouple probe was fitted through the special clamp and twisted into a spiral coil with the end of the wire in the center of the coil. This aided in holding the thermocouple as close to the center of the pouch as was possible. Thermocouples were also attached to tin cans.

Retorting Operations:

The retort used for this study was a Food Machinery and Chemical Corporation, 24 inches wide by 30 inches high, miniature non-agitating

FIGURE 2
FLOW DIAGRAM FOR CREAM STYLE CORN



type. The process times, temperature, and pressures were automatically controlled and recorded by means of Foxboro instruments.

In the initial phase of this study, the filled and sealed pouches were loaded into small retort crates in a vertical position. For the second phase, the pouches were loaded into a specially built rack to aid in holding the pouches during retorting. The rack was constructed so that four pouches were placed on a 16 x 16 inch stainless steel rod tray. These trays were then placed in a holding rack that held the trays one above the other with an inch and a half between each tray.

Prior to placing the filled racks into the retort, the retort was filled half full of water and preheated to 150° F. The retort was then loaded, the thermocouple leads connected from the sample pouches to the Foxboro E.M.F. Dynalog multi-record temperature recorder, and the water level adjusted so the racks were covered. The lid was secured and the pressure controller activated so that the 27 to 30 p.s.i. superimposed pressure was obtained. This pressure was maintained throughout the retorting and cooling cycle.

The time and temperature for retort processing for both commodities were varied to determine the effect of the two commodities packaged in the various films on heat transfer. Times were varied from equivalent time required for a #303 tin can which contains the same amount of product to three-fourths of the equivalent time. Temperatures were varied depending on the flexible film.

Since the polyester-intermediate density polyethylene material (8346-1) could only be used at 230° F., equivalent times at this temperature were used. These were 21 and 28 minutes for snap beans and 81 and 108 minutes for cream style corn. However, with the other films, processes of 9 and 12 minutes for snap beans and 49 and 65 minutes for cream style corn were made at 250° F. With films designated 8546-1, 8546-2, 8546-3, and 8546-4, a process of 56 minutes at 250° F. was given for cream style corn. Furthermore, snap beans were also processed for 21 minutes at 240° F. (Figure 1).

Storage:

For films designated 8346-1, 8346-2, and 8346-3, one-half of the samples were placed in 100°F. storage while the other half was stored at room temperature (70° F.). Samples for analysis were taken at 1, 2, 3, 4, 12, and 24 weeks. For films designated 8546-1, 8546-2, 8546-3, and 8546-4, samples were stored at room temperature and analyzed at 3, 6, and 10 months.

Analysis of the Finished Product:

Color of the finished product was determined in the manner described for the raw product.

Consistency of the cream style corn was determined using a 50 gram sample with the Bostwick Consistometer.

The pH of the snap bean liquor was determined with a Beckman Zeromatic pH meter.

In the initial phase of the quality study, *E. coli* was used as the inoculum. This organism was grown and standardized in the Department of Bacteriology, O.S.U. One milliliter aliquots of the standardized suspension were inoculated into each of the test pouches. After the proper processing and the desired storage period, one milliliter samples were removed for incubation and determination of bacterial populations. The procedure recommended in Standard Methods for the Examination of Dairy Products was used to determine the number of viable *E. coli* present.

In the uninoculated samples the procedure recommended in Standard Methods for the Examination of Dairy Products was used to count the number of viable aerobic mesophiles after processing.

Aliquots were removed from the cream style corn and bean brine and duplicate pour plates were made using Tryptone Glucose Extract Agar. The plates were then examined for growth and the number of colonies present counted according to the method described in Standard Methods.

According to this procedure, if less than 30 colonies appeared on each plate, the results were reported as less than 30. However, if there were between 30 and 200 colonies, the actual number was reported. If more than 300 colonies were present, plates of higher dilution were made or the actual number of colonies present were counted, if possible.

In the second phase, Mesophilic flat sour 6230-37 and Putrefactive Anaerobe 3679-42 were used as inoculum. The organisms were grown and standardized by Continental Can Company, Metals Research Division. Twenty pouches per process variable were inoculated with the organisms, i.e., ten pouches per organism. The pouches were examined after proper processing and storage for gas and acid production according to the procedure outlined by the Metals Research Division of Continental Can Company.

In the preliminary study, samples of snap beans which were considered as sterile after six months storage according to the bacteriological examinations were evaluated by a taste panel. The triangle method was used to present the samples to the panel. Members were asked to identify the like samples and rate them on a 1 to 10 scoring system with 1 being off flavor and 10 as excellent. The beans were boiled for 12 minutes before the samples were tasted.

Results and Discussion:

The production of a high quality sterile product was the main objective of this study. Therefore, the results will be discussed in the following order:

1. Retort operation and heat penetration.
2. Appearance of the films after retorting.
3. Quality evaluation of the finished product.

Retort Operation and Heat Penetration:

Since the primary concern in establishing a sterilizing time for foods in flexible films was the operation of the retort, considerations were given to developing retorting techniques which could be applied or adapted to commercial operations. As was illustrated in the literature (11), less internal pressure was required to burst the film pouches at elevated temperatures; thus, a superimposed air pressure was necessary to counteract the internal pressure developed in the pouches at high temperatures. Furthermore, other investigators (15, 18) indicated that a superimposed air pressure not only aided in this pressure-volume relationship, but also that heat penetration was undoubtedly improved.

Pouches which were subjected to superimposed air pressure of less than 27 to 30 p.s.i. during the retort cycle burst. These data indicated that for successful retorting of food packaged in flexible films a superimposed air pressure of 27 to 30 p.s.i. must be maintained in the retort during both the heating and cooling cycle. It was also found that fluctuating air pressures were harmful to the pouches, creating a wrinkled or "shop-worn" appearance.

When the pouches were successfully retorted, the factors then considered were: (1) the amount of heat, (2) the rate of heat transfer, and (3) the length of process. These three factors were interrelated since the length of process was directly dependent upon the amount of heat and the rate of heat transfer. A temperature of 250° F. was selected because most low-acid canned foods were processed at that temperature commercially. Heat penetration data were collected in order to establish a process time. A typical heat penetration curve is shown in Figure 3.

As can be seen in Figure 3, the contents of flexible film pouches were at approximately the same initial temperature while the contents of the tin can were at a slightly higher temperature. When the heating cycle began, the temperature of the cream style corn in the flexible materials rose much more rapidly than the cream style corn in the tin can. Cooling was also more rapid in the flexible container.

The data obtained from the heat penetration tests gave an accurate indication as to the heating characteristics of the cream style corn in the various containers. These data were converted to F_0 values according to the method of Bigelow (8). These data are presented in Table 2.

From Table 2 it should be noted that the samples in the tin can received the lowest F_0 and the range of F_0 values was the smallest for these samples. The highest average F_0 was obtained with film designated 8346-1; the samples processed in this film reached the holding temperature of 250° F. on the average of nine minutes faster than samples packaged in the film which heated the next fastest (Film 8346-3). There was an average of only one minute difference in reaching the holding temperature between the other two films evaluated.

When these data were further analyzed, the samples processed in the tin can were utilized as the control or standard. The process for the samples packaged in flexible films ranged from 1.77 (8346-3) to 2.27 (8346-1) times more than for samples packaged in the tin can. Further, in order to obtain an equivalent process for cream style corn packaged in flexible films as compared to the tin can, the process would be 45 minutes for 8346-1, 53 minutes for 8346-2, and 49 minutes for 8346-3.

Table 2—F_0 Values for the Three Flexible Films and the Tin Can (5 Replicates) Calculated from Processing Cycles of 250° F. for 65 Minutes.

FILM	F_0 VALUES Test 1	Test 2	Test 3	Test 4	Test 5	Av.	Range
8346-1	39.85	49.99	58.20	48.50	36.61	46.63	21.59
8346-2	21.99	33.20	46.68	34.89	45.49	36.45	24.69
8346-3	51.57	31.95	47.87	43.13	29.82	40.86	21.75
Tin Can	14.48	31.10	19.87	14.88	22.42	20.55	16.62

Appearance of the films after retorting:

Film 8346-1 when processed at 230° F. from 21 to 108 minutes showed no delamination or other defects. However, a longer process time was required due to its temperature limitations; thus, its desirability for commercial usage was reduced. There was a direct relationship between processing time and the amount of delamination for 8346-2. Pouches which were processed for 65 minutes at 250° F. had 100 percent delamination while at 49 minutes, approximately 50 percent delamination occurred. Pouches which received a 12-minute process were only

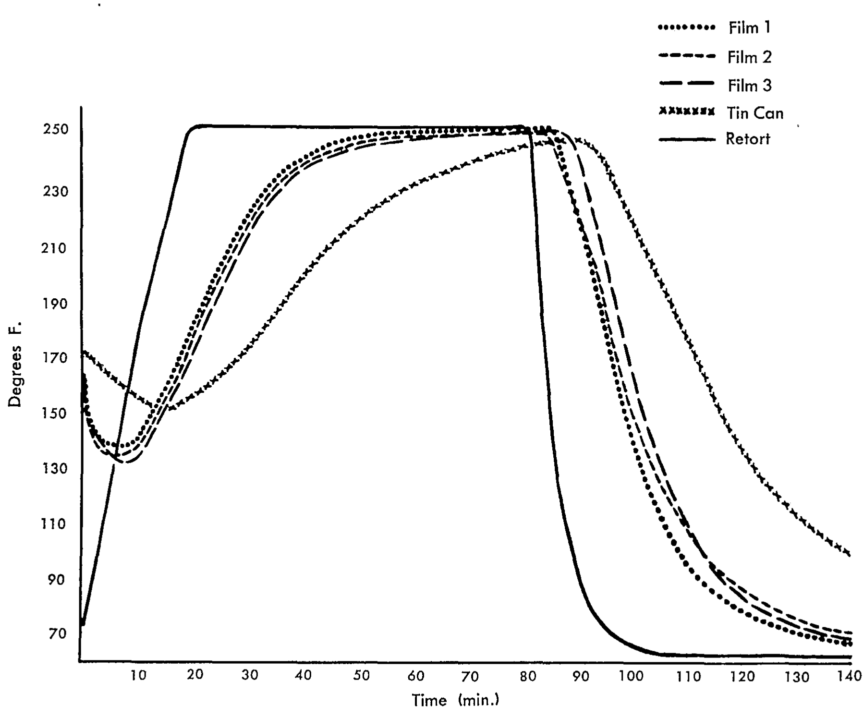


Fig. 3 — Heat penetration data represented as curves obtained from replicate 4.

slightly delaminated and wrinkled. Pouches made of film 8346-3 showed little or no apparent damage from high temperature process; however, some of the pouches were quite wrinkled and appeared to be "shop-worn." This same reaction was also obtained with pouches from 8546-1. Packages from film 8546-2 were very "shop-worn" after a 65 minute treatment. Most of the commodities packaged in this film were spoiled after one month storage. Pinholing was evident, thus reducing the shelf-life of the commodities. The data indicated that this film was undesirable for adoption to commercial processing.

Pouches made from films 8546-3 and -4 were very good regardless of retort treatment. These materials seemed to be much stronger and more resistant to the flexing obtained during the retort cycle. Since pouches of 8546-4 were clear, more variation was noticed in commodities packaged in this film. However, this would not be a disadvantage since in commercial operations the pouches would probably be overwrapped in an opaque material. These results are summarized in Tables 3 and 4.

Table 3—Physical Condition of the Various Flexible Films After Being Filled With Snap Beans Processed at Different Times and Temperatures and Stored.

Process Time and Temperature	FILMS			Tin Can (Control)
	8346-1	8346-2	8346-3	
230° F. for 21 minutes	good	------	------	------
230° F. for 28 minutes	good	------	------	------
240° F. for 21 minutes	------	Became cloudy, brittle and slight sign of delamination	Fair to good Wrinkled and "shop-worn"	
250° F. for 9 minutes	------	Became cloudy, brittle and slight sign of delamination	Fair to good Wrinkled and "shop-worn"	------
250° F. for 12 minutes	------	Became cloudy, brittle and slight sign of delamination	Fair to good Wrinkled and "shop-worn"	good

	FILMS			
	8546-1	8546-2	8546-3	8546-4
250° F. for 12 minutes	Slight delamination	Very "shop-worn"	Excellent	Excellent

The physical appearance of the pouches was not the only factor evaluated. The percent recovery was determined after the pouches were processed and any cause of seal failure was noted. These data are present in Table 5.

From Table 5 it can be seen that low, overriding air pressure, sealer damage, and product in the seal area caused a reduction in the recovery of pouches after retorting. Of these factors, a low overriding air pressure was most serious since many of the pouches burst when the pressure was reduced.

Table 4—Physical Condition of the Various Flexible Films After Being Filled With Cream Style Corn Processed at Different Times and Temperatures and Stored.

Process Time and Temperature	FILMS			
	8346-1	8346-2	8346-3	Tin Can (Control)
230° F. for 108 minutes	good	------	------	------
230° F. for 81 minutes	good	------	------	------
250° F. for 65 minutes	------	Bag delamination, 100% Brittle	Fair to good "shopworn" Wrinkled	good
250° F. for 49 minutes	------	Side seam delamination, 50% Brittle	Fair to good	------
	FILMS			
	8546-1	8546-2	8546-3	8546-4
250° F. for 65 minutes	100% delamination	Very wrinkled "shop-worn" Much evidence of Pinholing	Very good Indentions in pouch from retort rack.	Very good
250° F. for 56 minutes	100% delamination	Very wrinkled "shop-worn" Much evidence of Pinholing	Very good Indentions in pouch from retort rack.	Very good

Table 5—The Percent Recovery of Pouches by Retort Loads for Films 8546-1, -2, -3, and -4 When Retorted at 250° F. for 12 and 65 Minutes.

Film	No. Processed	No. Recovered	Percent Recovery
	12 Minutes at 250° F.		
8546-1 (a)	60	40	67
8546-2 (b)	60	33	55
8546-3	60	54	90
8546-4 (c)	60	53	88
8546-1	60	56	93
8546-2 (b)	60	39	65
8546-3	60	56	93
8546-4	60	59	98
8546-1 (d)	60	13	22
8546-2 (a)	60	50	83
8546-3 (e)	60	58	97
8546-4	60	60	100
	65 Minutes at 250° F.		
8546-1 (d)	64	8	13
8546-1	62	44	71
8546-2 (f)	63	36	57
8546-3 (e)	63	61	97
8546-4 (e)	64	58	91

(a) Top seam injured or damaged by sealer.
(b) Polyester films delaminated.
(c) Side seam damage.
(d) Overriding air pressure was less than 27-30 p.s.i. due to faulty operation of safety valve.
(e) Product in top seal area caused failure.
(f) Pouches extremely wrinkled and pinholed.

In general, the best films for processing foods were 8546-3 and 8546-4. These films were outstanding from both the standpoint of the recovery obtained and the appearance after processing.

Quality Evaluation of the Finished Product:

After the designated storage periods, samples of both commodities (snap beans and cream style corn) were opened and analyzed bacteriologically. Only the treatments which produced a sterile product after processing were evaluated for quality and reported herein.

With the 8346 films, samples were stored for six months at temperatures of 70° F. and 100° F. These samples were analyzed after 1, 2, 3, 4, 12, and 24 weeks. However, samples processed in the 8546 films were stored for ten months and were evaluated at 1, 3, 6, and 10 months. Each commodity will be discussed separately.

Snap Beans:

Quality evaluations included both subjective and objective measurements of color as well as determinations of general appearance and flavor. The average Agtron "F" values for samples processed in films 8346 and tin cans after one week and six months' storage are presented in Tables 6 and 7 respectively.

Table 6—Average Agtron "F" Values for Snap Beans Processed in Flexible Films at Various Times and Temperatures after One Week Storage at 70° F. and 100° F.

Packaging Material	Temperature	Time (min.)	Average Agtron "F" Values 70° F.	100° F.
8346-2	250° F.	9	60	58.4
8346-2	240° F.	21	57.7	58.5
8346-2	250° F.	12	58.0	57.0
8346-3	250° F.	9	59.0	57.2
8346-3	240° F.	21	58.2	57.0
8346-3	250° F.	12	58.8	57.0
Tin Can	250° F.	12	63.8	63.6

It should be noted that the color value before processing was the same for all treatments shown in Table 6. After one week storage, small differences in color were noted. The samples processed in tin cans had the highest Agtron "F" value at either storage temperature. These samples processed in film 8346-2 at 240° F. for 21 minutes had the lowest Agtron "F" value at 70° F. storage while samples processed in films 8346-2 and -3 at 250° F. for 12 minutes and samples in film 8346-3 processed at 240° F. for 21 minutes had the lowest value at 100°F. storage. There was less color variation among samples processed in film 8346-3 than those processed in film 8346-2. Further, snap beans which were packaged in film 8346-1 were not sterile. The process was at 230° F. for 28 and 21 minutes which, upon bacteriological examination, was not sterile.

Table 7—Average Agtron "F" Values for Snap Beans Processed in Flexible Films at Various Times and Temperatures After Six months Storage at 70° F. and 100° F.

Packaging Material	Temperature	Time (min.)	Average Agtron "F" Values 70° F.	100°F.
8346-2	250° F.	9	73.0	66.6
8346-2	240° F.	21	a	54.5
8346-2	250° F.	12	69.5	63.6
8346-3	250° F.	9	52.8	51.6
8346-3	240° F.	21	52.7	51.0
8346-3	250° F.	12	54.5	52.0
Tin Can	250° F.	12	66.0	67.8

a Samples spoiled after three months storage.

After six months' storage a much wider variation in color was noted. Samples processed in film 8346-2 at 250° F. for nine minutes had the highest Agtron "F" value at 70° F. storage, and samples processed in tin cans were highest at 100° F. However, the lowest Agtron "F" values at either storage temperature were those of samples processed in film 8346-3 at 240° F. for 21 minutes.

The data in Tables 6 and 7 indicated that the least change in color occurred in samples processed in the tin cans. The color change was less for snap beans packaged in film 8346-3, regardless of time and temperature of process, than it was for samples packaged in 8346-2. There was less change in color of samples processed for twelve minutes at 250° F. in both films than those samples processed at either 9 minutes at 250° F. or 21 minutes at 240° F. It should be pointed out that the color of snap beans packaged in film 8346-3 and processed at 250° F. for 12 minutes more closely resembled that of the beans packaged and processed in the tin can.

Subjective evaluations of uniformity of color and clearance of liquor were based on the U.S. Standards for Grades of Canned Green Beans and Canned Wax Beans. These data are presented in Tables 8 and 9.

Table 8—Average Uniformity of Color and Clearness of Liquor Scores for Snap Beans Processed in Different Packaging Materials at Various Times and Temperatures After One Weeks' Storage at 70° F. and 100° F.

Packaging Material	Temperature (°F.)	Time (Min.)	Av. Liquor Score[1]		Av. Uniformity of Color Score[2]	
			70°F.	100° F.	70°F.	100° F.
8346-2	250	9	8.2	8.8	11.0	11.4
8346-2	240	21	8.7	8.3	10.7	10.8
8346-2	250	12	8.6	8.8	10.8	11.0
8346-3	250	9	8.4	8.6	11.8	12.6
8346-3	240	21	8.2	8.2	12.0	12.0
8346-3	250	12	9.0	8.6	12.2	12.0
Tin Can	250	12	9.6	9.8	13.2	13.4

[1]Clearness of Liquor scale was 1-10, with ten being clear, one being cloudy.
[2]Uniformity of Color scale was 1-15, with fifteen being uniform.

The data in Table 8 indicated that after one week storage, slight differences among treatments were noticed. Samples processed in tin cans had the most uniform color and clearest liquor regardless of storage tempreature. It should be noted that the color of the other treatments was acceptable and that the liquor was quite clear.

As shown in Table 9, the beans processed in tin cans were rated as best in uniformity of color and clearness of liquor. The color of the snap beans processed in film 8346-3 was superior to that of samples processed in film 8346-2. There was little difference in clearness of liquor between samples packaged in the two films except for the cloudy liquors of the snap beans packaged in film 8346-2 and processed at 240° F. for 21 minutes.

By comparing the data in Tables 8 and 9, it can be seen that the snap beans processed in the tin cans had not changed in visual appearance. The samples processed in film 8346-3 had changed only slightly.

However, snap beans which were processed in film 8346-2 were considerably changed in visual appearance. In fact, the color of this product was a gray-green instead of the typical canned, bean color. These findings tended to support the data from the objective color evaluations.

Table 9—Average Uniformity of Color and Clearness of Liquor Scores for Snap Beans Processed in Different Packaging Materials at Various Times and Temperatures after Six Months' Storage at 70° F. and 100° F.

Packaging Material	Temperature (°F.)	Time (Min.)	Av. Liquor	Score (1)	Av. Uniformity of Color Score (2)	
			70°F.	100°F.	70°F.	100°F.
8346-2	250	9	7.8	7.8	8.6	9.0
8346-2	240	21	---	6.5	---	8.8
8346-2	250	12	9.0	8.7	8.5	8.7
8346-3	250	9	7.8	7.3	10.8	10.5
8346-3	240	21	8.0	8.3	10.8	11.0
8346-3	250	12	8.2	8.5	11.2	11.3
Tin Can	250	12	9.8	9.2	13.3	13.3

(1) Clearness of Liquor scale was 1-10 with ten being clear, one being cloudy.
(2) Uniformity of Color scale was 1-15 with fifteen being uniform.

After six months' storage, samples which were considered sterile were cooked and evaluated for flavor. The results indicated that samples packaged in tin cans were rated significantly higher than all other samples. Those processed in film 8346-2 were rated significantly lower than samples in tin cans. There was also a significant difference between samples processed in film 8346-3 at 250° F. for twelve minutes and those processed in film 8346-2 for 21 minutes at 240° F. The former samples were rated higher. In general, there were no flavor differences between the remaining treatments; although, all samples processed in film 8346-2 were rated lower than samples processed in film 8346-3.

It should be noted that the snap beans used in the six months storage study were not a variety that was highly recommended for processing. However, in the ten months study, three varieties of known processing characteristics were used.

The average Agtron "F" values for these varieties after three, six, and ten months storage at 70° F. are presented in Table 10.

From Table 10 it can be seen that the Slenderwhite variety seemed to be best suited for retort processing in flexible films. In the opague films (8546-1, -2, and -3) the beans of this variety became darker during the first six months of storage and then returned to near the original color reading after ten months' storage. The beans which were packaged in the clear film (8546-4) continued to darken throughout the storage period.

Snap beans of the Slendergreen variety darkened throughout the storage period regardless of the film in which they were packaged. After 10 months' storage, similar readings were obtained on the samples pack-

Table 10—Average Agtron "F" Values for Snap Bean Varieties Processed in Films 8546-1, -2, -3, and -4 at 250° F. for 12 Minutes after 3, 6, and 10 Months' Storage at 70° F.

Variety	Storage Period (Mo.)	Average Agtron "F" Values for Films 8546 — 1	2	3	4
Earligreen	3	63.7		65.0	64.3
	6	60.0	66.0	67.0	63.5
	10	70.0	63.0	66.0	61.0
Slenderwhite	3	61.0		61.0	65.8
	6		52.0	59.0	62.0
	10	62.3	60.0	50.0	51.0
Slendergreen	3	66.0	70.0	64.0	68.0
	6		57.0	61.0	62.0
	10	53.0	53.0	53.0	58.0

aged in the opaque films, while the color was slightly lighter for beans in the clear film pouches.

A different color reaction was obtained for beans of the Earligreen variety. In the two vinyl films (8546-1 and -2) the beans became lighter while in the polypropylene films (8546-3 and -4) the beans became darker.

Table 11—Average pH of Snap Bean Varieties Processed in Films 8546-1, -2, -3, and -4 at 250° F. for 12 minutes after 3, 6, and 10 Months' Storage at 70° F.

Variety	Storage Period (Mo.)	Average pH from Films 8546 — 1	2	3	4
Earligreen	3	5.48		5.45	5.41
	6	5.02	5.12	5.11	5.02
	10	5.28	5.11	4.96	5.22
Slenderwhite	3	5.27		5.14	5.36
	6		5.07	5.07	5.00
	10	4.92	5.14	5.11	5.30
Slendergreen	3	5.30	4.92	5.39	5.13
	6		5.00	5.12	5.06
	10	5.38	5.08	5.10	5.18

The pH of the beans of all varieties generally was within the range of 4.9 to 5.5 Samples having a pH outside this range were considered to be spoiled. The change in pH, in some cases, was closely associated with the previously discussed changes in color. In other words, the change in pH could, in part, have caused a change in color. The pH change was probably due to the oxygen permeability of the film or to microbial growth or in some instances to both factors.

In general, the beans were split and seeds were evident in all the clear packages. Sloughing was quite apparent for all varieties. This was probably due to excessive flexing of the package during the processing. It should also be noted that the color after 10 months' storage was as good or better than the color of the beans packaged in the 8346 films after six months' storage. Color variations were also reduced. This was probably due to the improvements in the pouch materials and to the selecting of desirable processing varieties.

Sweet Corn:

Objective color measurements were made on the finished product in the same manner and time periods as described for snap beans. The average Agtron "F" readings after one week and six months' storage of cream style corn processed in the various 8346 films are presented in Tables 12 and 13 respectively.

Tables 12—Average Agtron "F" Values for Cream Style Corn Processed in Different Packaging Materials at Various Times and Temperatures after One Weeks' Storage at 70° F. and 100° F.

Package Material	Temperature (°F.)	Time (Min.)	Average Agtron "F" Values	
			70°F.	100°F.
8346-1	230	108	58.50	55.88
8346-2	250	49	62.38	59.75
8346-2	250	65	54.88	51.00
8346-3	250	49	64.38	62.00
8346-3	250	65	58.25	55.25
Tin Can	250	65	57.67	55.17

The initial Agtron "F" value for all treatments shown in Table 12 was 84.63. As the data indicated, there was considerable darkening of the cream style corn after one week's storage. Samples processed in film 8346-2 at 250° F. for 65 minutes had the lowest Agtron "F" values at both storage temperatures (Table 13.) However, cream style corn processed at 250° F. for 49 minutes in film 8346-3 had the highest Agtron "F"values and was the lightest colored corn.

Table 13—Average Agtron "F" Values for Cream Style Corn Processed in Different Packaging Materials at Various Times and Temperatures After Six Months' Storage at 70° F. and 100° F.

Package Material	Temperature (°F.)	Time (Min.)	Average Agtron "F" Values	
			70°F.	100°F.
8346-1	230	108	50.63	44.83
8346-2	250	49	51.88	46.00
8346-2	250	65	44.25	44.50
8346-3	250	49	56.00	43.30
8346-3	250	65	50.50	45.50
Tin Can	250	65	53.25	55.50

From Table 13, it could be seen that the color values of cream style corn of all treatments except the tin can were approximately the same at 100° F. storage. The samples stored at 70° F. were more varied in color with the samples processed at 250° F. for 65 minutes in film 8346-2 having the lowest Agtron "F" value and the cream style corn processed in film 8346-3 at 250° F. for 49 minutes having the highest reading.

When the data from Tables 12 and 13 were compared, it was evident that the cream style corn processed in the tin can had changed least in color at both storage temperatures during the six month period. The color of the samples processed for 49 minutes at 250° F. tended to decrease more rapidly than those processed for 65 minutes at 250° F. The color changes which took place in samples packaged in 8346-2 seemed to be affected by length of process. It should be noted that although the samples processed in film 8346-1 received a longer exposure to heat, the color reactions were similar to those of other treatments.

On the basis of the preceding data, samples were processed in the 8546 films for 49, 56, and 65 minutes at 250° F. All samples processed for 49 and 56 minutes were spoiled after one month's storage; and, similarly, all samples packaged in film 8546-2 were spoiled after one month's storage. Most of this latter spoilage was due to the breakdown of film 8546-2. The average Agtron "F" values for samples processed at 65 minutes are presented in Table 14.

Table 14—Average Agtron "F" Values for Cream Style Corn Processed in Films 8546-1, -3, and -4 at 250° F. for 65 Minutes after 3, 6, and 10 Months' Storage at 70° F.

Storage Period (Mo.)	Average Agtron "F" Values for Samples Processed in Films 8546 —		
	1	3	4
3		33.6	28.7
6	43.0	49.0	41.6
10	49.9	61.6	54.5

The initial darkening of color due to processing seemed to end after three months' storage (Table 14). The samples then became lighter in color regardless of the packaging material.

Samples processed in Film 8546-3, an opaque pouch, became the lightest in color, i.e., the highest Agtron "F" value. When compared to the samples processed in the 8346 films, the corn was not as dark in color. However, the color was darker than the typical canned cream style corn color indicating a slight over-processing of the corn in the flexible pouches. It should be further pointed out that the variations in color of cream style corn packaged in the 8546 films were not as large as for those samples packaged in the 8346 films. This would indicate that a more even heat distribution was obtained throughout the pouch.

General Discussion:

The samples of both commodities were acceptable when packaged in the 8546 films. The quality of snap beans and cream style corn packaged in Films 8546-3 and -4 was slightly lower than that of samples processed in the tin can. However, the data indicated that foods packaged in flexible films could be successfully packaged, retort processed, stored at room temperature, and safely consumed. Foods prepared in this manner would offer many advantages to the processor, retailer, and consumer which were not previously available.

Since food packaged in these films could be heat processed in less time, the processor could provide a large quantity of high quality food during a short processing season. The retailer would benefit by increased sales due to the consumer appeal of the package and less shelf space to display the same amount of goods. The consumer would benefit by getting the desired portion of food, a higher quality of food due to short process, more convenience in preparation and few container disposal problems.

Summary and Conclusions:

This study was undertaken to determine the feasibility of retort processing foods in flexible films and to evaluate the quality and shelf-life of these foods. Two commodities were evaluated bacteriologically, physically, and organoleptically. Observations were made on the pouch materials concerning the appearance after processing and during storage.

The principle conclusions drawn from this study are as follows:

1. Heat penetration data indicated that the product center temperature reached the desired level in less time in the flexible films than in #303 tin cans; thus, the process time could be reduced.
2. Proper retort operations must include an overriding air pressure of at least 27 to 30 p.s.i. during both the heating and cooling cycles. Further, preheating the cooking water to 150° F. accelerated the come-up time and thus shortened the retort cycle.
3. A more uniform rate of heat penetration was obtained when a rack was used to support the pouches during retorting.
4. Films 8546-3 and 8546-4 seemed to be most desirable for retort processing due to greater recovery after retorting, durability during storage, and higher quality of the products enclosed.
5. In general, sterilization was obtained in all cases where the National Canners' Association recommendations for processing were followed. Also, sterilization was obtained at three-fourths the recommended process or 49 minutes at 250° F. for cream style corn when packaged in Films 8346-2 and -3. When cream style corn packaged in 8546 films was processed for 56 minutes at 250° F., the product was sterile as indicated by the inoculated packages, but spoilage occurred due to faulty seals or pinholing.
6. After proper retorting, snap beans and cream style corn were successfully stored in flexible films at room temperature for a ten month period.
7. The color of the snap beans and cream style corn fluctuated more in the clear packages than in the opaque pouches.
8. Variety had an important role in the processing of snap beans and cream style corn in flexible pouches.
9. Foods packaged in flexible films could be successfully retorted and stored for at least ten months with a resultant quality similar to that of the same commodities packaged in a tin can. Thus flexible films could become a commercially usable package which offers advantages to the processor, retailer, and the consumer.

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