AN ABSTRACT OF THE THESIS OF

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Title: SIGNIFICANCE OF AIR REMOVAL IN INSTITUTIONAL SIZE RETORTABLE POUCHES

Abstract approved: ______________________
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The effect of entrapped air content on heat penetration characteristics in institutional size retortable pouches packed with pears and green beans was investigated. In addition, products processed in pouches and in number 10 cans were compared using several indices of quality (color, texture, total phenolics, ascorbic acid) and sensory panel evaluations.

Heat penetration studies were conducted in an FMC Laboratory Retort. Pouches were placed in horizontal orientation, using both constrained and restrained racking methods. For green beans, a retort temperature of 121°C and 0.68 Atm (25 psig) overriding pressure, of steam and air, were used for processing. For pears a retort temperature of 98°C and 0.68 Atm (10 psig) overriding pressure, of air, were used. For both products, thermal processing times were found to

increase approximately 15 % for each 100 milliliter increase in entrapped air content, under constrained conditions. When restrained the increases were much larger. A Stock Rotomat laboratory retort which allowed the pouches to be rotated was also used. Two studies were done: first, pouches were rotated at 15 rpm, second, they were still retorted in vertical orientation. When rotated, the processing times were about one-third those obtained in the FMC retort. When the pouches were processed in vertical orientation little change in process time was noticeable even with large amounts of air, entrapped within the pouch.

Color of samples was measured by reflectance to obtain Hunter values. An Allo-Kramer shear press was used to measure the texture or firmness of both pears and green beans. Total phenolics were measured using the Folin-Ciocalteu method. The results showed that pears processed in the presence of air will darken.

In comparing products from retortable pouches with those from number 10 cans which had been processed from the same processing lot of raw product, it was found that generally the canned products were better than those processed in the pouch, however differences were slight.

Results of this study suggested that in order to obtain a better product from institutional size retortable pouches it is necessary to minimize the amount of air entrapped within the pouch.

Significance of Air Removal in Institutional Size Retortable Pouches.

by

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SIGNIFICANCE OF AIR REMOVAL IN INSTITUTIONAL SIZE RETORTABLE POUCHES

Introduction

Thermally processed foods have been consumed for about 150 years. Such foods have been packed in rigid containers of either tin coated steel or glass. Recently the retortable pouch has been developed to package these foods. The retortable pouch is a tri-laminate of plastic and aluminum foil formed into a slim package, capable of withstanding high temperatures (approved up to 121°C) for sterilization. Even though the retortable pouch has been in use in Europe, Japan and Canada for several years, its use in the U. S. is just beginning.

The first studies concerned with the use of retortable pouches for thermally processed shelf-stable foods were started in several laboratories about 1950; Hu et al (1955) reported work dealing primarily with the suitability of flexible films and laminates for thermally processed foods. Davis et al (1959, 1960) studied characteristics of packaging materials. Nelson and Steinberg (1956) and Keller (1959), reported on thermal processing of foods in retortable pouches. Gould et al (1962) studied heat processing of foods in flexible pouches considering both packaging material and product quality. Pflug et al (1963) studied the sterilization of food in flexible packages.

Manson et al (1970) developed a method to evaluate lethality in conduction-heating foods in rectangular containers.

Commercialization of the retortable pouch in the U. S. was delayed until 1977, when the FDA finally approved plastic laminates that could be used with foods exposed to retort temperatures.

Badenhop and Milleville (1980) discussed the possibility of replacing # 10 cans with institutional size retortable pouches. They suggested that there could be a significant inroad of pouches in the institutional market during the 1980's.

In the development of foods packed in institutional size retortable pouches there are some areas that remain obscure. One is the problem of residual gases entrapped within the pouch. Some effects have been discussed by several researchers, Evans (1977), Lampi (1977), Roop (1979), and Beverly et al (1980). All have agreed that the amount of entrapped uncondensable gas is critical since this gas entrapped within the pouch has a significant effect on heat penetration characteristics. Uncondensable gas can also cause severe pressure differentials between the pouch interior and the heating environment, even causing the pouch to burst if the process is not properly controlled.

The purpose of this study was to quantitatively determine some of the effects that uncondensible gases have in thermal processing and subsequent storage of french sliced green beans and diced Bartlett pears packed in institutional size retortable pouches. Selection of these two products provided an opportunity to look at very different tissues (high acid fruit and low acid vegetable) with different thermal processing requirements.

LITERATURE REVIEW

Retortable Pouches

Improved packaging materials, containers, and methods are continually being developed to maintain the quality of food products processed in them. The retortable pouch is a new kind of container consisting of a three-ply laminate. The external film is polyester, the middle ply is aluminum foil and the inner ply is a high performance heat sealable polyolefin film, Norman (1979).

The polyester film gives the pouch strength, protection to the foil from creasing and perforation, and an attractive appearance. The foil provides the essential barrier to protect the product from oxygen and light and prevents loss of flavor volatiles. The inner film, inert to the food product, has high integrity at retorting temperatures of up to $121^{o}C$ and is heat-sealable.

The retortable pouch has been called the greatest packaging development since the invention of canning and freezing. Even though fabrication of this package has been possible in the U. S. since the mid 1960's and was the object of considerable research and development work in the 60's and early 70's, it was in the latter 70's that interest in its use became appreciable. Use of the retortable pouch was established earlier in Japan, where it was reported in 1979 that some 400-500 million pouches were sold each year. It was further estimated that a European market might sell in 1981 between 55-60 million retortable pouches per year (Bannar, 1979).

Development of the retortable pouch in the U. S. was delayed by the U. S. Food and Drug Administration until 1977 when the materials for producing pouches were approved. At this point also the Defense Department of the U. S. Goverment began a project called Meals Ready to Eat (MRE), a program which involved the use of retortable pouches to replace the thermally processed foods contained in the "c" ration packs.

Retortable pouches were introduced to U. S. consumers by the Continental Kitchens Division of the International Telephone and Telegraph Co. which started a marketing test for a line of pouched entrees in 1978. In 1980 Kraft Inc. began running marketing test of a series of A la Carte entrees. It has been reported that this test exceeded its goal of selling the equivalent, on a nationwide annual basis, of 30 million eight-ounce packages of beef stew, sweet and sour pork, creamed chicken, beef burgundy and beef stroganoff (Peters, 1980). ITT Continental claimed similar results for its marketing test.

There are some advantages in replacing the # 10 can with the institutional size retortable pouch for the institutional market. The pouch is lower in cost,and permits the packaging of products in containers of less weight and volume than is possible with rigid containers. Because of the lower requirement for excessive heat during sterilization, resulting from a more favorable geometry for heat transfer, the quality and flavor of the products are improved. Furthermore savings in reduced cost of brine and syrup are realized since less volume of the pack liquid is required because the package conforms to the shape of the product which it contains. This also results in reduced shipping weights, the pouch is less hazardous to open and use, and disposal is convenient since empty pouches require less volume and are much lighter in weight.

Pouches for the institutional food market require less marketing effort than marketing to the retail trade. Less cost and effort are required to educate institutional users than individual consumers (Badenhop, 1980). From a practical viewpoint, the first product entering the market in institutional size retortable pouches will probably be fruits and other acid foods. Some of the factors which have precluded acceptance and growth of retort pouched foods by the industry are the slow speed of the equipment that fills the pouches and the huge investment that food processors will be required to make in order to change their packaging methods. Another important factor is the cost for form-fill-sealing, retorting and packaging which is four to five times more expensive than present processing inefficiencies. Another factor is that premium priced entrees are available in frozen boil-in-the-bag type pouches, constituing a small but elite market. Current retortable pouch packaged products compete in this high-priced market and do not represent distribution savings over frozen foods. Finally in socio-economic terms, there is currently very little need in the U. S. for shelf stable foods in a retortable pouch. Low priced foods are available in other types of shelf stable containers, and competitive products are available frozen.

In developing countries however, where the frozen food industry is not well established and there are no efficient frozen or refrigerated food distribution systems, the chance of success is higher, presuming that machinery development will follow to permit a low cost equipment system (Whelan, 1980).

Thermal Process Calculations

Thermal processing is a fundamental operation in food preservation. It is used to inactivate food spoilage microorganisms and enzymes. Occasionally it is also used to improve texture and other quality characteristics of foods.

One of the major tools for calculating thermal processes for retorted foods is Ball's formula method, introduced by C. Olin Ball in 1923. With this and other proposed calculation methods, Hicks (1951), Gillespy (1951), Stumbo (1948, 1949, 1953) Manson (1970), the basic objective of the calculation has been to establish the time at retort temperature which will result in the reduction of a hypothetical population of spores to some small (although finite) value. The end point or total reduction is also based in part on maintaining the quality of the food. Therein lies the most important boundary condition on the process, for without maintenance of quality factors (color, flavor, texture, nutritional content), there would be no incentive to purchase the product. Thus, some safe but reasonable end point must be established for the reduction in spores to reduce the probability of either health or economic hazard.

Assuming that an end point or reduction in an assumed population of spores can be established, the process is calculated by determining the combination of time and temperature necessary to accomplish that objective.

Excessive thermal processing should be avoided. Optimization of economy and product quality demands a well controlled thermal process.

Ball's formula method is a procedure that predicts the degradation of thermally vulnerable factors during heat processes, through combined applications of physical principles for heat and mass transfer in food and reaction kinetic principles for thermal degradation. This method was chosen because, in spite of its limitations, it is widely used in the food industry and it is a simple and fast method.

Ball's Method For Thermal Process Calculations

Considering a suspension of bacterial spores subjected to a constant lethal temperature T, it was found experimentally that the rate of destruction of the spores is given by:

$$-\frac{dn}{dt} = k_T\, n \qquad (1)$$

This is equivalent in terms of common logarithms to:

$$\frac{d(\log_{10} n)}{dt} = \frac{1}{D_T} \qquad (2)$$

where $D_T = 2.303/k_T$. Thus, a plot of the logarithm of the concentration (n) of the surviving spores vs time is a straight line called a survivor curve.

The coefficient D_T is a characteristic of the type of spore in the medium under consideration and is found experimentally to vary with temperature according to :

$$D_T = D_{T_{ref}} \, 10^{(T_{ref}-T)/z} \qquad (3)$$

Here, D_T is the D value at temperature T; T_{ref} is an arbitrary reference temperature; $D_{T_{ref}}$ is the D value at T_{ref}; and z is a characteristic of the microorganism which can be considered constant over normal processing conditions.

Consider a single type of spore suspended in a food container which is heated and cooled during a thermal process. The temperature at a given point in the container is a function of time, T(t). The change in spore concentration at that point is found by substituing Eq. 3 into Eq. 2. Integrating between terms t_a and t_b, when spore concentrations are "a" and "b", respectively, gives:

$$-\int_a^b d(\log_{10} n) = \frac{1}{D_{T_{ref}}} \int_{t_a}^{t_b} \frac{dt}{10^{(T_{ref}-T(t))/z}} \qquad (4)$$

Evaluating the left-hand integral results in two expressions for the sterilizing value "F"

$$F^z_{T_{ref}} = D_{T_{ref}} (\log a - \log b) = \int_{t_a}^{t_b} \frac{dt}{10^{(T_{ref}-T(t))/z}} \qquad (5)$$

The left hand expression gives the relationship between F and the change in concentration of spores. In particular, "a" is the initial concentration of spores in the food; its value is established by experimental observation. If "b" is a "safe" final concentration of spores established from public health or spoilage rate consideration, the "required F value" can be expressed:

$$(F^{z}_{T_{ref}}) \text{ required } = D_{T_{ref}} (\log a - \log b) \qquad (6)$$

The right hand side of Eq. 5 relates to the time-temperature process T(t) that the spores have undergone between times t_a and t_b, and it will be the "F" value of the process:

$$(F^{z}_{T_{ref}}) \text{ process } = \int_{t_a}^{t_b} \frac{dt}{10^{(T_{ref}-T(t))/z}} \qquad (7)$$

The subscript T_{ref} on F indicates that the entire integrated time-temperature effect on the spores is equivalent to the time F minutes at the single temperature T_{ref}. Common reference temperatures are 121°C for low acid foods and 100°C or 93.3°C for higher acid products. The superscript z emphasizes that only one type of spore is considered.

Eq. 7 was used for the thermal process calculations and results are reported as the time t_b for a given heating and cooling cycle, for given values of z, and T_{ref} , which produces $F_{process} = F_{required}$, or Lethality = 1 ;

$$\text{Lethality} = \frac{(F^{z}_{T_{ref}})_{process}}{(F^{z}_{T_{ref}})_{required}} = 1 \qquad (8)$$

Pouch Testing Methods

A. Burst Test Measurement

The internal burst test for seal integrity has been generally accepted as a good overall measure of the ability of the retortable pouches to withstand transportation and handling (Lampi et al 1976). It was proposed by Schultz (1973) for the same purpose. A prime advantage of the test is its ability to detect the weakest section of the pouch seal no matter how narrow the seal might be. One apparatus for its measurement involves the placement of the open end of an unsealed pouch over an air source fixture, and clamping it around the fixture to prevent air leakage. Air is then admitted into the pouch at a predeterminated rate until the pouch bursts. The pressure required to burst the pouch is recorded.

B. Tensile Test Measurement

Seal tensile strengths (the pulling apart of a heat seal) are measured dynamically on Instron or similar equipment by measuring the force or weight required to cause failure over the total width of a sample strip, usually 25 mm wide. The detection of any channels, stress points and the effect of occluded particles or other small weak areas within this dimension is obscured by adjoining high value (stronger) areas. Tensile tests should be, therefore, supplemented by the burst test (Lampi, 1979). For this study a Thwing-Albert electronic tensile tester was used.

MEASUREMENT OF COLOR

Color is an important factor in determining the acceptability of a product by the consumer. The importance of color is derived from the fact that the consumer associates certain color characteristics with quality. Color was defined by Judd (1952), who stated that, "Color is the evaluation of radiant energy (physics) in terms that correlate with visual perception (psychology)."

A. Green Beans

The color of green beans is primarily due to the presence of chlorophyll A and B. The principal color change in green beans was noted by Siegele (1955) to be due to the conversion of chlorophyll A and B to pheophytin A and B. Mackinney and Weast (1940) noted that the formation of pheophytin involved the removal of magnesium from the chlorophyll molecule. The conversion can be illustrated by the following equations:

Chlorophyll A to Pheophytin A

$$C_{55}H_{72}O_5N_4Mg + 2H^+ = C_{55}H_{74}O_5N_4 + Mg^{++}$$

Chlorophyll B to Pheophytin B

$$C_{55}H_{70}O_6N_4Mg + 2H^{+} = C_{55}H_{72}O_6N_4 + Mg^{++}$$

thus the change in color of the green beans from green towards yellow involves the loss of magnesium from the chlorophyll molecule.

B. Bartlett Pears

Color is an important quality aspect of processed pears. Color is a quality attribute which together with flavor and texture plays an important role in food acceptability. In addition, color may provide an indication of chemical changes in a food such as occur during heating, e. g., browning. The color of pears is mainly a matter of reflection rather than transmission.

Polyphenolic compounds are of interest in pears because of their effect on color. Several color defects in pears have been associated with the presence of polyphenolic compounds. Weurman and Swain (1953) suggested that chlorogenic acid is a major subtrate for polyphenol oxidase in pears, the activity of which leads to the browning of tissue when the fruit is cut. Ranadive and Haard (1971) correlated the tendency to brown with total phenolic content and in particular with chlorogenic acid and catechin content.

A large number of polyphenolic compounds have been isolated and identified from pears (Nortje and Koepper, 1965; Sioud and Luh, 1966; Durkee _et al_., 1968; Duggan, 1969; Mogel and Hermann, 1974).

However, the major polyphenolic compounds present in pears appear to be chlorogenic acids, (+) catechin, (-) epicatechin, and two leucoanthocyanidins.

C. Color Measurement

Developed in 1952, the Hunter Color and Color Difference Meter has been increasingly used over the years. Cain _et al_ (1953) used the Hunter Meter in collecting data on the effect of canning and freezing on different varieties of green beans. Woodroff, Heaton , and Ellis (1962) reported on the color of different varieties of beans and their change in color over storage as measured by Hunter Meter.

Three scales are evaluated by the Hunter Color and Color Difference Meter, "L", "a", and "b". which may be described in terms of a modification of the color solid. The "a" and "b" scales are laid out in Cartesian Coordinates, while the "L" scale is perpendicular to the plane of the diagram. The Hunter "a" values are measures of redness when positive or greenness when negative, while the Hunter "b" values are measures of yellowness when positive or blueness when negative.

Measurement of Texture (Firmness)

Various methods have been used to measure texture (firmness) objectively by physical means. Until recently, most methods consisted of instruments with calibrated springs and scales to which was attached a blunt pointed needle or knife. Guyer, Kramer, and Ide (1950) used a modified fruit pressure tester in evaluationg the texture of various varieties of green beans. The instrument was modified in that the plunger normally found was replaced with a blunt cutting edge. A highly significant difference between varieties was found at all stages of maturity.

Van Buren et al. (1957) studied firmness using a texturometer which evaluated firmness in terms of force required to compress the beans to a certain level. Culpepper (1936) used a blunt pointed needle to evaluate changes in texture of green beans with increase in maturity.

A more recent means of measuring texture is by use of the shear press. The shear press simulates the action of chewing where the teeth first compress and then shear through the food. The instrument has been found to be highly versatile in that with proper modifications it could measure the texture of a wide variety of foods, and give reproducible results. Sistrunk (1959) measured the texture of canned beans using the Maryland Shear Press. He found that shear press measurement of texture was negatively correlated with sloughing and highly significant. Cain et al (1953) used the same instrument to study the effect of canning and freezing on different varieties of Blue Lake Green Beans. More recently measurements of texture have been evaluated using an Allo-Kramer Shear Press.

Browning Prevention with Sulfur Dioxide

Many compounds containing sulfur have been widely used to prevent discoloration of fruits. These include sulfurous acid and its salts (bisulfites and metabisulfites), the mechanism of the inhibition of enzymic browning by sulfur dioxide was studied by Embs and Markakis (1965) with mushroom PPO on catechol at pH 6.5. They showed that inhibition was not due to the removal of oxygen by oxidation of sulphite to sulphate, but was due partly to inactivation of the enzyme itself and partly to the formation of o-quinone sulphite. The onset of browning was delayed until all the sulfur dioxide had been consumed by these reactions and then proceeded at a rate dependent on the residual activity of the enzyme.

EXPERIMENTAL

Pouch Integrity Studies

A. Air Burst Test

This test was done to evaluate the seal integrity of retort pouch seals, with a Continental Pouch Air Burst Tester. In this test three seals are evaluated simultaneously to detect the weakest section of seal. The procedure for this test was as follows: pouch lips were inserted around the air outlet and between the rubber covered jaws. Clamp jaws tight on lips of pouch and valve was released letting air into pouch, bursting pressure was observed and recorded in Psig. Valve was closed and burst pouch was removed.

B. Seal Tensile Strength Test

The purpose of the seal strength test is to determine the dynamic force required to separate a heat seal. For this purpose a Thwing-Albert electronic tensile tester was using the following procedure; representative samples were obtained from the pouches from both manufacturer seal and from packer seal. Strips were cut 2.5 cm wide, and 7.5 cm long with a Precision Strip Cutter Board. The samples were inserted into the upper and lower jaws of the tensile tester, tightly to avoid slippage, the force applied was 9 Kgs full scale load with a cross head speed of 12.7 cm/min and a chart speed of 1.3 cm/min. The results were recorded as Kgs strength/2.5 cm width.

C. Method for Detection of Seal Contamination

In order to detect any contamination of the seal it was delaminated in the following manner: the outer ply (polyester) was removed with a chromic-sulfuric acid solution (25 c.c. of chromerge dissolved in 4 Kgs of sulfuric acid), by immersing the seal of the pouch into this solution under a hood for 10 min, and then washing the pouch with detergent. The aluminum ply was removed with a 2 N solution of sodium hydroxide by placing the seal into this solution and under the hood for 15 min, after it was rinsed with water and the seal examined.

MEASUREMENT OF AIR CONTENT

A. Destructive Method

Air content was measured by opening the pouch under water and trapping the air coming out of the pouch with an inverted filter funnel connected to an inverted burette full of water. The amount of air was measured as the volume of water displaced from the burette.

B. Calculation Method.

Air content was calculated for pouches filled with product (of density ρ) to a volume (P) by weighing the sealed pouch in air (W_a) and in water (W_w). The pouch laminate volume (v) and weight (w) were also obtained, and all these values were entered in Eq. 4.

This method developed by Evans (1977) assumes that the volume of a sealed pouch is directly related to the volume of air entrapped within the pack.

Therefore, $$a = V - v - P \qquad \text{Eq. (1)}$$

if; $$V = (W_a - W_w)/\rho_{H_2O} \qquad \text{Eq. (2)}$$

and, $$P = \frac{W_a - w}{\rho} \qquad \text{Eq. (3)}$$

then: $$a = \frac{(W_a - W_w)}{\rho_{H_2O}} - \frac{(W_a - w)}{\rho} - v \qquad \text{Eq. (4)}$$

Where:

a = Air content of pack, volume (c.c.) of air.

V = Pack overall volume (filled and sealed pouch) in c.c.

v = Pouch laminate volume.

P = Product volume.

W_a = Pack weight in air.

W_w = Pack weight in water.

w = Pouch laminate weight.

ρ = Product density (g/c.c.).

ρ_{H_2O} = Water density (g/c.c.).

THERMAL PROCESS STUDIES

A. Insertion and Location of Thermoccuples in Retortable Pouches.

Thermocouples are used to obtain time-temperature data to develop the heating characteristics of a food product heated in a package at the slowest heating point.

Ecklund (1949) was probably the first to describe a thermocouple assembly designed specifically for measuring temperatures in canned foods during the evaluation of heat sterilization processes. Ecklund type thermocouples were used in this study.

The lack of rigidity of retortable pouches rules out the devices and systems commonly used to obtain heat penetration data for food products processed in rigid containers.

The thermocouples were inserted in the following manner: a 15 cm long Ecklund thermocouple was fitted through a 3.5 mm diameter orifice in the empty pouch and sealed using rubber gaskets before filling. The thermocouple junction was supported and maintained in a fixed location with plastic tubing fastened to the pouch with tape. This fixed known location was necessary in order to obtain meaningful data. It was assumed that the plastic tubing and the tape offered negligible resistance to heat transfer.

After the retortable pouches were fitted with thermocouples, they were carefully filled with the food product and pieces of that product were inserted on the thermocouples.

Thermocouples were located at the geometric center of the pouches, which contained 100 ml or less air entrapped within the pouch. For pouches containing more than 100 ml air the thermocouple was elevated to a position one third of the total pouch thickness from the top as shown in Fig. 3.

B. Determination of the Cold Spot

Several tests were run to locate the coldest spot when entrapped air was present within the pouch. One is as follows: each pouch was fitted with 3 thermocouples 15 cm long, one in each side of the manufacturers seal, all ending in the center, then with plastic tubing they were adjusted so that one was always in the middle, and the other two at different positions from the center. Pouches were filled with product to a total thickness of 3.8 cm, and mechanically evacuated and sealed in a Multivac Sealer model AG-4. Different amounts of air were injected to obtain pouches with 5, 100, 200, and 300 ml of entrapped air within the pouch.

Thermocouples were then connected to a Kaye Digistrip I thermocouple monitor and the pouches were retorted. After retorting air content was measured by both methods.

C. Processing Procedure

An FMC Laboratory Retort and a Stock Rotomat Laboratory Retort, both using pressurized steam-heated water with compressed air or steam supplying the overriding pressure through a water leg from a steam-heated water reservoir, were used to heat-process the retortable pouches. This steam-heated water medium was chosen since they are being used by several retortable pouch food processors in the U. S.

Heat distribution studies were done by measuring temperatures at different points in the retort to determine temperature variation. No significant temperature difference was observed among thermocouple locations. Temperature differences at the several locations throughout the retort were consistently less than 1.1^{o}C. No evidence of cold pockets was found in the retort.

The retorting procedure was as follows:

1) Retort loaded and closed.
2) Preheated water pumped to retort.

3) Compressed air and steam added to give a pressure of 25 psig.
4) Retort up to temperature; process timing starts.
5) At end of process time pressure was maintained hot water was pumped out and cold water was supplied.
6) Cooling water drained when the pouches are cooled to 40°C or lower.

D. Heat Penetration Studies with French Sliced Green Beans with Different Amounts of Entrapped Air Within the Pouch

Institutional size retortable pouches fitted with one 15 cm Ecklund thermocouple, located as previously described, and prepared with a spot of silicone in one corner to inject the different amounts of air, were filled in a custom made semi-manual filler, with 2.1 Kg of french sliced green beans (previously washed, snipped, sorted, blanched, cut and cooled to approximately 30°C). Three-tenths Kg of 10 % brine was added to give a total thickness of 3.8 cm.

Pouches were sealed in a Multivac sealer with 27.5 in vacuum (which leaves 5 ml residual gases entrapped in the pouch). Different amounts of air (100, 200, and 300 ml) were added to each pouch through the silicone seal with a hypodermic syringe.

These pouches were placed in trays in horizontal orientation with 3.8 cm dividers between the trays, to constrain the pouches and they were loaded into an FMC laboratory retort model 500-W, this retort has a horizontal flow of water across the trays carrying the pouches, water is introduced at the top of the car and directed to a perforated vertical plate (at right of cross-sectional diagram Fig. 1) which distributes water uniformly across the entire retort load.

Thermocouple readings were taken with a Kaye Digistrip I thermocouple monitor. Pouches were thermally processed at 121^{o}C and 0.68 Atm overriding pressure of steam and air to obtain an F_o value of 5.

E. Heat Penetration Studies with Diced Bartlett Pears

Retort pouches, fitted with thermocouples and prepared as before, were filled with 2.7 Kgs of diced Bartlett pears (previously washed, sorted, peeled, and diced). No syrup was added. The total thickness was 3.8 cm.

Pouches were sealed, injected with different levels of air and loaded into the retort in the same fashion as for green beans, diced pears were thermally processed at 98^{o}C and 0.68 Atm overriding pressure of air to obtain an F_{200} value of 3.

FMC CONVENIENCE FOODS STERILIZER
HOT WATER WITH OVERRIDING AIR PRESSURE
WATER FLOW PRINCIPLE

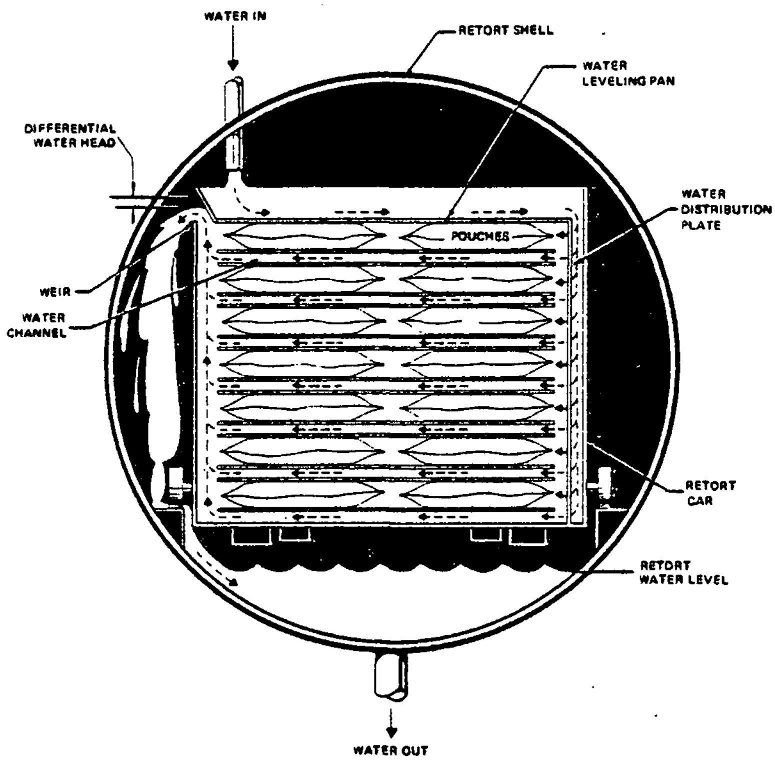


Fig 1. Cross-section of FMC retort showing horizontal flow of water across the trays.

Color Determination by Hunter

Hunter "L", "a" , and "b" values were determined for all samples by using a Hunter D-25 Colorimeter in the reflectance mode and a 4 cm glass rectangular cell.

The Hunter "L", "a" , and "b" scales consist of a lightness scale, "L", and chromaticity scales, "a", and "b". The lightness scale is divided into 100 equivalent units, with white equal to 100, and black equal to "0" (zero), and shades of gray in between. This scale is designed to simulate human perception of lightness (Hunter 1975). The positive side of the "a" scale measures redness; while the negative side measures greeness. The positive side of the "b" scale measures yellowness; while the negative side measures blueness.

The Hunter light source was kept in alignment with the light collecting sphere (position I) to obtain readings which include only diffuse reflected light.

In the experiments involving the Hunter Colorimeter, whole pieces of samples were used and liquid from cans or pouches was used to fill the interstices.

Texture (Firmness) Determination

Texture (firmness) of product was measured using an Allo-Kramer model S2HE shear press. A sample of 100 grams of drained product was placed in the cup of the standard cell, the shear press was set at a range of 2 and 100 lbs of total force. The resistance to shear (firmness) was calculated by multiplying the area obtained from the recording chart times a force unit.

Total Phenolic Content

Phenolics were measured using the Folin-Ciocalteu reagent. Preparation of the reagent and the reaction conditions used were the same as suggested by Singleton and Rossi (1965). 25 g of the sample were placed in a semimicroblendor jar with 100 ml of water and blended at full speed for 1 min. The solution was placed in a Bronwill Biosonik III ultrasonic disintegrator for 1 min to disintegrate the cell walls. Next the solution was centrifuged and 10 ml of the supernatant solution was placed in a volumetric flask with the Folin-Ciocalteu reagent. Total reaction volume was 100 ml. The analysis was done in duplicate.

A standard curve from zero to seven-hundred mcg gallic acid (recrystallized twice) was prepared. The molar absorptivity of gallic acid used was 22,500. Results were calculated in gallic acid equivalents. Sample absorbance was determined at 765 nm using 1.0 cm pathlength cells and a Perkin-Elmer 550 spectrophotometer.

Ascorbic Acid

Ascorbic acid was determined according to the method described by Loeffler and Ponting (1942). A fifty g sample previously chopped in a Waring Blendor was weighed, placed in a semimicroblendor jar with 100 ml of 1 % metaphosphoric acid and blended at full speed for 1.5 min. The solution was filtered through Whatman No. 4 paper. An aliquot was diluted in a volumetric flask with 1 % metaphosphoric acid.

Ascorbic acid was determined in a Beckman grating spectrophotometer at 525 nm, as follows:

a) Dye factor (L_d): The instrument was calibrated to zero absorbance with 1 % metaphosphoric acid. The absorbance of the 2,6-dichlorophenol-indophenol solution (dye solution) was determined. Nine parts dye solution and 1 part 1 % metaphosphoric acid were mixed and placed into a 1 cm quartz cuvette. Absorbance X 100 was recorded as G_{dn}. Dye factor equal $L_d = D_d - G_{dn}$.

b) Sample reading (L_s) : Nine parts dye solution and 1 part sample solution were mixed and placed in a 1 cm quartz cuvette.
Absorbance X 100 was recorded as G_s. The dye-sample solution was decolorized by adding ascorbic acid crystals, mixed again, and absorbance X 100 was recorded as G_r. Sample reading equal $L_s = G_s - G_r$.

The standard curve was prepared using standard solutions of ascorbic acid in 1 % metaphosphoric acid treated as above. The standard curve was used to determine the constant K value, which is the mg of ascorbic acid per unit change of absorbance on the scale (L_d - L_s).

c) Calculation: Ascorbic acid content of the sample was determined as follows:

$$\text{Ascorbic acid (mg/100 g sample)} = \frac{K(Ld - Ls) \times 100}{D}$$

where D was the dilution factor (g original sample/ ml of final test sample).

Comparison Between Products Thermally Processed in Institutional Size Retortable Pouches and Food Cans

The same previously discussed physical and chemical methods of analyses were used to compare both products (french sliced green beans and diced Bartlett pears) thermally processed in institutional size retortable pouches (containing 5 ml of entrapped air) and in food cans.

Sensory Evaluation

A sensory evaluation to compare quality of the products was also accomplished with a 40 member trained taste panel from the Oregon State University Food Science Department. The panelists were asked to judge color, over-all appearance, texture, flavor, and over-all desirability, and rank hedonically the samples according to preference. The samples were ranked from one to nine, one meaning extremely undesirable and nine meaning extremely desirable. Individual booths lighted with white incandescent light were used.

I. Diced Bartlett Pears

For the retort pouched samples two treatments were used one was diced pears with nothing added, the other was diced pears treated with 200 ppm of sulfur dioxide (to prevent browning).

One number 10 can sample of diced pears packed in light syrup, and obtained from the same processing lot of raw product as the pouched pears, was used for the taste panel. All three samples were stored at 21°C.

The pouches and can were opened and 30 gr samples were served to the sensory panel at room temperature in coded paper cups, placed in trays at random.

II. French Sliced Green Beans

Two samples of retort pouched french sliced green beans were tested. One was stored at 21°C for 24 weeks and the other was stored at 37°C for 24 weeks, both with 5 ml entrapped air within the pouch. One can sample (303X 406 can), from the same processing lot as the pouched product, was also tested.

The pouches and can were opened, poured into a pan, boiled for 3 min, and then placed in boiling water baths to keep the product hot and at constant temperature (90°C) until served. 30 gr samples were served in coded paper cups, placed in trays at random, and presented to panelists at 55-60°C.

The mean scores for each sample were compared using a statistical t test.

RESULTS AND DISCUSSION

Air Burst Test

The air burst test was used to evaluate pouch performance of institutional size retortable pouches from three different manufactures (Reynolds Metals Co., American Can Co., and Ludlow Co.). Pouches were sealed in a Multivac sealer where settings for sealing temperature and pressure were controlled to obtain the best seal for each different pouch. Table 1 shows that when the parallel burst tester spacing plates were reduced from 3.8 cm profile to 2.5 cm, increases in burst pressure up to 69.5 % were obtained for Ludlow pouches. However Reynolds pouches had the highest readings at both (3.8 and 2.5 cm) profile separations. However this is not a sign of superiority. As stated by Evans et al (1978) seal strength at ambient temperature has little relation to seal strength at processing temperature since high heat processing temperatures may reduce seal strength due to the loss of the volatile plasticizer that is part of the thermoplastic mixture which forms the sealing ply.

Effectiveness of Evacuation Methods

Results from table 2. indicate that depending on the evacuation method there will be different amounts of air and/or uncondensible gases remaining in the sealed pouch.

The values for mechanical vacuum and mechanical vacuum with nitrogen backflush evacuation methods, were obtained using a Multivac sealer. The value for steam exhaustion was obtained using an FMC filler sealer. It is necessary to have knowledge of the effects that these gases have in order to maintain optimal processing conditions and achieve commercial sterilization of the product.

Seal Tensile Strength Test.

Table 3. shows the effect on tensile strength of different amounts of air entrapped in retortable pouches thermally processed in an FMC horizontal still retort (at 100°C for 30 min) and in a Stock Rotomat retort that rotated the pouches at 15 rpm (at 100°C and 6 min). Statistical analysis of these results showed that there is no correlation between different amounts of air entrapped within the pouch and the change in the seal tensile strength. This indicates that rotating the pouches during retorting had no effect on seal tensile strength after retorting.

Results from table 4. show that processing time had no significant effect on pouch seal tensile strength after retorting, when institutional size retortable pouches containing 2.7 Kg of diced pears and 5 ml of entrapped air were rotated at 15 rpm in a Stock Rotomat retort.

Table 1. CHANGE IN BURST PRESSURE WITH INCREASING PROFILE THICKNESS[A], IN INSTITUTIONAL SIZE RETORTABLE POUCHES.

MANUFACTURER	PROFILE SEPARATION[B]		% INCREASED
	3.8 cm	2.5 cm	
American Can Co.	18.8 ± 0.46	27.7 ± 1.27	67.8
Ludlow Co.	21.5 ± 0.78	30.9 ± 1.74	69.5
Reynolds Metals Co.	26.1 ± 0.42	45.2 ± 1.41	57.7

[A] Burst test Values reported in psig.

[B] Means of 15 observations ± standard deviation.

Table 2.- AVERAGE AMOUNT OF RESIDUAL GASES ENTRAPPED IN INSTITUTIONAL SIZE RETORTABLE POUCHES, WITH DIFFERENT EVACUATION METHODS.

EVACUATION METHOD	RESIDUAL GASES[a] ml
Mechanical Vacuum	5 ± 4.45
Mechanical Vacuum with N_2 Back flushed	250 ± 43.61
Steam Exhaustion	150 ± 55.99

[a] Means of 25 observations ± standard deviation

Table 3.- EFFECT OF AIR ENTRAPPED IN RETORTABLE POUCHES ON SEAL TENSILE STRENGTH[a].

Retort	Amount of Air, ml	Kgs Strength / 2.5 cm Width[b]
FMC	5	6.6g
FMC	100	5.3g
FMC	200	3.7h
FMC	300	6.6g
Stock Rotomat	5	7.0g
Stock Rotomat	100	6.9g
Stock Rotomat	200	7.0g
Stock Rotomat	300	6.9g

[a] Using a Thwing-Albert Electronic Tensile Tester.

[b] Average of 5, 2.5 cm wide sections from same pouch.

[g,h] Means with the same letter within a vertical subgroup do not differ significantly.

Table 4 .- EFFECT OF PROCESSING TIME IN A STOCK ROTOMAT RETORT ON POUCH SEAL TENSILE STRENGTH[a].

Retort	Processing Time, min	Kgs Strength / 2.5 cm width[b]
Stock Rotomat	5	7.6g
Stock Rotomat	10	7.7g
Stock Rotomat	20	6.9g
Stock Rotomat	30	7.3g

[a] Using a Thwing-Albert Electronic Tensile Tester.

[b] Means of 5, 2.5 cm wide sections from same pouch.

[g] Means with the same letter do not differ significantly.

Determination of Coldest Spot in a Pouch During Process

After drawing heat penetration curves similar to those shown in Fig. 2 for each thermocouple, it was observed that for pouches with an air content of 5 or 100 ml the coldest heating point was in the geometric center (1.9 cm from bottom), and for pouches containing 200 or 300 ml the coldest spot was located at one third of the total thickness from the top (2.52 cm from the bottom) Fig. 3.

Heating-Characteristics Studies for Diced Pears

The heating time required to reach an F_{200} value of 3 was determined for diced Bartlett pears packaged in institutional size retortable pouches 30.5 cm wide, 38.1 cm long, and 3.8 cm thick.

Figure 4 gives the heating characteristics of pouches filled with 2.7 Kg of diced Bartlett pears, with different amounts of air (5, 100, 200, and 300 ml) entrapped within the pouch and thermally processed under constrained (firmly sandwiched between two adjacent racks) conditions.

From these results, it is shown that, required thermal processing times increased approximately 15 % for each 100 milliliter increase of air content, under constrained conditions.

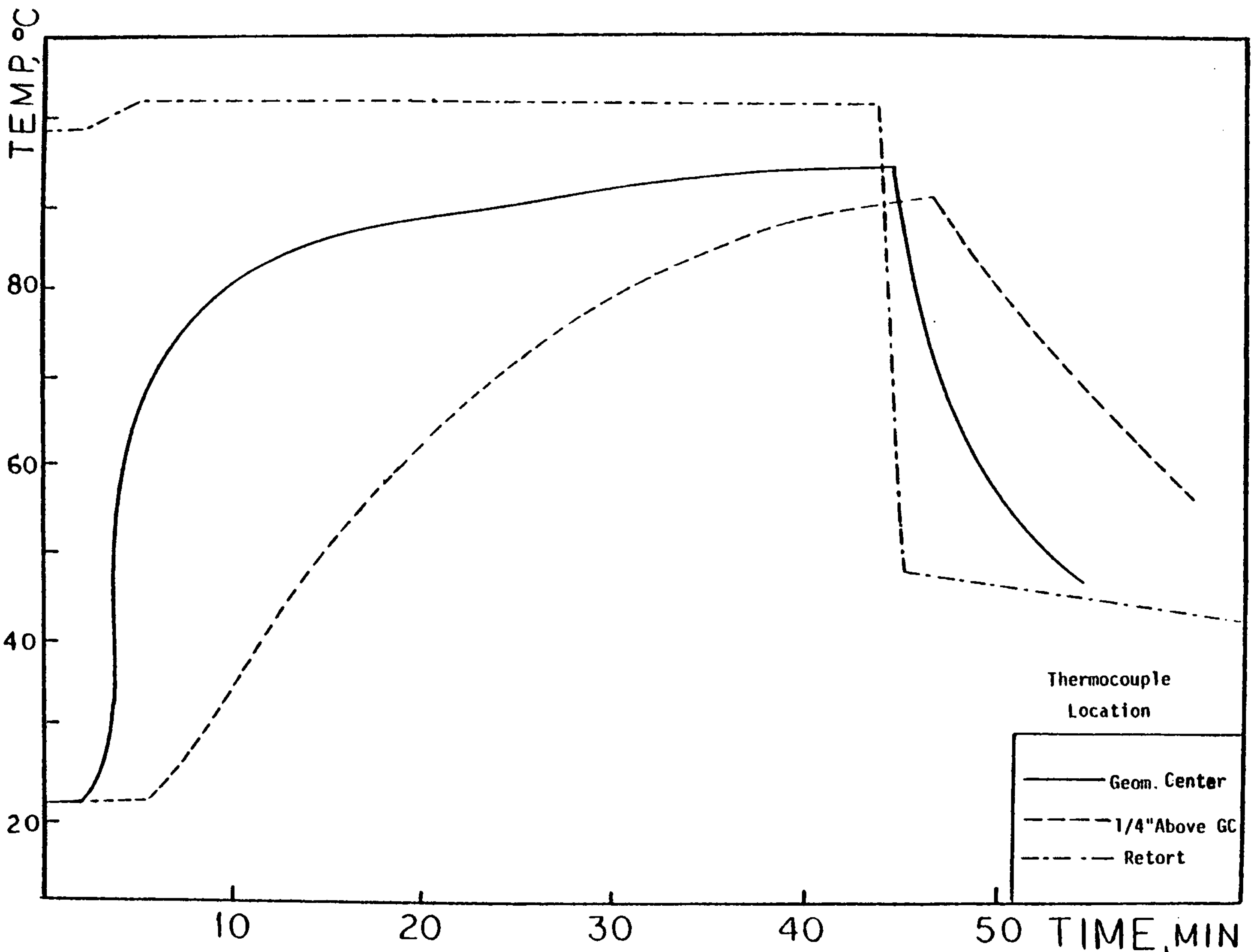
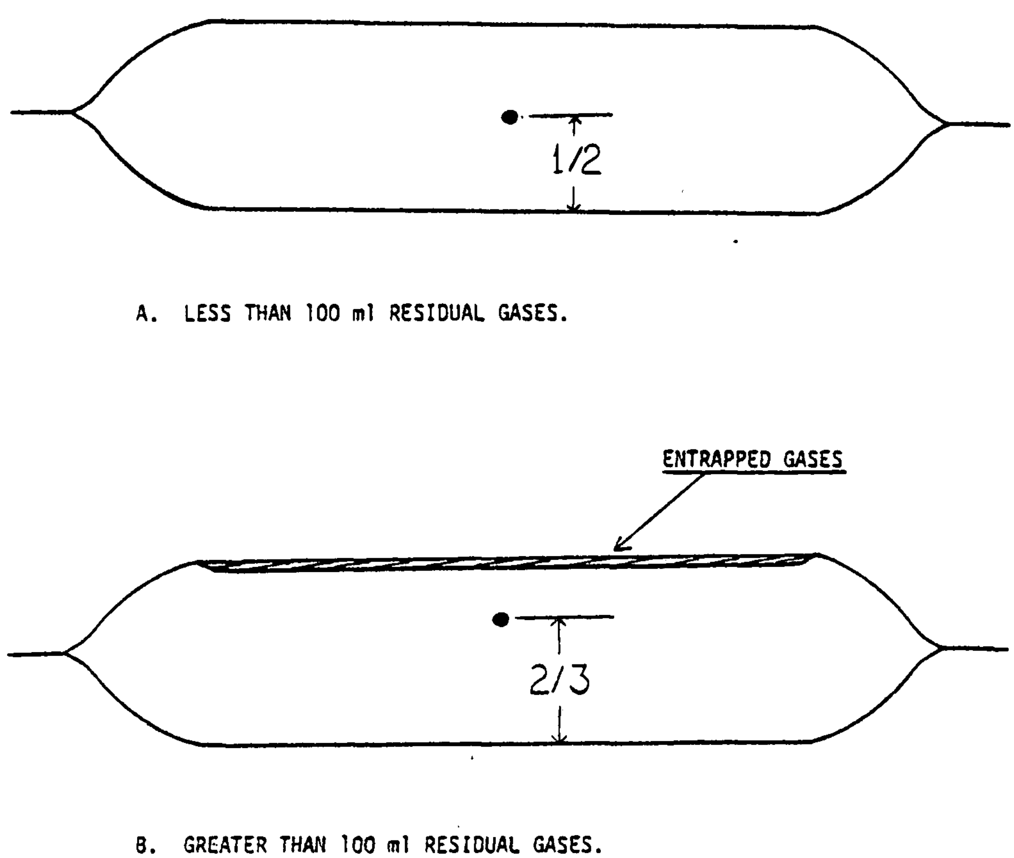


Fig. 2.- COLDEST SPOT DETERMINATION IN INSTITUTIONAL SIZE RETORTABLE POUCHES

Fig 3.- COLDEST SPOT LOCATION IN RETORTABLE POUCHES CONTAINING DIFFERENT AMOUNTS OF ENTRAPPED GASES.



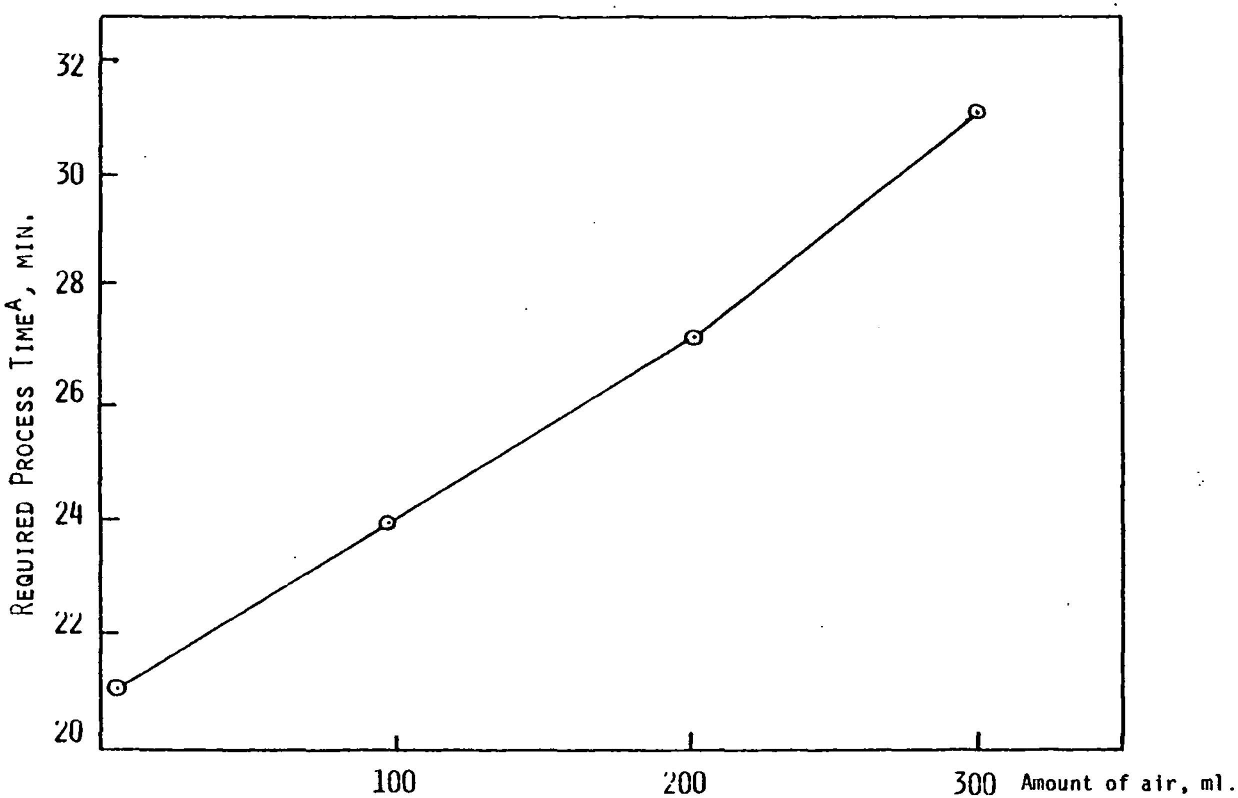


Figure 4. Effect of entrapped air on sterilization process time for diced Bartlett Pears processed in institutional size retortable pouches.

[A] at 100°C for F^{18}_{200} of 3

Color of Diced Bartlett Pears

Entrapped air had a very significant effect on the color of diced pears thermally processed in institutional size retortable pouches. As the amount of entrapped air was increased (table 5) the pears appeared to have darker color, lower Hunter "L" value (less lightness) Fig. 5, higher "a" value (tendency to redness) and a decreasing "b" value.

Diced pears processed in pouches (5 ml entrapped air) are compared with those processed in No. 10 can with tin coating in table 6. The Hunter "L" value is slightly higher for the can and the "a" value is lower, indicating that there is darker color for the product coming from the pouch, but the "b" value is lower for the can. The visual overall appearance of the pouch product was dramatically much darker than the canned pears. Canned pears had better texture than pouched pears (Table 6). The total amount of phenolics here connot be directly compared, due to the binding effect that tin, from the can, has on phenolics.

Determination of total phenolics showed a reduction in phenolics as air content within the pouch was increased, this explains the darker color of fruit obtained when entrapped air is present, since reduction in phenolics implies the formation of polymeric compounds responsible for browning. Results are shown in Table 7.

TABLE 5. COLOR OF DICED BARTLETT PEARS THERMALLY PROCESSED IN INSTITUTIONAL SIZE RETORTABLE POUCHES, WITH DIFFERENT AMOUNTS OF AIR ENTRAPPED WITHIN THE POUCH.[A]

AMOUNT OF AIR, ML	HUNTER VALUES		
	"L"	"a"	"b"
5	+ 51.4	- 1.1	+ 17.7
100	+ 47.0	- 1.4	+ 15.3
200	+ 44.3	+ 1.1	+ 14.8
300	+ 40.2	+ 3.6	+ 13.8

[A] STORED AT 21° C FOR 24 WEEKS

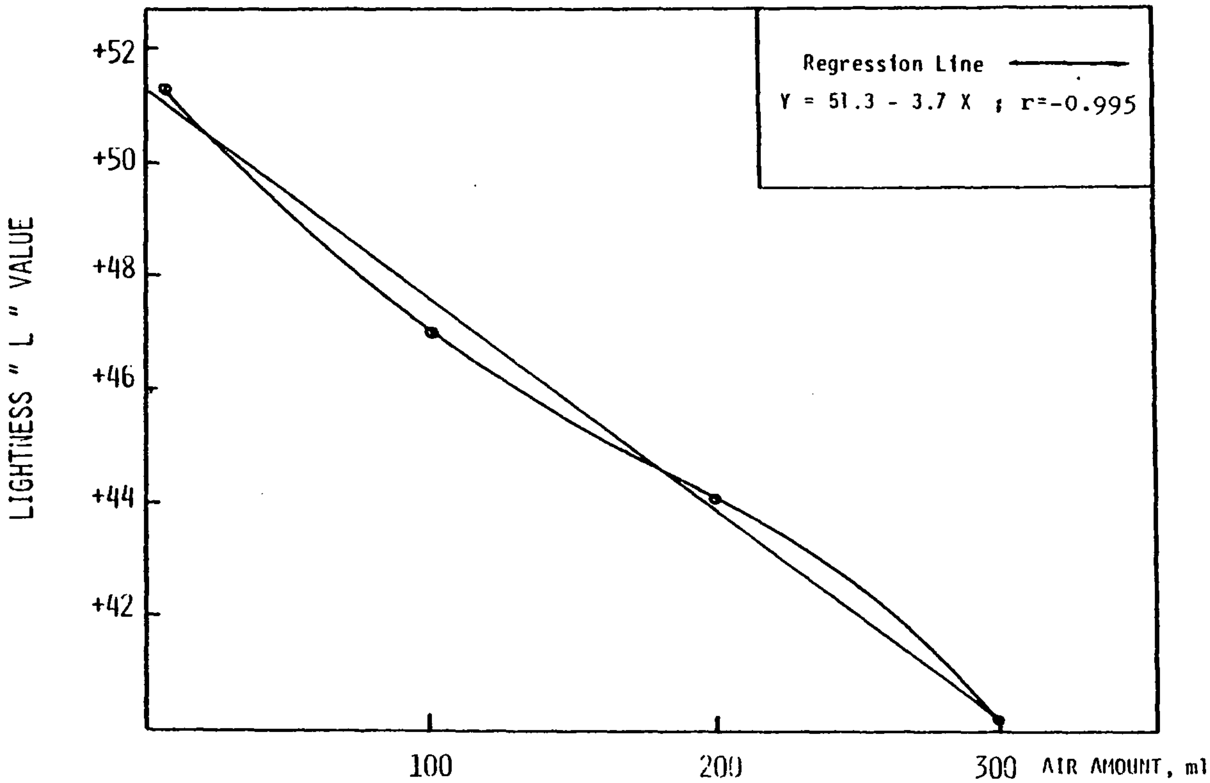


Fig. 5. HUNTER "L" VALUE FOR DICED PEARS PROCESSED IN INSTITUTIONAL POUCHES.

TABLE 6. COMPARISON BETWEEN DICED BARTLETT PEARS THERMALLY PROCESSED IN INSTITUTIONAL SIZE RETORTABLE POUCHES AND No. 10 FOOD CANS.

	HUNTER VALUES			TEXTURE, KG/ 100G	TOTAL PHENOLICS, PPM GALLIC ACID
	"L"	"a"	"b"		
INSTITUTIONAL SIZE RETORTABLE POUCH (30.5 X 38.1 X 3.8 CM)	+ 51.4	- 1.1	+ 17.7	7.6	711.1
NUMBER 10 FOOD CAN (603 X 700)	+ 52.4	- 4.2	+ 14.0	8.9	418.3
DIFFERENCE	ns	*	ns	*	*

ns Not significant.

* Significant at $p<0.05$.

TABLE 7. DETERMINATION OF TOTAL PHENOLICS IN DICED BARTLETT PEARS THERMALLY PROCESSED IN INSTITUTIONAL SIZE RETORTABLE POUCHES WITH DIFFERENT AMOUNTS OF AIR ENTRAPPED WITHIN THE POUCH.

AMOUNT OF AIR, ML	TOTAL PHENOLICS, PPM GALLIC ACID[A]
5	711.1_g
100	580.9_h
200	556.2_i
300	532.3_j

[A] AVERAGE OF 5 VALUES.

[g,h,i,j] Means with different letter differ significantly ($p<0.05$).

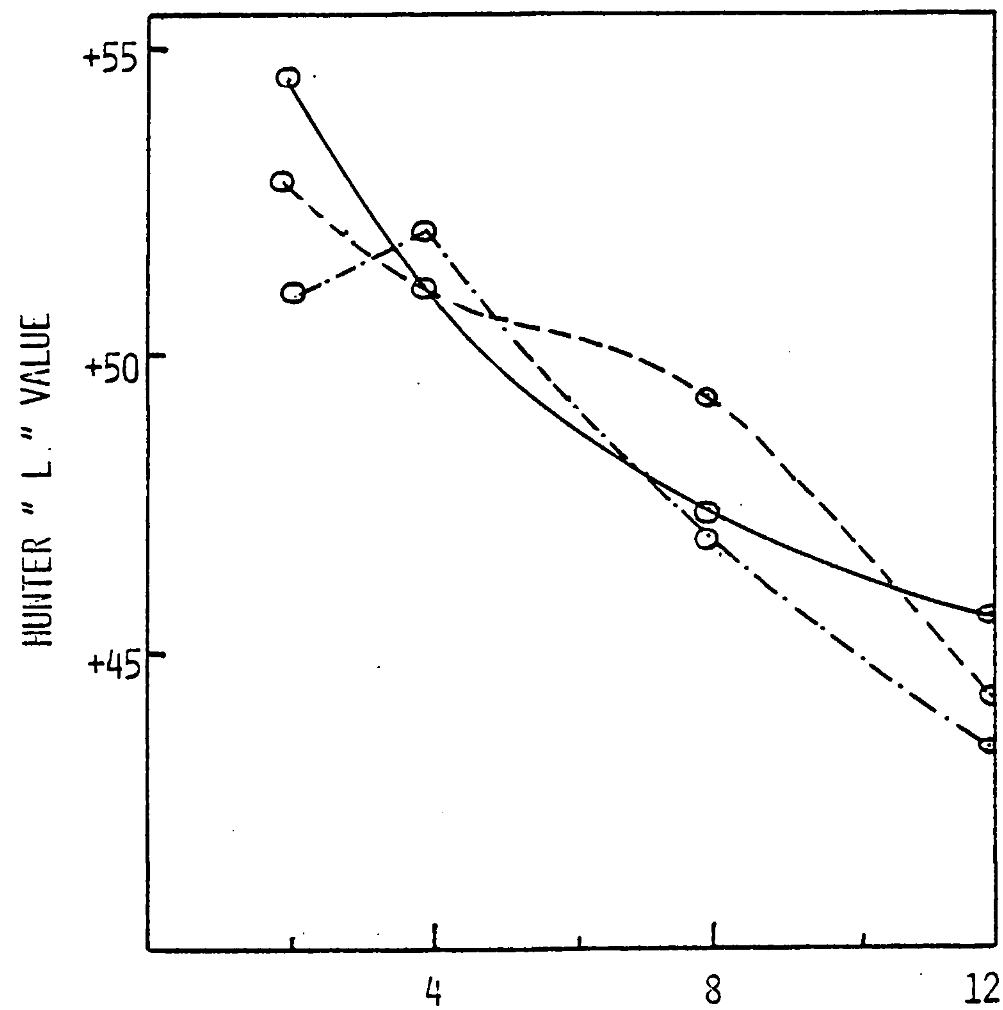
Color Stability Under Accelerated Storage Conditions

After stored samples of pouched pears, containing 5 ml of entrapped air, at different temperatures and times, the following results were observed. The Hunter "L" value decreased as storage time and temperature were increased, hence more browning occurred as shown in Fig. 6. Hunter "a" value increased as the pears browned, which indicated that the samples became more red as browning occurred, when storage temperature and time were increased, Fig. 7. Hunter "b" value had no significant change upon storage at different temperatures during all 12 weeks. Results are the average of three readings.

Texture Determination

Texture of the pouched products (diced pears and french sliced green beans) is reported in terms of the force (Kg /100 g Sample) required to compress a standard sample in an Allo-Kramer shear press. The work area diagrams of the samples were of similar shape, consisting of a gradual rise of the base line, followed by a sharp rise to a peak and then an almost vertical return to the base line.

The compression values are shown in Tables 8 and 9 for diced pears and green beans, respectively. These indicate that an increase in fruit and vegetable firmness with the increase in entrapped air content was marked. The maximum firmness occurred when the pouches containing the products had 300 ml entrapped air, this firming effect is likely



STORAGE TEMPERATURE 21.1°C (solid line)

STORAGE TEMPERATURE 26.7°C (dashed line)

STORAGE TEMPERATURE 37.8°C (dash-dot line)

FIG. 6. LIGHTNESS "L" VALUE CHANGES ON DICED PEARS PROCESSED IN INSTITUTIONAL POUCHES AND STORED AT DIFFERENT TEMPERATURES.

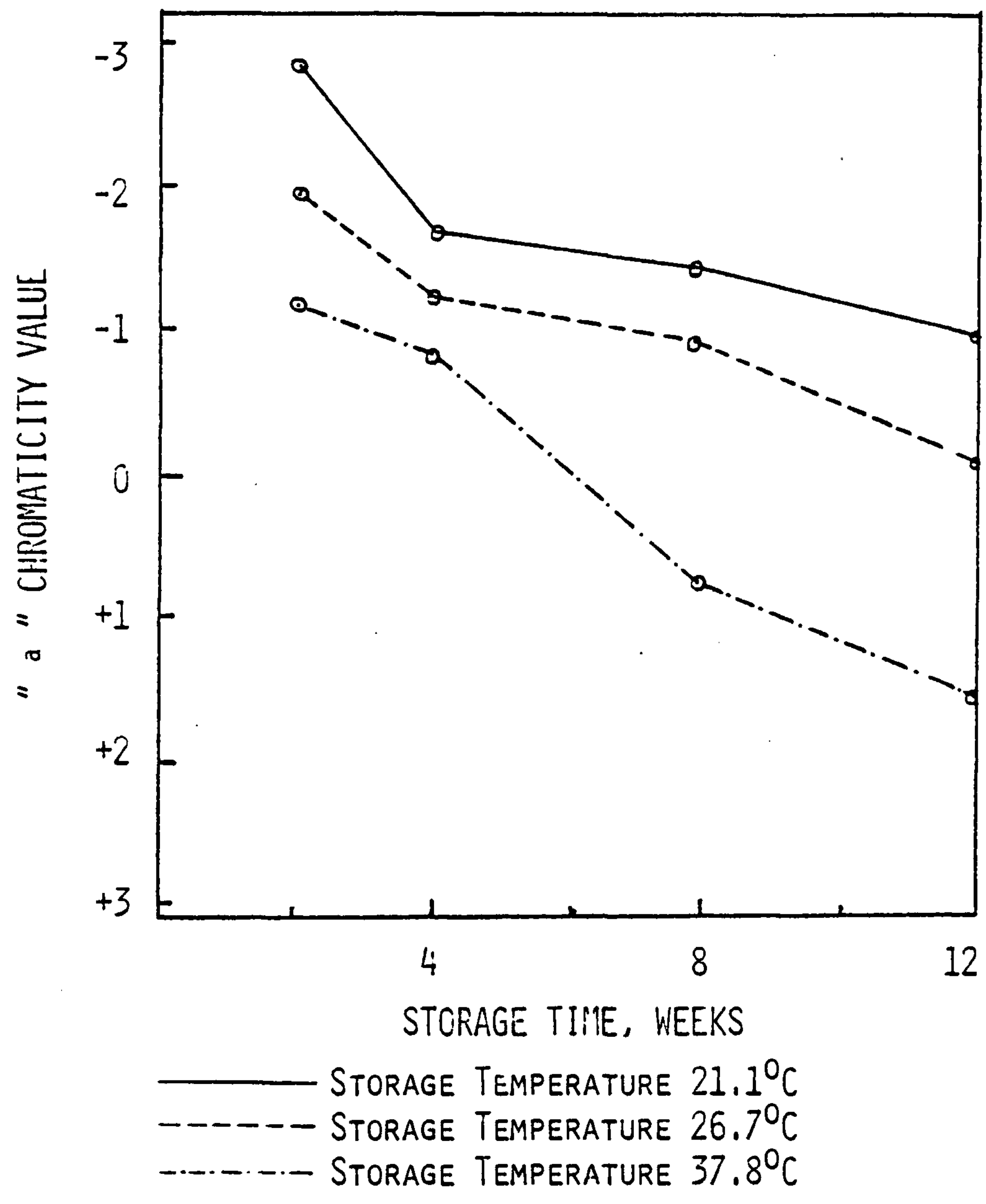


FIG. 7. CHROMATICITY "a" VALUE CHANGES ON DICED PEARS PROCESSED IN INSTITUTIONAL POUCHES AND STORED AT DIFFERENT TEMPERATURES.

TABLE 8. TEXTURE (FIRMNESS) MEASUREMENTS OF DICED BARTLETT PEARS THERMALLY PROCESSED IN INSTITUTIONAL SIZE RETORTABLE POUCHES WITH DIFFERENT AMOUNTS OF AIR ENTRAPPED WITHIN THE POUCH.

AMOUNT OF AIR, ML	SHEAR PRESS COMPRESSION WORK[A], KGS/100 G SAMPLE
5	7.6g
100	9.3h
200	9.4h
300	10.5i

[A] AVERAGE OF 5 VALUES OBTAINED WITH AN ALLO-KRAMER SHEAR PRESS.

[g,h,i] Means with different letter differ significantly ($p<0.05$)

TABLE 9. TEXTURE (FIRMNESS) MEASUREMENTS OF FRENCH SLICED GREEN BEANS THERMALLY PROCESSED IN INSTITUTIONAL SIZE RETORTABLE POUCHES WITH DIFFERENT AMOUNTS OF AIR ENTRAPPED WITHIN THE POUCH.

AMOUNT OF AIR, ML	SHEAR PRESS COMPRESSION WORK[A], KGS / 100 G SAMPLE
5	12.7g
100	14.5h
200	16.3i
300	21.4j

[A] MEASUREMENTS MADE IN AN ALLO-KRAMER SHEAR PRESS.

[g, h, i, j] Means with different letter differ significantly (p 0.05) attributable to the effect of more severe heat treatment, since as air increases it forms an insulating layer between the heat transfer medium and the product to be cooked, thus greater heat treatment was necessary to achieve same F_o value.

Sensory Evaluation of Diced Pears

Table 10. shows the mean values of the sensory evaluation panel for Bartlett diced pears thermally processed in No. 10 food cans and in institutional size retortable pouches. These results show that the canned product was preferred over the pouched product. Statistical analysis of the difference between canned pears and pouched pears (without sulfur dioxide and with sulfur dioxide added) showed that there were significant differences at both 5 and 1 % levels (those treated with sulfur dioxide ranked the lowest scores in all color, over-all appearance, texture, flavor, and over-all desirability). 75% of the panelists preferred the canned pears over the pouched pears without sulfur dioxide added, and no preference was registered for the pouched sample treated with sulfur dioxide.

Table 10.- SENSORY EVALUATION OF DICED PEARS THERMALLY PROCESSED IN INSTITUTIONAL SIZE RETORTABLE POUCHES AND No. 10 FOOD CAN[a].

	COLOR	OVER - ALL APPEARANCE	TEXTURE	FLAVOR	OVER - ALL DESIRABILITY	N[b]	% P[c]
RETORT POUCH 5 cc AIR W/O SO_2	6.9	6.7	6.6	6.4	6.3	40	25
RETORT POUCH 5 cc AIR W/ SO_2	5.9	5.7	5.6	5.0	4.9	40	—
No. 10 FOOD CAN W/O ENAMEL	7.6	7.4	7.5	7.2	7.4	40	75
LSD at 5 %	0.398	0.477	0.503	0.604	0.475		
LSD at 1 %	0.528	0.633	0.667	0.800	0.630		

a Mean Hedonic Rating, Scale: 9 (Like extremely) to 1 (Dislike extremely).

b N = Number of participants.

c % P = Percent of participants that preferred such product.

Heating Characteristics Studies for French Sliced Green Beans

Figure 8. gives the heating characteristics of the pouches filled with 2.1 Kg of french sliced green beans and 0.3 Kg of 10 % brine solution, with different amounts of air (5, 100, 200, and 300 ml) and thermally processed under constrained conditions, where the heating time required to reach an F_o value of 5 was determined.

From these results it can be seen that, as with diced pears, the required thermal processing times increased approximately 15 % for each 100 milliliter increase of entrapped air content, under constrained conditions.

Color of French Sliced Green Beans

Hunter values obtained for french sliced green beans are given in Table 11. from these results it was shown that green beans thermally processed in retortable pouches changed color from green towards a more pale (yellow) green color as entrapped air increased, increasing in lightness ("L" values) and decreasing in greeness ("a" values). The changes in "b" values were not significant.

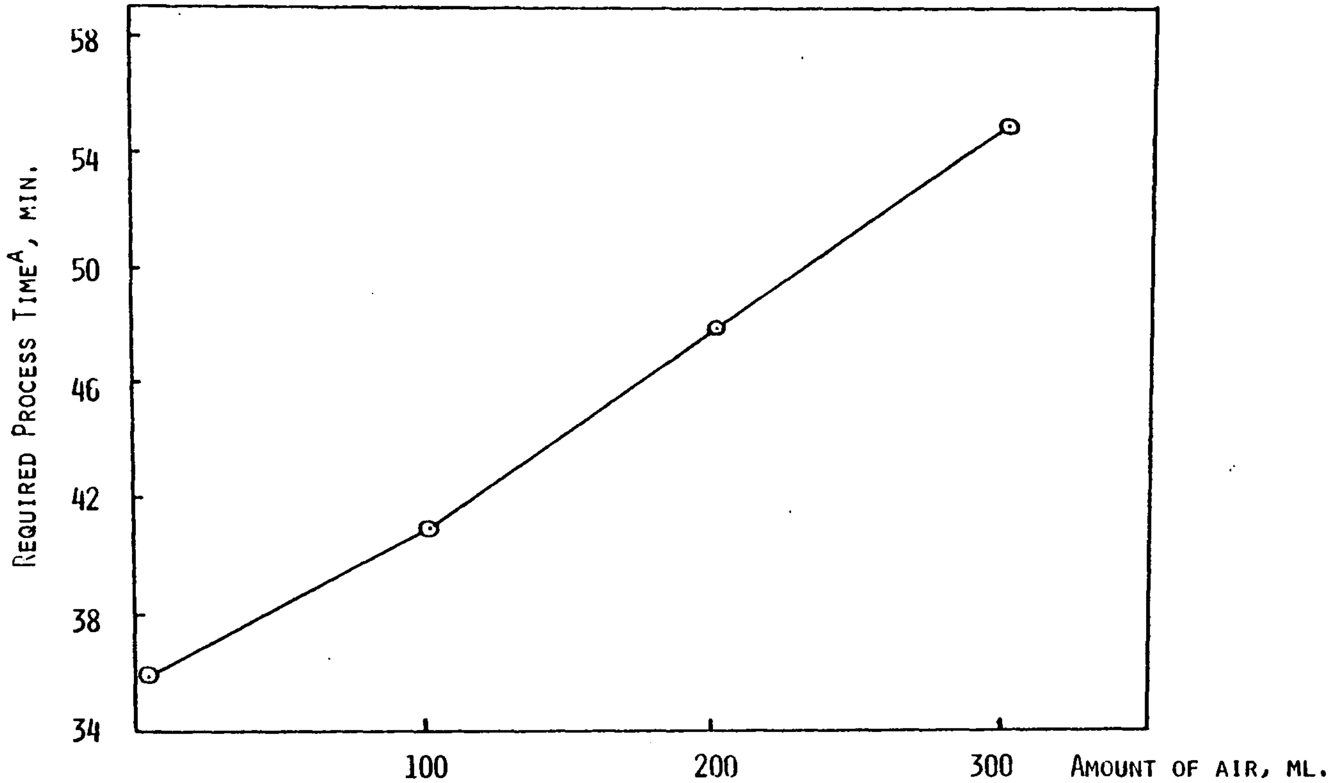


FIG. 8. EFFECT OF ENTRAPPED AIR ON STERILIZATION PROCESS TIME FOR FRENCH SLICED GREEN BEANS PROCESSED IN INSTITUTIONAL SIZE RETORTABLE POUCHES.

[A] AT 121°C FOR F_0^{18} OF 5

Table 11. COLOR OF FRENCH SLICED GREEN BEANS THERMALLY PROCESSED IN INSTITUTIONAL SIZE RETORTABLE POUCHES WITH DIFFERENT AMOUNTS OF AIR ENTRAPPED WITHIN THE POUCH.[A]

AMOUNT OF AIR, ML	Hunter Values		
	"L"	"a"	"b"
5	+ 34.8	- 0.7	+ 17.0
100	+ 37.2	- 1.5	+ 17.0
200	+ 40.4	- 2.1	+ 16.1
300	+ 42.5	- 2.1	+ 16.4

[A] Stored at 21°C for 24 weeks.

Ascorbic Acid Content

Table 12. shows the ascorbic acid content of french sliced green beans thermally processed in institutional size retortable pouches, with different amounts of air entrapped within the pouch. From these results it was observed that ascorbic acid content increased as the amount of entrapped air increased.

TABLE 12. ASCORBIC ACID CONTENT OF FRENCH SLICED GREEN BEANS THERMALLY PROCESSED IN INSTITUTIONAL SIZE RETORTABLE POUCHES, WITH DIFFERENT AMOUNTS OF AIR ENTRAPPED WITHIN THE POUCH.

AMOUNT OF AIR, ML	ASCORBIC ACID, MG/100G[A]
5	0.83
100	0.95
200	1.31
300	1.54

[A] AVERAGE OF THREE VALUES.

Ascorbic Acid Retention

Table 13. shows the comparison of ascorbic acid content in cut green beans thermally processed in institutional size retortable pouches and No. 10 food cans, stored at room temperature for 10 months. The retortable pouches containing 5 ml of entrapped air were processed at different times (12, 20, and 24 min) at the same temperature (121^{o}C) as the No. 10 can which was processed 18.4 min.

The retortable pouches processed 20 and 24 min were overprocessed (F_o values of 9 and 13 respectively), whereas the No. 10 can required 18.4 min to achieve an F_o of 5. Although the pouched beans were overprocessed, they showed higher concentration of ascorbic acid than the canned sample. This might be because the canned beans have 5 times as much liquid as the pouched beans and therefore this soluble vitamin might have leached to the brine. However the less severe heat treated sample (12 min processing time with an F_o of 5) had significantly higher concentration of ascorbic acid (more than three times as much) than the canned sample.

TABLE 13. ASCORBIC ACID RETENTION OF CUT GREEN BEANS THERMALLY PROCESSED IN INSTITUTIONAL SIZE RETORTABLE POUCHES AND No. 10 FOOD CANS[A].

Packaged	Thermal Processing Time, min	Ascorbic Acid[C] mg/100 g
Retortable Pouch[B]	12	2.02
Retortable Pouch[B]	20	1.62
Retortable Pouch[B]	24	1.01
No. 10 Food Can	18.4	0.61

[A] Processing Temperature = $121^{\circ}C$

[B] Institutional Size (30.5 X 38.1 X 3.8 cm)

[C] Average of Three Values

Comparison Between Canned and Pouched Green Beans

When comparing french sliced green beans thermally processed in institutional size retortable pouches and 303 food cans (Table 14.) a greener color was obtained for the canned than for the pouched beans. Slightly firmer texture was also obtained for the canned product and a lower ascorbic acid content was obtained.

Sensory evaluation results (Table 15.)were compatible with the physical and chemical analysis presented above. Generally the canned product ranked better than the pouch product, but the difference was not statistically significant at a confidence level of 5 %. However the percent of participants that preferred the canned green beans over the pouched beans was considerably higher (65 %). It should be noted that here a small can (303 X 406 processed 18 min at 121°C) containing approximately 0.5 Kg of product was compared with an institutional size retortable pouch containing 2.4 Kg of product (green beans and brine) processed at the same temperature (121°C) for 35 min.

Table 14. COMPARISON BETWEEN FRENCH SLICED GREEN BEANS THERMALLY PROCESSED IN INSTITUTIONAL SIZE RETORTABLE POUCHES AND " 303 " FOOD CANS.

	Hunter Values			Texture, Kg /100g[a]	Ascorbic Acid, mg / 100g[a]
	" L "	" a "	" b "		
Institutional Size Retortable Pouch , (30.5 X 38.1 X 3.8 cm)	+ 34.8	- 0.7	+ 17.0	12.7	0.83
Number 303 Food Can	+ 35.4	- 1.3	+ 17.0	13.4	0.68
Difference	ns	*	ns	ns	*

[a] 100 g of Sample, wet weight basis.
ns= not significant
* significant at p 0.05

Table 15. SENSORY EVALUATION OF FRENCH SLICED GREEN BEANS THERMALLY PROCESSED IN INSTITUTIONAL SIZE RETORTABLE POUCHES AND No.303 FOOD CAN[a].

	COLOR	OVER - ALL APPEARANCE	TEXTURE	FLAVOR	OVER - ALL DESIRABILITY	N[b]	% P[c]
RETORT POUCH 5 cc AIR [d]	6.9	6.4	6.2	5.3	5.5	40	25
RETORT POUCH 5 cc AIR [e]	6.5	6.2	6.6	5.1	5.1	40	10
No.303 FOOD CAN W/ENAMEL	6.8	7.2	7.0	6.3	6.4	40	65
LSD at 5 %	0.651	0.597	0.530	0.712	0.604		

a Mean Hedonic rating, scale: 9 (Like extremely) to 1 (Dislike extremely).

b N = Number of participants.

c % P = Percent of participants that preferred such product.

d Stored at 21°C for 24 weeks.

e Stored at 37°C for 24 weeks.

Effect of Entrapped Air on Process Time Under Restrained Conditions

Under restrained conditions erratic and non uniform readings were obtained and in most cases desired process temperature was not achieved even for long periods of time (up to 1 hr) this is likely to be due to the bouyant effect that water from the retort exerts on the pouch. As the entrapped air increased the maximum thickness increased greatly and in a nonuniform manner resulting in a poor heat transfer.

Effect of Entrapped Air on Process Time Under Rotating Conditions

Where pouches were rotated at 15 rpm, the processing times were greatly reduced from 21 min (pears processed in FMC retort) to 6 min, obtaining a very attractive product immediately after processing, but the beneficial effects of this shorter cook were quickly lost upon storage. Nevertheless little effect was detected on processing time as entrapped air was increased.

Effect of Entrapped Air Under Still Retorting, Vertical Orientation

A similar situation was observed when pouches were still retorted in vertical orientation. Various amounts of entrapped air had no effect on processing times, however increases of time were observed versus rotary cook. Process times were an average of 11 min.

CONCLUSION

Significance Of Air Removal in Institutional Size Retortable Pouches

Based on the results of the present study, the following conclusions can be drawn.

It is essential to minimize the amount of entrapped air within institutional size retortable pouches in order to obtain better quality products thermally processed in the pouches. Large volumes of air retard the rate of heat transfer to the product and therefore there is a need for longer processing time to achieve commercial sterility of the products being processed. This longer time will cause some overcook of the product and, more oxygen in the pouch will cause more oxidative reactions to occur, all a detriment of one of the major advantages of the retort pouch i.e. the improvement of product quality.

It is also concluded that further development in product formulations and improved filling and sealing equipment is necessary to obtain better air evacuation and faster processing times, since as shown in this study the expectation of obtaining a product with a much higher quality is not attainable with the equipment and procedures now available.

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APPENDIX

TABLE 16. COLOR OF DICED PEARS THERMALLY PROCESSED IN INSTITUTIONAL SIZE RETORTABLE POUCHES.

Temperature of Storage (°C)	Hunter "L" values [A]			
	2 wks	4 wks	8 wks	12 wks
21	54.6	50.7	47.3	45.6
27	53.1	50.8	49.6	44.2
38	51.1	52.1	46.6	43.3

[A] Lower Hunter "L" values indicate a darker color.

TABLE 17. COLOR OF DICED PEARS THERMALLY PROCESSED IN INSTITUTIONAL SIZE RETORTABLE POUCHES.

TEMPERATURE OF STORAGE (^{o}C)	HUNTER "a" VALUES[A]			
	2 WKS	4 WKS	8 WKS	12 WKS
21	-3.0	-1.7	-1.5	-1.0
27	-2.0	-1.2	-0.9	-0.1
38	-1.3	-0.9	+0.8	+1.5

[A] HIGHER HUNTER "a" VALUES INDICATE MORE RED COLOR.

TABLE 18. EFFECT OF ENTRAPPED AIR ON STERILIZATION TIME FOR DICED BARTLETT PEARS IN INSTITUTIONAL SIZE RETORTABLE POUCHES[A].

AMOUNT OF AIR, ML	REQUIRED PROCESS TIME (MIN) AT 100°C FOR F_{200}^{18} OF 3
5	21
100	24
200	27
300	31

[A]SIZE 30.5 X 38.1 X 3.8 CM.

TABLE 19. EFFECT OF ENTRAPPED AIR ON STERILIZATION PROCESS TIME FOR FRENCH SLICED GREEN BEANS IN INSTITUTIONAL SIZE RETORTABLE POUCHES[A].

AMOUNT OF AIR, ML	REQUIRED PROCESS TIME (MIN) AT 121°C FOR F_0^{18} OF 5
5	36
100	41
200	48
300	55

[A] SIZE 30.5 X 38.1 X 3.8 CM.

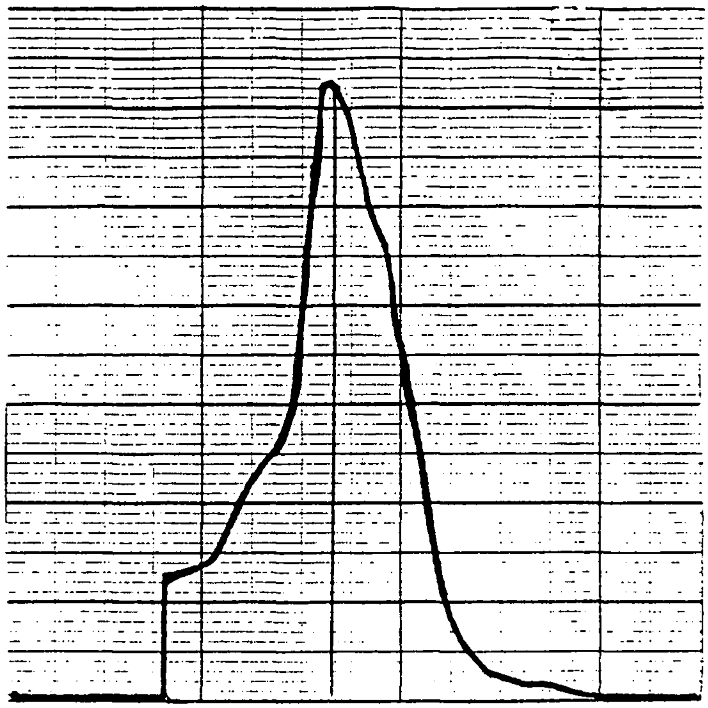

Fig 9. TYPICAL WORK CURVE OBTAINED WITH ALLO-KRAMER SHEAR PRESS.