ALTERNATIVE CONTAINERS
FOR
PRESERVING PEACHES

BY

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Thesis submitted in part-fulfilment
of the requirements for the
Masters Diploma in Technology (Food Technology)
in the school for Physical Sciences at the Cape Technikon.

Date of submission: August 1992

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Abstract

Kakamas peaches and Bulida apricots were heat processed in transparent and aluminium laminated plastic bags and compared with fruit heat processed in standard cans. Heat processing conditions were optimized to produce acceptable processed products. Appropriate chemical and microbiological properties of all treatments as well as sensory quality of peaches were investigated. Although rectifiable disadvantages such as texture softening and fading of colour appeared during storage, peaches and apricots were successfully heat processed in aluminium laminated pouches. Heat processed peaches had a maximum storage life of 12 months and apricots 6 months when stored at ambient temperature in aluminium laminated pouches.

Summary

Transparent and aluminium laminated flexible plastic packaging materials were evaluated during the 1987/88, 88/89, 89/90 and 90/90 seasons and some of the chemical, microbiological and sensory properties of fruit heat processed in aluminium laminated plastic bags were compared with those of fruit heat processed in cans.

Transparent plastic material used in this study could not be used successfully due to the low barrier properties to oxygen which caused unacceptable browning of fruit after a 2 week storage interval at ambient temperature. Peaches can be successfully heat processed in aluminium laminated plastic bags and stored in the dark for up to 12 months at ambient temperature although an acceptable degree of browning will occur after this storage period as shown by colour measurement readings. Apricots heat processed in aluminium laminated pouches could also be stored successfully for 6 months at ambient temperature in the dark, but showed unacceptable browning after 12 months storage.

Total solids, total soluble solids, ascorbic acid, mineral contents and drained mass did not differ significantly ($p<0,05$) between fruit heat processed in aluminium laminated plastic pouches and those heat processed in cans.

No microbial differences could be detected between fruit heat processed in aluminium laminated pouches and cans under the heat processing conditions used.

Calcium chloride addition to the syrup prevented softening of apricots in aluminium laminated pouches after heat processing.

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Acknowledgements

First I would like to thank my supervisors Herman van der Merwe and Chris Hansmann for their interest and invaluable help both in the planning of the experiments and in the writing of the dissertation. I would also like to thank my colleagues at INFRUITEC for their invaluable help and moral support.

Secondly I would like to thank Wiehan Victor and the Canning Fruit Board for the donation of the experimental fruit.

Thirdly I would like to thank Dr. Pieter van Rooyen of The Stellenbosch Institute for Fruit Technology for permission to use the results of this study for my thesis.

Last but not least I would like to thank my mother for all her moral support.

Statement

I, Rolf Schoonenberg, declare herewith that the contents of this thesis represent my own work and opinions expressed and recommendations made are my own and are not necessarily those of the Cape Technikon.

Signed .RSchoonenbe..... at .Stellenbosch.........

on ...1st........ day of
.....November........1992

1 INTRODUCTION

1.1 General

During the 1988/89 season 57 585 ton apricots and 170 747 ton peaches were produced in South Africa having a value of R 127 868 000. Of this crop 42 640 ton apricots and 108 670 ton peaches were heat processed (South Africa, 1991).

Presently fruit is heat processed on a large scale in cans or metal containers and some glass jars are used as well. A total volume of 3 568 597 cartons[1] of apricots and peaches were canned in the Western Cape during the 1988/89 season (Victor, 1991). This means that an enormous storage space is needed to store the empty cans and later the filled cans before they are sent to the consumer. Storage space is very expensive and the transport cost is also very high. The cost of cans is also high and represents 30-35% of the total production cost while the fruit only represents 17-20% (Victor, 1987).

Appearance is an important property of food. Pomeranz & Meloan (1971) state that colour is very important for fruit. Discoloration or the fading of colour is often accompanied or identified by consumers as being associated with undesirable changes in texture and flavour. Although nutritional information is available on the labels of the

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[1] Expressed on a basis of 24 A2½ cans per carton.

cans the consumer would prefer if they could see the product that they buy.

Laminated plastic packages which are presently widely used for other food products (Lampi, 1977) might be successfully implemented for heat processed fruit. These packages have the advantage that less storage space is needed for the packaging material as well as for the end products. This in turn could mean a saving on storage and transport costs. Furthermore a transparent material can be selected so that the consumer can see the product. Steffe *et al.* (1980) state that it is possible during heat processing, due to the form of these packages, to get commercially sterile products by using shorter or lower temperature processes as for cans, which would also mean a big saving in energy cost.

Therefore the possibility of producing heat processed fruit products of the same or better quality in an alternative packaging has to be investigated.

1.2 Problem Statement

As a result of above-mentioned reasons a study was undertaken to heat process apricots and peaches in laminated plastic packages with the following objectives:

i To optimize the heat processing conditions of fruit packed in pouches.

ii To study some of the microbial and chemical changes that might occur in the heat processed fruit during and after heat processing.

iii To compare some nutritional aspects and sensory quality of the fresh and heat processed fruit packed in pouches with that of fruit heat processed in standard cans.

2 LITERATURE REVIEW

2.1 Containers

Fruit is a seasonable product and methods have been developed to package and preserve the fruit in times of abundance, in either the fresh or processed form, so that it can be consumed all year round (Sacharow & Griffin, 1980).

Sacharow & Griffin (1980) state that the beginnings of food packaging are rooted in man's advancement in the production and processing of foods.

The container is an essential factor in the preservation of foods by heat. After the food is sterilized, is it the container that protects the heat processed food from spoilage by recontamination. A hermetically sealed container is defined as a container which is designed and intended to be secure against the entry of micro-organisms and to maintain the "commercial sterility"[1] of its contents after processing (Lopez, 1981).

Three different containers are normally used for processed fruit namely glass jars, tin cans and pouches (Sacharow & Griffin, 1980). Appearance is an important

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[1] All organisms which can cause disease in men have been killed, other viable organisms are still present but unable to grow due to unfavourable conditions.

attribute of food and therefore transparent glass containers and transparent pouches could be advantageous (Piggot, 1988).

2.1.1 Glass Jars

The production and shaping of glass were developed between 4000 and 3000 BC (Downes, 1989) and food was stored for a limited time in urns and bottles.

In the beginning of the 18th century the Frenchman, Nicolas Appert developed a method to preserve food in glass containers. This was the beginning of the food processing industry (Bitting, 1937).

Glass containers are ideally suited for the packaging of certain foods and are widely used for the packing of fruit, vegetables and juices. It is an inert, hermetic and durable packaging material.

The transparency of glass makes it the ideal choice for the display of certain products on the shelf. Glass containers can be handled at speeds in excess of 1200 containers per min (Lopez, 1981).

2.1.2 Cans

The sanitary tin plate can is a very suitable container for foodstuffs. It can be exhausted, hermetically sealed and treated to heat and cold without impairment. It is also a rigid container which can withstand the processing machinery and rough handling (Patrick, 1989). It is relatively resistant to the action of food components such as organic acids and oxygen (Gotz, 1989), due to the presence of tin which slows down this process of corrosion (Cronshaw, 1933).

Organic acids at a high concentration will corrode the tin plate which is of importance when processing fruit, because certain of the products have a high acidity (Cruess, 1958).

Basson (1989) states that oxidation of food components, by oxygen, is one of the most significant causes for the deterioration of foodstuffs and it can result in destruction of valuable nutrients. Undesirable flavors and loss of colour may develop and texture may also be adversely affected. Toxic compounds may also be produced.

In unlaquered cans the oxygen reacts with the tin plate and therefore will not be able to react with the food (Gotz, 1989).

Due to the very high price of tin which is ± 15 times the cost of steel, the tin layer is very thin. For this reason the industry is looking for alternatives such as tin free steel (TFS) also called electrolytic chromium coated steel. The TFS is much cheaper, but cannot replace tin plate in a number of packaging areas. TFS is currently used for can ends, drawn and redrawn cans and crowns (Patrick, 1989). A schematic comparison of the two processes is given in Appendix B, Fig. 1.

Lacquers are widely used to coat the cans for heat processed foods, to prevent the chemical interaction of the food with the tin plate. This interaction is undesirable because it usually results in damage or pinholing of the can wall but it can also deteriorate the flavor and appearance of the contents (Cruess, 1958).

In the case of dark coloured fruit a fading of colour will occur but this can be prevented by the use of lacquers (Patrick, 1989). Downs (1989) states that the coatings mainly used for fruit are epoxy-phenolic, oleoresinous, phenolic and acrylic.

Apricots and peaches are prone to cause pinholing of the walls of the cans due to the high acidity in combination with oxygen and anthocyanins (Cruess, 1958). For this reason they have to receive an efficient exhaust and unlacquered cans are used so that the plain tin coating reacts with the residual oxygen (Hirst & Adam, 1933).

2.1.3 Pouches

Experiments performed in the mid and late 1950's proved that flexible polymeric-foil[2] laminated pouches could be used for heat processing of foods (Hu *et al.* 1955).

Lampi (1977) states that in the development of the retort pouch extensive use was made of the expertise of the canning, packaging and frozen food industries. Although the pouch industry is to a degree comparable with the afore-mentioned it also has its own specific problems. The material has to withstand a processing temperature of up to 121,1°C for up to 40 min and this without contamination, loss of the laminate bond or heat seal. The resistance to abuse, integrity and package strength has to be equal or better than the metal can.

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[2] These pouches consist of an outer layer of polyester for strength, an aluminium layer in the middle as an air and water barrier and an inner poly-olefin layer for the heat sealing (The Institute of Packaging (SA), 1989).

Up to 1961 studies were concentrated on basic feasibility, areas of improvement for the film, techniques and the food product composition requirement (Lampi, 1977).

The U.S. Army (Quartermaster Food and Container Institute for the Armed Forces) became interested in this concept and this was a great incentive for research from 1957 to 1960. Trial commercial production runs of peaches and pears were made. These packages were carried by troops over a 4 day period. Failures were 1,5% at the end of the first day and increased at negligible rate thereafter (Rubinate, 1964).

Yoell (1991) states that several laminations are used but if good gas and water vapour barriers are needed one of the laminates has to be aluminium. Aluminium is a very good water vapour barrier in comparison with other laminates. Even if there are a 1000 perforations m^{-2} in 9 micron foil, the diffusion of water vapour through the perforations is 0,1 to 0,2 g d^{-1} m^{-2} at 38°C with 100% relative humidity (RH). In the case of 30 micron polyester film this value is 10 to 18 g d^{-1} m^{-2} and 8 g d^{-1} m^{-2} for 25 micron uncoated polyester film.

These perforations are not big enough to let microorganisms through and no microbial spoilage will occur because of them (Lampi, 1977).

Aluminium has also very good oxygen barrier properties, less than 1 cm^3 d^{-1} m^2 (Lampi, 1977) and a long shelf life can be obtained by the use of it.

Nonfoil films have different oxygen permeabilities ranging from 5,5 to 6,0 cm^3 d^{-1} m^2 and can be used for a shelf live of 1 to 6 months (Lampi, 1977).

It is important that as much of the oxygen is removed from the pouch as possible because this has a detrimental effect on the food product (Basson, 1989). Lampi (1977) discusses different ways of air removal. Shorter (1982) describes methods on how to use scavengers to remove the oxygen in the headspace while Madhwaraj *et al.* (1992) describe a new steam-flush-water-seal technique.

Davis *et al.* (1960) determined that the most critical pouch differential pressure situation occurred at the start of the cooling cycle. At this stage water vapour is present in the pouch and if the outside pressure drops the pouch can blow-up and burst. For this reason superimposed air pressure has to be used, especially at the beginning of this cycle, if the processing temperature is >100°C.

2.2 Thermal Process Evaluation

2.2.1 General

To determine if a heating process is adequate certain parameters have to be taken in consideration. Normally the survival of bacteria is used (Stumbo, 1973). A general equation of the survivor curve is given in Appendix C Formula 1.

Toledo (1980) describes this kind of reaction as a first order reaction and according to Yen *et al.* (1971) this formula can be used for any heat vulnerable factor, which reduces exponentially viz. vitamins, colour components and enzymes.

2.2.2 Unit Of Lethality

It is necessary to decide on a unit of lethality to be able to compare the relative sterilizing capacities of heat processes. The unit for food pasteurization and sterilization processes is 1 min at a given reference temperature usually, 121,1°C (Stumbo, 1973).

The lethal effectiveness of the cumulative heat effect is expressed in terms of its equivalent in min at some given reference temperature. It is represented by the symbol F_r where r is the reference temperature (Yen *et al.*, 1971).

Stumbo (1973) states that the F_r value alone is not enough because heat vulnerable factors can differ in their relative resistance for different temperatures.

For this reason the symbol z[3] is used together with F. The value of z employed is characteristic of the thermal destruction curve of the heat vulnerable factor. So to correctly define F_r^z it is the equivalent, in min at some given reference temperature, of all lethal heat in a process, with respect to the destruction of a heat vulnerable factor characterized by some given z value.

2.2.3 Process Requirements For Lethality

According to Stumbo (1973) it is important that the heat process applied to the product is severe enough to kill all the organisms which are important in connection with public health. The main problem with foods with a pH above 4,5 is the survival of *Clostridium botulinum* spores.

The heat treatment has to be very severe to assure that the probability of spore survival is one spore in 10^{12} cans. This is called the 12D concept (Toledo, 1980).

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[3] z = Number of °C required for the thermal destruction curve (TD) to traverse one log cycle. Mathematically, equal to the reciprocal of the slope of the TD curve.

Fortunately most processed fruit products have a pH below 4,5 and *Cl. botulinum* is not a problem (Cruess, 1958). Less severe heat treatments are needed for fruit to obtain "commercial sterility" (Ball & Olson, 1938). Heat processes of less than 121,1°C and usually about 95-105°C can be used (Siebrits, 1992).

On the other hand there are micro-organisms which are heat resistant such as the mold *Byssochlamus fulva* which can cause disintegration of processed fruit (Cruess, 1958). The heat process therefore has to be severe enough to inactivate these organisms.

Apricots are prone to softening after processing. Basson (1989) states that if the processing conditions are too low not all the enzymes will be denatured, which can cause browning and softening of the fruit.

Cruess (1958) states that molds and yeasts will survive if the processing conditions are not severe enough, with subsequent microbial growth and deterioration of the fruit. Pectin breakdown has also been reported (Chitarra *et al.*, 1989) while Basson (1989) reports on non-enzymatic browning and sugar hydrolysis.

Another problem is that a too severe heat treatment can cause physical change. Pears can show a pink discoloration due to several factors one of which is over processing (Luh *et al.*, (1960) and Van der Merwe (1963)).

2.2.4 Heat Penetration Measurements

A special copper-constantan thermocouple, which is small and has a low thermal inertia, is used to measure the rate of heat penetration. Wire with a gauge of < 24 has to be used, because of the heat conduction through the thermocouple wire. The heat penetration data from the fruit and the retort water are recorded by using a temperature-indicating or temperature-recording potentiometer (Stumbo, 1973).

The thermocouple is placed in the slowest heating area of the container which is normally just below the geometric center (National Canners Association Research Laboratories, 1968).

Due to the emergence of the computer, computer data acquisition is increasingly applied and readings can be taken practically continuously. The results can be stored on disk and processed at a later stage (Hayakawa, 1979).

2.2.5. Plotting Heat Penetration Data

Examples of a heating curve and a cooling curve are given in Appendix B Figures 2 and 3.

2.2.6 Methods of Determining Lethality

2.2.6.1 General Method

According to Stumbo (1973) the general method was first described by Biglow in 1920 and in 1923 it was improved by Ball. It is a graphical procedure for integrating the lethal effects of various time-temperature relationships at a given point in a confined body of food during heat processing.

According to Toledo (1980) the slowest heating point is usually a point at or near the geometrical center of the food container. By the time-temperature relationship obtained by the thermal death curve, lethal-rate values can be assigned for each temperature.

Ball & Olson (1957) state that the lethality of a process is defined to be the length (min) of an equivalent process at 250°F (121,1°C).

Patashnik (1953) published a table of lethality ratios (F/t) values based on a time interval of 1 min and stated that a process can be approximately evaluated without plotting a sterility or lethality curve.

Adaptations of this table for processing fruit at 90°C (194°F) and at 100°C (212°F) are given in Appendix A (Tables 1 and 2). These tables are for food products with a z value of 18 which is the normal value for fruit (Hofmeyr, 1989).

2.2.6.2 Conversion Of Heat Penetration Data

Temperature conversions for different retort and initial temperatures can be calculated with formulae (Ball & Olson, 1957). If the initial temperature stays constant but the retort temperature changes a formula can be used. There is also a formula for when the retort temperature remains the same but the initial temperature is changed. See Appendix C Formulae 2 and 3.

Berry & Bush (1989) describe several experiments for foods which show straight line heating curves (first order reaction, Toledo (1980)) and found that the difference in initial temperature has an important influence on process establishment, depending on the product.

2.2.6.3 Mathematical Methods.

According to Stumbo (1973) products for which the semilog heating curve is one straight line can be expressed by an equation. See Appendix C Formula 4.

Using this equation it is possible to determine the lethality of heat at a single point more accurately (Stumbo, 1973).

Flambert & Deltour (1972) and Zechman & Pflug (1989) have used the above-mentioned method to determine the slowest heating point in metal containers.

The shape of the container is also very important. Alles & Cowell (1971) and Manson *et al.* (1970) investigated the use of rectangular , Manson *et al.* (1974) pear-shaped and Simpson *et al.* (1989) oval-shaped containers.

New computer programmes for estimating temperatures at specific sites are available (Hayakawa, 1979) and comparisons are made between the new and the old methods (Govaris & Scholefield, 1988).

Most of the values for thermal process estimation are based on °F (Stumbo, 1973), but Hayakawa & Downes (1981) express these values in °C.

2.2.7 Thermal Process Evaluation For Pouches

According to Toledo (1980) the rate of heat transfer in a slab is a linear function of the slab thickness and differs from the heat transfer in cylinders.

For this reason critical factors for processing of retort pouches had to be determined (Berry & Kohnhorst, 1983). Bhowmik & Tandon (1987) published a method for thermal process evaluation. Heat transfer coefficients were determined by Lebowitz & Bhowmik (1989) while the influence of entrapped air was researched by Weintraub *et al.* (1989).

2.2.8 Thermal Conductivity

Rha (1975) states that the thermal conductivity of a food depends on the thermal conductivity of the food components. The thermal conductivity of water can be used to make a first approximation of the food because fresh food contains a large percentage of water. This approximation can be made if the thermal conductivity of most of the food components is in the same order of magnitude and not much different from water. The mayor exception is air.

Kostaropoulos (1971) has written a review on thermal conductivity and of methods to determine this parameter. Unfortunately he only mentions peaches and not apricots. Kostaropoulos *et al.* (1975a and 1975b) also do not mention apricots. The thermal conductivity of apples is given by Lozano *et al.* (1979). Bhumbla *et al.* (1989) have reported on the thermal conductivity of fruit juices. Califano & Calvelo (1991) determined the values of potato and Rahman & Potluri (1991) of dried squid meat.

2.2.9 Thermal Diffusivity

During processing of food the heat transfer is often unsteady state, which means that the temperature of the food changes over time. It is important to determine what temperature change occurs in the food as well as how fast the heat is transferred. The ratio of thermal conductivity to the product of heat capacity and density is called thermal diffusivity (Rha, 1975).

Therefore after determination of thermal conductivity it is also important to determine how the heat moves through the product. Flambert (1974) describes a new method as do Bhowmik & Hayakawa (1979). The apparent thermal diffusivity of spherical foods is described by Hayakawa & Succar (1983). The thermal diffusivities of fish products are described by Han & Loncin (1985) while Di Pentima & Güemes (1987) described sweet corn and Chang & Toledo (1990) investigated carrots. No literature was found relating to apricots and peaches.

2.3 Nutrient Retention

Loss of nutrient components or the appearance of degradation products are mostly first order reactions (Toledo, 1980) and are directly proportional to their concentration.

Elkins (1979) reported on the nutrient retention of green beans, peaches and sweet potatoes in cans. He found that in the case of peaches the ascorbic acid and thiamine content decreased 17% and 9% respectively during processing as well as during storage. No significant losses of minerals except copper were found.

Chen & George (1981) confirmed this loss of ascorbic acid with green beans. They also found that the ascorbic acid loss was 2% higher with retort pouches than with cans.

Mulley *et al.* (1975) looked at the destruction of thiamine at different processing temperatures.

General papers relating to the loss of nutrients were published by Teixeira *et al.* (1969), Manson *et al.* (1970), Downes & Hayakawa (1977) and Anonymous (1986). Castillo *et al.* (1980) have published an article on the prediction of nutrient losses for retort pouches.

2.4 Microbiological Considerations

The thermal death times (TDT) of bacteria and spores are of great importance and several authors have published papers on this subject (Hayakawa *et al.*, 1981; Condon *et al.*, 1989 and Hachigian, 1989).

With the arrival of the retort pouch it was inevitable that a new method was developed to determine the T.D.T. and Erdtsieck & Beumer (1976) describe the use of T.D.T.-pouches.

3 EXPERIMENTAL

3.1 Experimental Design

The experimental design of the experiments during the 1987/88, 88/89, 89/90 and 90/91 seasons is given in Table 3.1.

Table 3.1 Experimental design of the fruit heat processed during the different seasons.

Season	Factorial design randomly repeated 4 times	
	Apricots	Peaches
1987/88	1 X 2 X 3	4 X 2 X 3
1988/89	1 X 2 X 3	2 X 2 X 3 X 2
1989/90	2 X 2 X 3 X 2 X 2	1 X 2 X 3 X 4
1990/91	2 X 2 X 3 X 4 X 2	1 X 2 X 3 X 3

3.2 Material

3.2.1 Fruit

During the 1987/88, 88/89, 89/90 and 90/91 seasons the Canning Fruit Board donated the Bulida apricots and the Kakamas peaches for the experiments. The apricots used were collected at the Langeberg Foods Ltd. receiving depot in the Robertson area.

The Kakamas peaches originated from the Ashton area. They were collected at the receiving depot of Langeberg Foods Ltd. in Paarl.

3.2.2 Cans

The A2½[1] plain body cans[2] (D3/1P)[3] with a sedronic[4] welded side seam and ends (I1F)[5] were used for canning control samples of apricots and peaches.

3.2.3 Pouches

In preliminary trials before the 1987/88 season apricots and peaches were heat processed in three different types of pouches[6] to determine their effectiveness (Table 3.2).

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[1] 99 mm diameter and 119 mm high.

[2] Food Can SA, Paarl.

[3] The inside of the can has a tin layer of 8,4 g/m^2 while the outside has a 2,8 g/m^2 layer.

[4] Copper wire electrode.

[5] The outside of the lid has a 2,8 g/m^2 tin layer and the inside is covered with a oleoresinous lacquer. A D100A compound was used as a seal between the lid and the can.

[6] Kohler Packaging (Pty.) Ltd.

Table 3.2 Composition of pouch material used in preliminary trials before the 1987/88 season.

Outside material	Middle material	Inside material
Nylon (± 20 micron)	Binding (± 10 micron)	LDPE[7] (± 70 micron)
PET[8] (± 12 micron)	None	PP[9] (± 70 micron)
PET[8] (± 12 micron)	Aluminium (± 7 micron)	PP[9] (± 70 micron)

In the first trial the fruit in the different pouches was stored in a laboratory on a window-sill facing north.

For the second trial the fruit in pouches was placed on a window-sill facing north as well as in a bench cupboard in the dark.

The size of the pouches used was 240 mm by 340 mm with the opening at one of the narrow ends.

Only the PET/aluminium foil/PP pouches were used for all subsequent experiments.

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7 LDPE = Low density polyethylene.
8 PET = Polyethylene terephtalate.
9 PP = Polypropelene.

3.3 Sampling At/For

3.3.1 Depot

Each season a representative sample (200 kg) of sound quality apricots and peaches was randomly selected (Snedecor & Cochran, 1987) from 4 bins each containing ± 500 kg fruit.

3.3.2 Analyses

Out of the 200 kg fresh fruit obtained from the source, 4 samples (2 kg) were randomly drawn just before heat processing (Snedecor & Cochran, 1987). Each sample was homogenized for 2 min at high speed in a Waring Blendor[10].

Aliquots (1 to 2 drops of juice) of the homogenized samples as well as of the prepared syrup were placed on folded filter paper and the syrup expressed. The total soluble solids content (TSS) was determined for each of these samples.

Directly after heat processing 1 container each, representing one of the 4 replicates, was randomly selected (Snedecor & Cochran, 1987) for each heat processing condition and opened. The content of each can was placed on a 8 gauge sieve (South Africa, 1976). The syrup was

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[10] Food Systems Africa C.C., Durban.

drained off for two min and the fruit was homogenized as individual samples. The TSS was determined as described above.

The homogenized samples were also used for the duplicate determination of total solids (± 10 g to the nearest mg), ascorbic acid (± 5 g to the nearest mg) and the single determination of mineral content (± 5 g to the nearest mg).

3.3.3 Discoloration In Preliminary Trials

Before the 1987/88 season 5 pouches of the different pouch materials were used in heat processing trials. One container of each material type was randomly selected (Snedecor & Cochran, 1987) for 4 weeks at weekly intervals and opened to visually determine the discoloration of the contents.

3.3.4 Heat Processing

During the subsequent experiments 10 containers for each of the 4 replicates were heat processed for each heat processing condition so that enough heat processed fruit was available for later tests. One container of each of the 4 replicates of the different heat processing conditions was selected at random (Snedecor & Cochran, 1987), as needed for the later tests.

3.3.5 Microbiological Determinations

During the 1987/88 season 1 container each representing one of the 4 replicates was randomly selected (Snedecor & Cochran, 1987), directly after heat processing, for each heat processing condition. The total contents were macerated in a Colworth Stomacher[11] and 1 cm^3 of this liquid was used.

During the 1988/89 season two each of the inoculated containers of apricots and peaches heat processed under different conditions were selected, directly after heat processing and used in the same way.

3.3.6 Drained Mass

During the 1987/88 season containers were selected from the remaining containers after 3 months storage. Five pouches of both the apricots (5 min at 90°C) and peaches (7 min at 95°C) as well as 5 cans of each fruit were randomly selected (Snedecor & Cochran, 1987) for the determination of drained mass (South Africa, 1976).

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[11] Labotec, SA.

3.3.7 Cut-Out Brix

Aliquots (1 to 2 drops) of the syrup obtained from the drained mass determination (3.3.6) were used.

3.3.8 Texture

One container from each of the 4 replicates of apricots and peaches heat processed in different containers and under different heat processing conditions was randomly selected (Snedecor & Cochran, 1987).

3.3.9 Discoloration

One container from each of the 4 replicates of apricots and peaches heat processed in different containers and under different heat processing conditions during each season was randomly selected at 3, 6 and 12 months storage intervals (Snedecor & Cochran, 1987).

3.3.10 Colour Determination

During the 1990/91 season 1 container from each of the 4 replicates of apricots and peaches heat processed in different containers and under different heat processing conditions was randomly selected after 12 months storage (Snedecor & Cochran, 1987).

3.3.11 Sensory Evaluation

During the 1990/91 season 9 specially prepared cans and 9 of the normally heat processed pouches of peaches (both heat processed for 20 min at 100°C) were used for the determination.

3.4 Preparatory Actions

3.4.1 Total Soluble Solids

The TSS contents of the homogenized samples (3.3.2) were determined by refractometer (Williams, 1984).

After preparation the syrup strengths were confirmed by refractometer (Williams, 1984).

The cut-out Brix of the syrups of both the apricots and peaches heat processed in different containers during the 1987/88 season were determined 3 months (Cruess, 1958) after storage by refractometer (Williams, 1984).

3.4.2 Halving And Destoning Of Fruit

Apricots were halved with a knife by cutting along the suture and destoned.

Peaches were halved and destoned with a Filper Pitter[12]. Any pit residues in the pitholes were removed manually with a pit-knife.

3.4.3 Lye-peeling

The fruit halves (± 5 kg), randomly selected according to Snedecor & Cochran (1987) from the 200 kg lots (3.3.1), were placed in a basket and immersed in boiling (± 100°C) sodium hydroxide (NaOH) solution for approximately 30 sec. A 10% (m/m) NaOH solution was used for apricots whilst a 2% (m/m) NaOH solution was applied for peaches. After lye-peeling the fruit was thoroughly washed with running tap water.

3.5 Filling And Heat Processing

3.5.1 Filling

Fixed masses of fruit 450 g (443 to 464 g, South Africa, 1973) and syrup (365 g) were used for A2½ cans according to Government regulations (South Africa, 1976).

The TSS of the fresh fruit were taken in consideration in determining the concentration of the syrup according to a mass balance (Toledo, 1980) for cut-out values of 19,5° and 18,5°B (± 0,5°B) (after 3 months storage) for apricots and

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[12] Filper Corp. San Ramon California, USA.

peaches respectively (Appendix A Table 3). In the case of cans 365 g of a warm (± 80°C) syrup solution (3.4.1) was added while for pouches 200 g of a cold (± 25°C) syrup solution (3.4.1) was added.

During the seasons batches of 10 aluminium laminated pouches[13] replicated 4 times, were filled for each heat processing condition.

During the 89/90 and 90/91 seasons, in addition to the normal syrup, a syrup containing 200 mg/l $CaCl_2$ was also used for the apricots heat processed in pouches.

During the 1990/91 season 20 cans of peaches were filled in the same way but a lower syrup strength was used to give a cut-out of 15,5°B which corresponded to the cut-out °B of the peaches heat processed in pouches. These peaches were used for the descriptive analyses (Piggot, 1988) of the fruit heat processed in different containers.

3.5.2 Exhausting

The open cans were placed on the driving belt of a horizontal continuous exhaust box[14] and exhausted for 10 min at 90°C.

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[13] Kohler Packaging (Pty) Ltd.

[14] Molenaar, Paarl, No 3403, 1985.

3.5.3 Vacuumising

The pouches were placed flat in the vacuum chamber of a Multivac Mod A300/52 machine[15] and a vacuum of 980 mbar was applied before the pouches were heat sealed (110 to 130°C for 6 sec) with a functional and a vanity seam (Lampi, 1977).

3.5.4 Sealing Of Cans

Directly after exhausting the cans were sealed at atmospheric pressure with a double seam (Hersom & Hulland, 1963) using an electric seamer[16], inverted and placed in a retort basket.

3.5.5 Retorting

The cans with apricots were placed in a vertical still retort[17] and heat processed for 15 min at 90°C except for the 1987/88 season when they were heat processed for 10 min at 95°C. Canned peaches were heat processed for 20 min at 100°C (Van Rhyn & Hansmann, 1987). The temperature (± 2°F) was controlled by a Taylor pneumatic control system[18]. After heat processing the cans were cooled to ± 40°C by immersion in water.

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[15] Geiger & Klotzbücher (Pty.) Ltd., SA.
[16] Metal Box, SA, MB No 1-4, 1967.
[17] Molenaar, Paarl No 1950, 1950.
[18] Rapid Instrumentation, Oakdale.

The pouches were placed flat in a special round (540 mm diameter 700 mm high) diamond mesh crate with 10 shelves 40 mm from each other (Fig. 3.1) and heat processed in the same retort.

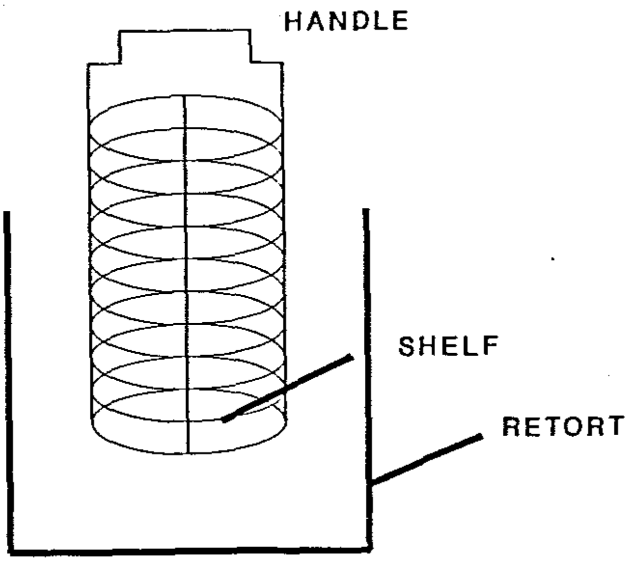

Fig. 3.1 Special developed retort basket to heat process retort pouches.

During the preliminary trials apricots were heat processed for 5 min at 90°C and peaches for 7 min at 100°C.

The processing time and temperature combinations, as result of the different experimental findings, for the 1987/88, 88/89, 89/90 and 90/91 seasons are given in Appendix A Table 4.

After heat processing the pouches were cooled to ± 40°C in water.

3.6 Analyses

All analyses during the 1987/88 season were done in duplicate unless stated differently on the fresh as well as fruit heat processed in cans (control samples) and pouches. All treatments were repeated 4 times to represent the 4 replicates.

3.6.1. Total Solids

The total solids (TS) were determined on the samples (± 5 g to the nearest mg) according to Williams (1984).

3.6.2 Ascorbic Acid

Ascorbic and dehydroascorbic acids were determined on the samples (± 10 g to the nearest mg) by a microspectrofluorometric method according to Deutsch (1967).

3.6.3 Mineral Content

A single determination of each sample (± 5 g to the nearest mg) was done. Calcium, copper, iron, magnesium, manganese, potassium, sodium and zinc were determined by a flamespectrophotometric method and phosphorus by a colorimetric method according to Williams (1984) by the Soil Science Department of the Stellenbosch Institute for

Fruit Technology. All results are expressed as mg/100 g fresh fruit.

3.6.4 Drained Mass

Inspection Service's regulations were used (South Africa, 1976) for 5 containers of both apricots and peaches heat processed in aluminium laminated pouches and cans, after 3 months storage.

3.6.5 Cut-out Brix

The °B of the syrup after 3 months storage from 5 containers was determined by refractometer (Williams, 1984)

3.6.6 Texture

Texture was determined during all the seasons as hardness (deMan *et al.*, 1976). One container representing each of the replicates of each heat process was used. An Instron Table Model Universal Testing Instrument[19] using a compression load cell type 2511-201 with a maximum capacity of 19,6 N was employed for the determinations. A 10 mm diameter round point was used for the penetration and allowed to move into the fruit till it reached 3 mm above the load cell. The cross-beam speed was 30 cm/min.

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[19] Instron Corporation, Canton, Massachusetts, U.S.A.

The pressure was recorded on a Model S chart recorder[20] with a chart speed of 10 cm/min. The instrument was calibrated to give a full-scale chart reading for 9,8 N (1000 g). Texture measurements were taken 1 day after heat processing at ambient temperature.

Ten halves from each container of apricots were used per treatment and placed directly on the load cell and the baseline on the recorder was adjusted.

Two pieces of peaches were removed with a cork bore (diameter 24 mm) from 5 halves from each container. The top part was cut off to assure that no possible skin residues could influence the reading. Afterwards it was placed in a stainless steel ring (inside diameter 24 mm) and cut to a thickness of 10 mm. This ring with the sample was placed on the load cell and the baseline on the recorder was accordingly adjusted.

3.7 Microbiological Determinations

During the 1987/88 season the most probable number (MPN) method implemented by Harrigan & McCance (1976) was used for the prepared samples (3.3.5).

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[20] Leeds & Northup, Sumneytown Pike, North Wales, Pa. 19454, U.S.A.

During the 1988/89 season a 10^8 spores/cm^3 solution of *Clostridium butyricum* MB 132[21] was prepared according to Harrigan & McCance (1976). Both cans and pouches were inoculated with 2 cm^3 of this solution before sealing and heat processing (Stumbo, 1973).

Inoculated apricot samples in pouches were heat processed for 10 and 23 min at 90°C and for 10 and 15 min at 100°C respectively. Those in cans were heat processed for 15 min at 90°C. Inoculated peach samples in pouches were heat processed 20 and 30 min at 100°C and the cans 20 min at 100°C.

After heat processing the mixture of fruit and syrup was placed in sterile bags and those were placed in a Colworth Stomacher[22] and blended for 2 min at 500 rpm. After blending 1 cm^3 of this mixture was aseptically used to make a serial dilution (Harrigan & McCance, 1976) to 10^{-8}. One cm^3 of the dilutions was aseptically placed in Petri dishes and molten Agar at ± 45°C was poured into the dishes by the poured plate method (Harrigan & McCance, 1976).

The plates were placed in anaerobic jars[23]. Anaerobic conditions were obtained by the use of Anaerocult A[24]. The plates were incubated for 24 h at 37°C followed by 1 to 2 days at room temperature before the number of colony

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[21] Nampak R & D, SA.
[22] Labotec.
[23] Oxiod.
[24] Merck.

forming units[25] (CFU) was counted. Two containers of each treatment were plated out in duplicate for each dilution.

3.8 Computerized Heat Penetration Studies

3.8.1 Graphical Studies

During the 1988/89 and 89/90 seasons a thermocouple wire of 20 Gauge consisting of copper and constantan Type T[26] was used (Fig 3.2). The two metals were twisted together at the end and soldered (National Canners Association Research Laboratories, 1968).

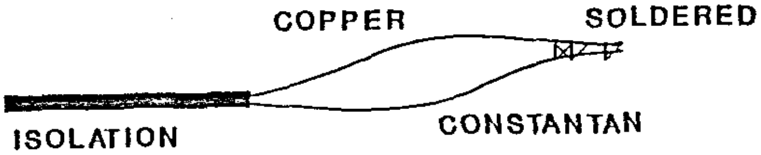

Fig. 3.2 Schematic drawing of a thermocouple.

A 12 mm hole was made just below the center of an A2½ can and in the middle of the PET/aluminium/PP pouch. The wire was put into a polyvinyl chloride (PVC) gland and the gland was hermetically sealed into the container by the use of rubber washers (Fig. 3.3).

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[25] CFU = number of living organisms or clumps of organisms forming a colony (Harrigan and McCance, 1976).

[26] Temperature Controls, Randburg, SA.

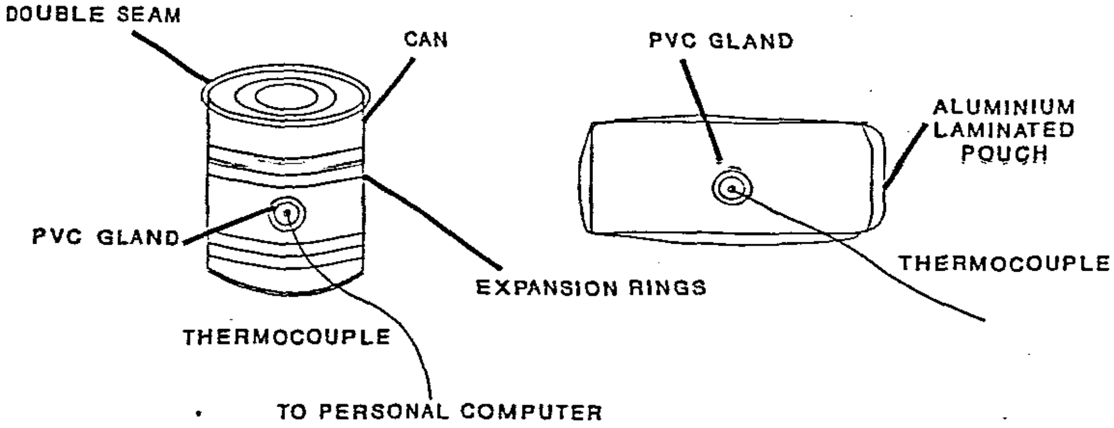

Fig. 3.3 Schematic drawing of placement of thermocouples in cans and aluminium laminated pouches.

After the fruit and syrup were added to the pouches, the tip of the wire was pressed into the fruit and the pouches sealed.

The cans went through an exhaust process (3.4.2) before sealing. The wire was thus pressed into the fruit before this process.

A Hewlett-Packard 3852A data acquisition/control unit and a Hewlett-Packard Vectra AT personal computer (PC) comprised the computer hardware. Under control of the PC the data acquisition unit performed data acquisition at 10 sec intervals. Data was stored on disk in the PC using a sequential ASCII file format. This facilitated direct file access by spreadsheet programs.

In the case of cans temperature readings of the fruit were also taken during exhausting. During retorting and cooling the temperatures of the fruit and the cooking/cooling water were taken for both types of containers. Results were later processed with a Lotus 123[27] Version II programme.

3.8.2 Tabulated Studies

During the 1989/90 season temperature readings of the fruit in the containers were taken at 1 min intervals and written down in a table. These temperatures were compared with a lethal rate value as worked out by Patasnik (1953) and added up. After the heat process these added values gave the effective time (min) that the fruit was at a specific processing temperature.

3.9 Storage

Fruit in cans as well as in aluminium laminated pouches were stored in plastic lug boxes at ambient temperature in a dark store for 1 year.

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[27] Lotus Development Corporation

3.10 Tests For Discoloration

3.10.1 Preliminary Trials

The degree of browning of the different packaging materials was visually determined for 4 weeks at weekly intervals by one observer on a 4 point scale . (See Table 4.10).

3.10.2 Aluminium Laminated Pouches Versus Cans

The degree of browning was visually determined after 3, 6 and 12 months storage by one observer on a 4 point scale (3.10.1) and compared with fruit heat processed in cans.

3.10.3 Colour Measurements

Tristimulus colour determinations (Kramer & Twigg, 1980) of the C.I.E. co-ordinates (X, Y, Z) according to Van Der Heijden *et al.* (1979) were done on the apricots and peaches heat processed during the 1989/90 season after 12 months storage.

The Colourgard system 05 colorimeter[28] coupled to an AT Vega computer[29] (Miad 100A with a mathematical co-processor) for data processing was used.

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[28] Premier Technologies Cape Town, 1990.
[29] Softec Cape Town 1990.

The colorimeter was calibrated with a white tile (X=84,30, Y=86,52 and Z=100,71). A luminescent C light source was used which is comparable to overcast daylight.

The fruit and syrup were placed in a Waring Blendor[30] and homogenized for 1 min at low speed taking care that no air was entrapped. For both the apricots and peaches heat processed in cans and pouches, 2 colour readings of each container were taken for each heat processing condition.

3.11 Sensory Evaluation

A descriptive comparison (Piggott, 1988) of peaches heat processed in pouches with those heat processed in cans was made.

3.11.1 Panel

A specialist panel of 11 male members was used. They are responsible for the annually evaluation of heat processed fruit of new cultivars at the Stellenbosch Institute for Fruit Technology. Their ages range from 33 to 59. Three of the members were regular smokers. The members were employees of the Canning Fruit Board, Apricot, Peach and Pear Growers Association, Inspection Services, Langeberg Foods Ltd. and the Stellenbosch Institute for Fruit Technology.

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[30] Food Systems Africa C.C., Durban.

3.11.2 Evaluation

The following characteristics were evaluated: General appearance, colour, texture, sweetness and off flavors and the results were plotted according to Zook & Wessman (1977). An example of the score sheet used is given in Appendix D.

4. RESULTS

4.1 Material

4.1.1 Preliminary Trials

Fruit processed in nylon/binding material/LDP and PET/PP (transparent) pouches during the preliminary trials began to show a superficial brown discoloration after 2 weeks storage. Processed fruit in the PET/aluminium/PP pouches did not show this discoloration. Fruit in transparent pouches exposed to light did not differ with regard to discoloration from those kept in the dark after 2 weeks storage.

4.2 Analyses

4.2.1 Total Solids

The mean TS contents of the fresh apricots and peaches of the 1987/88 season are given in Table 4.1 and those of fruit processed in different containers in Table 4.2.

The moisture contents of both the fresh apricots and peaches differ significantly from the literature values ($p<0,05$).

There is a significant difference ($p<0,05$) in moisture content of both the apricots and peaches processed in aluminium laminated pouches compared with those processed in cans.

Table 4.1 The mean[1] composition of fresh apricots and peaches of the 1987/88 season, compared with the literature values.

Fruit	Moisture (%)	TS[2] (%)	TSS[3] (°B)	Vit. C[4] (mg/100g)
Apricot	83,98	16,02	14,5	3,74
Lit[5]	86,60	13,40	---[6]	7,2[7]
P	$< 0,05$	$< 0,05$		$< 0,05$
Peaches	85,00	15,00	13,5	3,4
Lit[5]	86,20	13,80	---[6]	8,1[7]
P	$< 0,05$	$< 0,05$		$< 0,05$

---

[1] 4 Determinations in duplicate.
[2] Total solids.
[3] Total soluble solids.
[4] Ascorbic + Dehydro-ascorbic acid.
[5] Paul and Southgate (1978).
[6] No determination.
[7] Values transformed to the same moisture content as the experimental fruit.

Table 4.2 The mean[8] composition of apricots and peaches processed in different containers during the 1987/88 season[9].

Fruit	Container	Moisture (%)	TS[10] (%)	TSS[11] (°B)	Vit.C[12] (mg per 100g)
Apricot	Can	$83,3^a$	$16,7^c$	$15,3^e$	$2,7^f$
	Pouch[13]	$83,8^b$	$16,2^d$	$15,1^e$	$2,4^f$
Peaches	Can	$84,4^g$	$15,6^i$	$14,5^k$	$2,2^m$
	Pouch[15]	$84,7^h$	$15,3^j$	$14,1^l$	$2,1^m$

4.2.2 Total Soluble Solids

The TSS content of fresh apricots ranged between 14,4° and 15,3°Brix during the 1987/88, 88/89, 89/90 and 90/91 seasons. Those of fresh peaches ranged between 13,5° and 15,0° Brix. The mean TSS contents of the fresh apricots and peaches from the 1987/88 season are given in Table 4.1 and of the fruit processed in different containers in Table 4.2.

In the case of the processed apricots no significant difference ($p>0,05$) in TSS did occur between the two containers. The TSS of peaches in aluminium laminated

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[8] 4 Determinations in duplicate.

[9] Means in a column followed by the same letter do not differ significantly at $P = 0,05$.

[10] Total solids.

[11] Total soluble solids.

[12] Ascorbic + Dehydro-ascorbic acid 1 day after processing.

[13] Aluminium laminated pouch.

pouches were slightly less than those in cans and showed a significant difference ($p<0,05$).

4.2.3 Ascorbic Acid Content

The mean ascorbic acid contents of fresh apricots and peaches from the 1987/88 season are shown in Table 4.1 and those of fruit processed in different containers in Table 4.2. The fresh apricots and peaches showed a significant difference ($p<0,05$) in ascorbic acid content compared with the literature value. In the case of the apricots and peaches processed in different containers no significant difference ($p>0,05$) was obtained.

4.2.4 Mineral Content

The mean mineral contents of apricots and peaches from the 1987/88 season are given in Table 4.3 and those of fruit processed in different containers in Table 4.4.

Table 4.3 The mean[14] mineral contents of fresh apricots and peaches from the 1987/88 season, compared with the literature values.

Fruit	Mineral content (mg/100g)								
	K	Ca	Mg	Na	Fe	Cu	Mn	Zn	P
Apricots	110	5,5	5,7	8,1	0,14	0,11	0,02	0,07	6,0
Lit[15,16]	330	17,5	12,4	Tr	0,41	0,12	--[17]	0,10	21,7
P	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05		<0,05	<0,05
Peaches	92	4,2	6,2	9,7	0,13	0,07	0,01	0,08	5,9
Lit[15,16]	264	5,1	8,1	3,0	0,41	0,05	--[17]	0,10	19,3
P	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05		<0,05	<0,05

Table 4.4 The mean mineral[18] contents of 1987/88 season's apricots and peaches processed in different containers[19].

Fruit	Container	Mineral content (mg/100g)								
		K	Ca	Mg	Na	Fe	Cu	Mn	Zn	P
Apricot	Pouch[20]	102^{a}	$5,1^{b}$	$5,9^{c}$	$7,3^{d}$	$0,11^{e}$	$0,10^{g}$	$0,01^{h}$	$0,05^{i}$	$5,8^{j}$
	Can	109^{a}	$4,6^{b}$	$6,2^{c}$	$8,5^{d}$	$0,16^{f}$	$0,10^{g}$	$0,01^{h}$	$0,07^{i}$	$5,9^{j}$
Peach	Pouch[20]	89^{k}	$3,8^{l}$	$5,7^{m}$	$9,0^{n}$	$0,12^{o}$	$0,06^{q}$	$0,01^{r}$	$0,06^{s}$	$5,4^{t}$
	Can	91^{k}	$3,9^{l}$	$5,9^{m}$	$8,9^{n}$	$0,14^{p}$	$0,05^{q}$	$0,01^{r}$	$0,06^{s}$	$5,5^{t}$

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[14] 4 Determinations.

[15] Paul and Southgate (1978).

[16] Values transformed to the same moisture content as the experimental fruit.

[17] No determination.

[18] 4 Determinations.

[19] Means in a column followed by the same letter do not differ significantly at P = 0,05.

[20] Aluminium laminated pouch.

The fresh apricots and peaches showed significant differences ($p<0,05$) in mineral contents with the literature values (Paul & Southgate, 1978). No significant differences ($p>0.05$) except for Fe were found when fruit processed in aluminium laminated pouches were compared with cans.

4.2.5 Drained Mass.

The mean drained masses of the 1987/88 season's apricots and peaches processed in different containers are given in Table 4.5.

Table 4.5 The mean[21] drained masses of 1987/88 season's fruit processed in different containers after 3 months storage[22].

Fruit	Container	Drained mass (g)
Apricot	Can	$429,5^a$
	Pouch[23]	$434,0^a$
Peach	Can	$427,5^b$
	Pouch[23]	$432,5^b$

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[21] Mean of 5 determinations.

[22] Means in a column followed by the same letter do not differ significantly at $P = 0,05$.

[23] Aluminium laminated pouch.

The drained masses of both the apricots and peaches processed in aluminium laminated pouches are not significant higher ($p>0,05$) than those processed in cans.

4.2.7 Cut-out Brix

Table 4.6 The mean[24] cut-out Brix of 1987/88 season's fruit processed in different containers after 3 months storage[25].

Fruit	Container	Cut-out Brix °B
Apricot	Can	19,4^{a}
	Pouch[26]	17,1^{b}
Peach	Can	16.5^{c}
	Pouch[26]	15,0^{d}

The cut-out Brix after 3 months storage of the fruit in pouches is significantly ($p<0,05$) lower than that of fruit processed in cans (Fig. 4.6).

4.2.7 Texture

The mean hardness measurements of apricots and peaches processed in different containers during the 1987/88 season are given in Table 4.7.

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[24] Mean of 5 determinations.

[25] Means in a column followed by the same letter do not differ significantly at $P = 0,05$.

[26] Aluminium laminated pouch.

Table 4.7 The mean hardness[27] of apricots and peaches processed in different containers during the 1987/88 season as determined 1 day after processing[28].

Fruit	Container	Heat/time-process	Hardness[29] (g)
Apricots	Can	95°C/10 min	22[30a]
	Pouch[31]	95°C/5 min	72[30b]
Peaches	Can	100°C/20 min	502[30c]
	Pouch[31]	80°C/7 min	1417[30d]
		85°C/7 min	1376[30e]
		90°C/7 min	1172[30f]
		95°C/7 min	1000[30g]

Significant differences ($p<0,05$) in hardness of apricots processed in different containers occurred. The peaches processed during the 1987/88 season in aluminium laminated pouches were significantly harder ($p<0,05$) compared with those processed in cans.

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[27] Round pressure point 10 mm diameter.
Bar speed 30 cm/min.
Chart speed 10 cm/min.

[28] Means in a column followed by the same letter do not differ significantly at $P = 0,05$.

[29] Repeated 4 times.

[30] Mean of 10 readings.

[31] Aluminium laminated pouch.

Table 4.8 The mean hardness[32] of peaches processed in different containers during the 1988/89 season as determined 1 day after processing[33].

Fruit	Container	Heat/time-process	Hardness[34] (g)
Peaches	Can	100°C/20 min	412[35a]
	Pouch[36]	90°C/25 min	1309[35b]
		90°C/30 min	1192[35c]
		100°C/25 min	585[35a]
		100°C/30 min	389[35a]

The apricots of the 1988/89 season processed in pouches were too soft and no determinations could be done. The peaches in pouches processed at 90°C were significantly ($p<0,05$) harder than those processed in cans. The peaches processed in pouches at 100°C did not differ significantly ($p>0,05$) in hardness with those processed in cans.

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[32] Round pressure point 10 mm diameter.
Bar speed 30 cm/min.
Chart speed 10 cm/min.

[33] Means in a column followed by the same letter do not differ significantly at P = 0,05.

[34] Repeated 4 times.

[35] Mean of 10 readings.

[36] Aluminium laminated pouch.

Table 4.9 The mean hardness[37] of peaches processed in different containers during the 1989/90 season as determined 1 day after processing[38].

Fruit	Container	Heat/time-process	Hardness[39] (g)
Peaches	Can	100°C/20 min	542[40a]
	Pouch[41]	100°C/19 min	736[40b]
		100°C/21 min	598[40a]
		100°C/23 min	547[40a]
		100°C/25 min	292[40c]

The apricots processed in both the pouches and cans were too soft and no determinations could be done. The hardness of peaches processed in pouches for 21 and 23 min at a 100°C did not differ significantly ($p>0,05$) from the fruit processed in cans. The peaches processed in pouches for 19 min were significantly ($p<0,05$) harder compared with those processed in cans. The peaches processed for 25 min in pouches were significantly ($p<0,05$) softer than the peaches processed in cans. This difference from last season can possibly be explained by the ripeness of the fruit.

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[37] Round pressure point 10 mm diameter.
Bar speed 30 cm/min.
Chart speed 10 cm/min.

[38] Means in a column followed by the same letter do not differ significantly at P = 0,05.

[39] Repeated 4 times.

[40] Mean of 10 readings.

[41] Aluminium laminated pouch.

The mean hardness measurements of the apricots processed in pouches and cans during the 1990/91 season as determined 1 day after processing are given in Fig. 4.1.

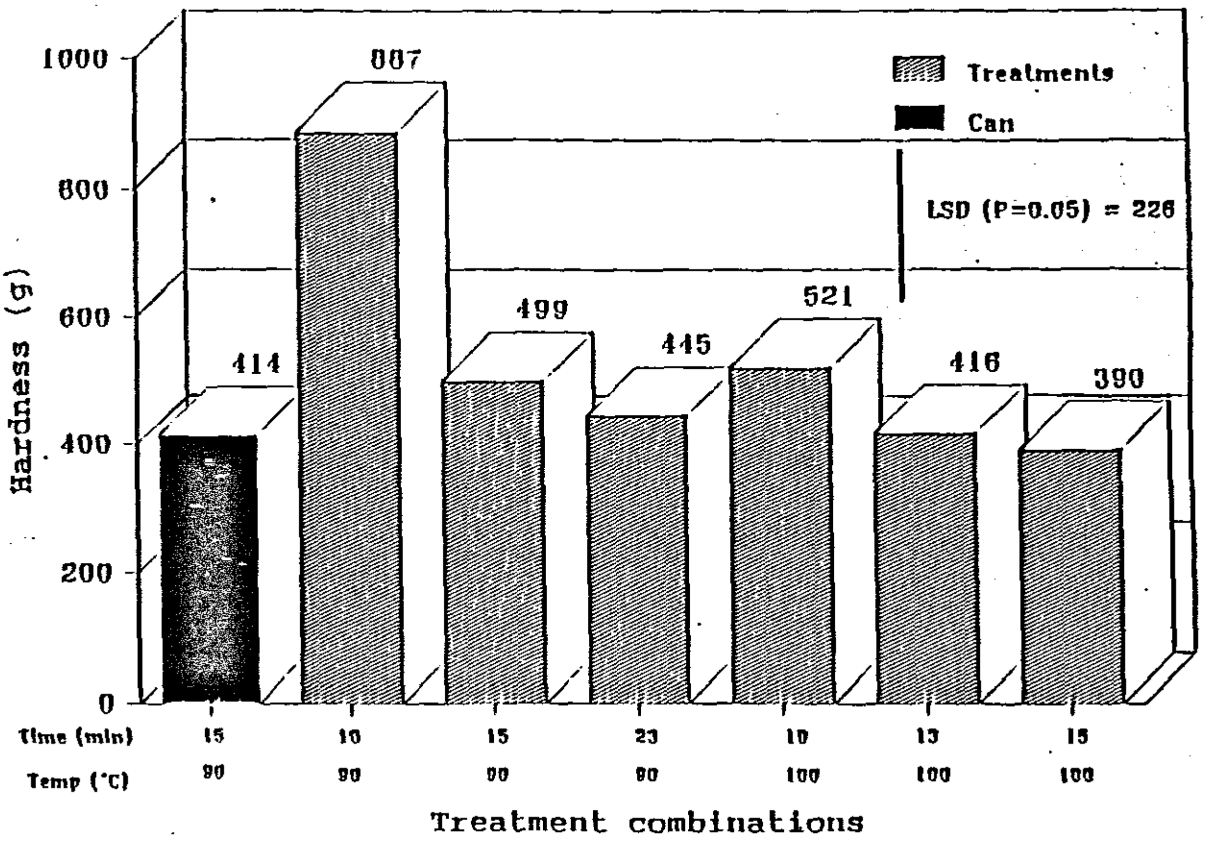

Fig. 4.1 A comparison between mean[42] hardness[43] of Bulida apricots processed under different conditions in aluminium laminated pouches with those processed in cans during the 1990/91 season as determined 1 day after processing.

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[42] Mean of 10 readings repeated 4 times.

[43] Round pressure point 10 mm diameter.
Bar speed 30 cm/min.
Chart speed 10 cm/min.

The apricots processed in pouches for 10 min at 90°C were significantly ($p<0,05$) harder than the apricots processed in cans. The other treatments did not show a significant difference ($p>0,05$) in hardness compared with the apricots processed in cans.

The influence of $CaCl_2$ on the hardness of apricots from the 1990/91 season processed in pouches as determined 1 day after processing is shown in Fig. 4.2.

The apricots with or without the addition of $CaCl_2$, processed for 10 min at 90°C as well as those processed for 15 min at 100°C did not show a significant difference ($p>0,05$) in hardness from each other. The apricots processed, with the addition of $CaCl_2$, for 15 min at 90°C and 10 min at 100°C were significantly ($p<0,05$) harder than the apricots processed under those conditions without the addition of $CaCl_2$.

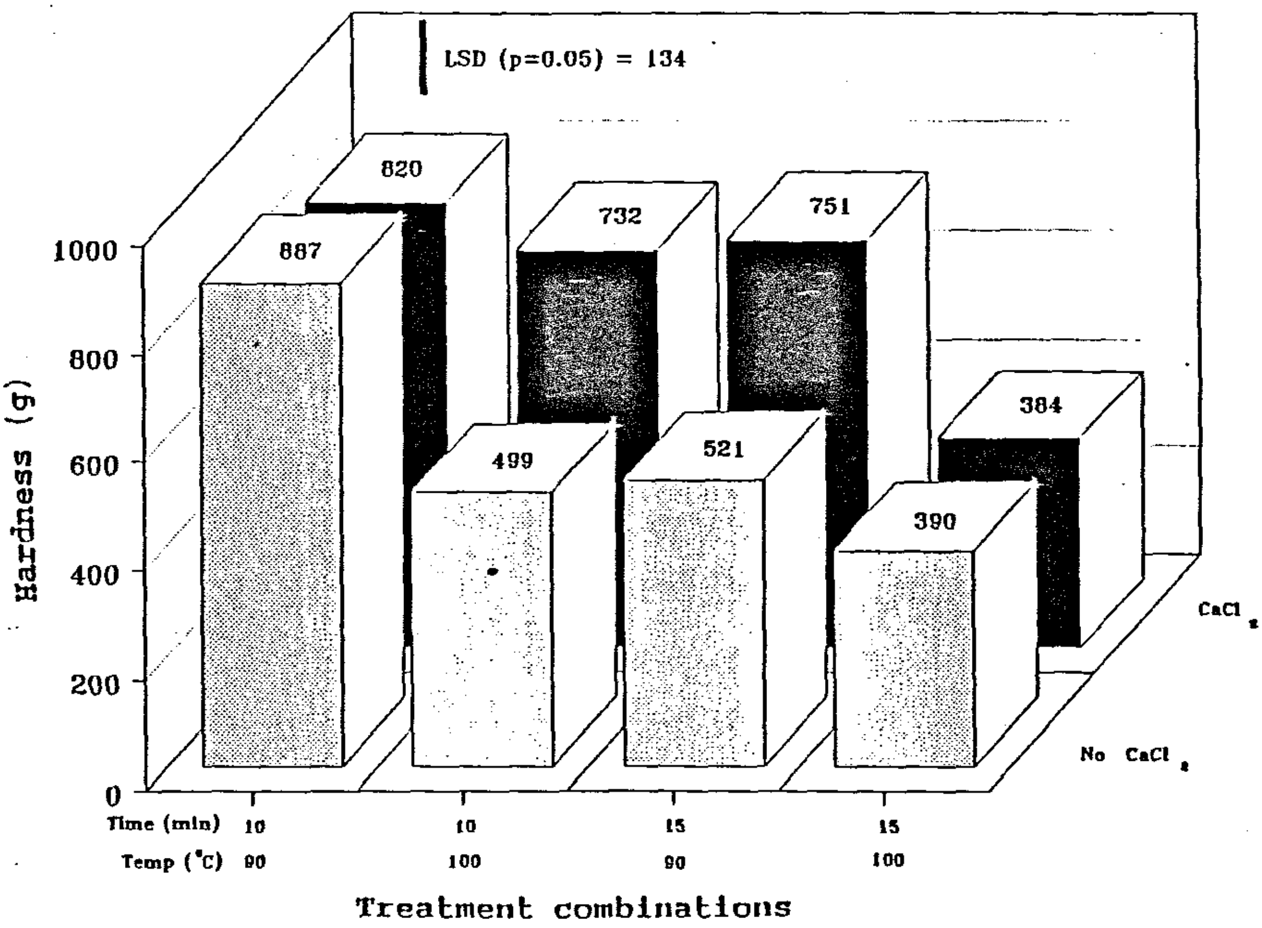

Fig. 4.2 A comparison between the mean[44] hardness[45] of Bulida apricots processed under different conditions in aluminium laminated pouches during the 1990/91 season, with and without the addition of $CaCl_2$[46] as determined 1 day after processing.

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[44] Mean of 10 readings repeated 4 times.

[45] Round pressure point 10 mm diameter.
Bar speed 30 cm/min.
Chart speed 10 cm/min.

[46] 200mg/l $CaCl_2$ added

The mean hardness measurements of the peaches from the 1990/91 season as determined 1 day after processing are given in Fig. 4.3.

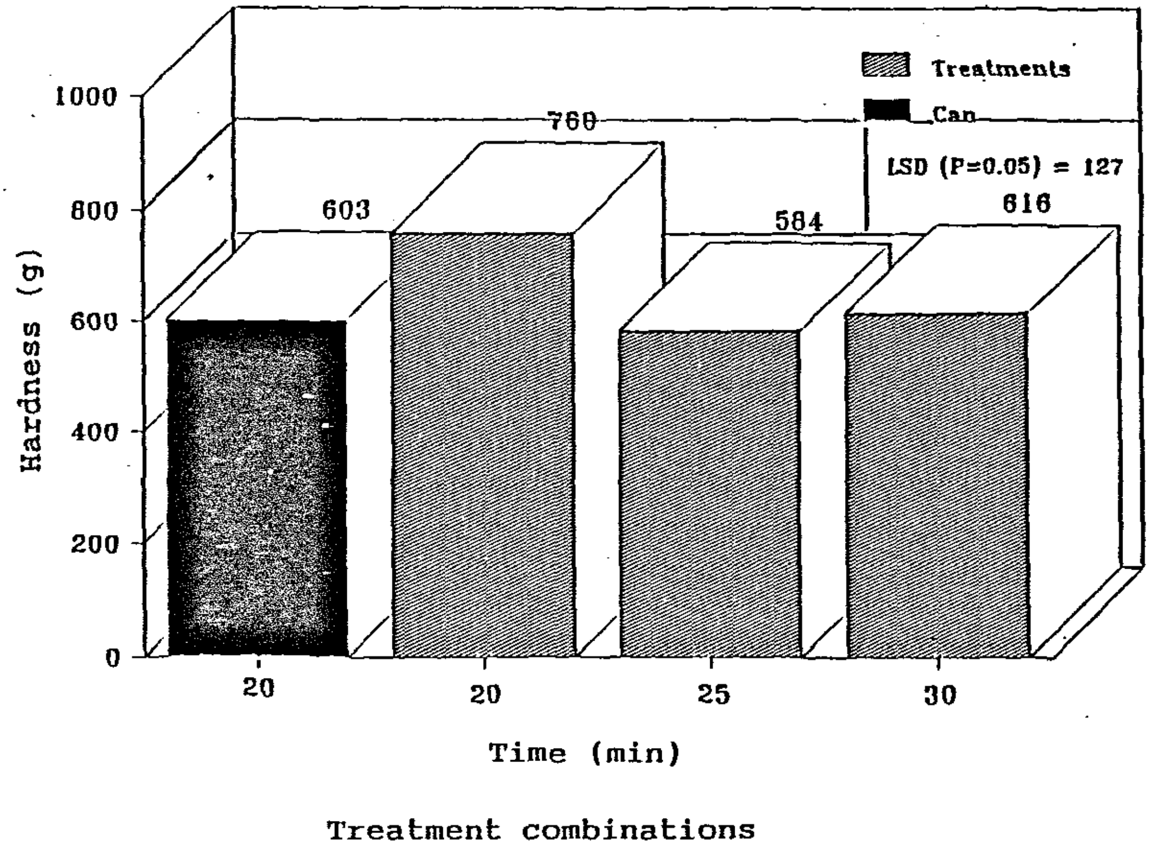

Fig. 4.3 A comparison of the mean[47] hardness[48] of Kakamas peaches processed in aluminium laminated pouches for different times at 100°C with those processed in cans during the 1990/91 season as determined 1 day after processing.

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[47] Mean of 10 readings repeated 4 times.

[48] Pressure point 10 mm diameter.
Bar speed 30 cm/min.
Chart speed 10 cm/min.

The peaches processed for 20 min at 100°C were significantly ($p<0,05$) harder than the fruit processed in cans. The hardness of the peaches processed for 25 and 30 min at 100°C did not differ significantly ($p>0,05$) with those processed in cans.

4.3 Microbiological Determinations

Apricots and peaches of the 1987/88 season processed in aluminium laminated pouches as well as cans (controls) showed growth up to the 10^{-10} dilution.

During the 1988/89 season no significant ($p>0,05$) difference in CFU could be shown between apricots processed in laminated pouches at 90°C for both 10 and 23 min and cans processed for 15 min at 90°C. In all three treatments 1500 CFU were isolated. In apricots processed in aluminium laminated pouches at 100°C for 10 and 15 min respectively no CFU were isolated.

In the case of peaches in aluminium laminated pouches processed for 20 and 30 min at 100°C and cans processed for 20 min at 100°C no CFU were isolated.

4.4 Computerized Heat Penetration Studies

4.4.1 Graphical Studies

The heat penetration results of apricots processed at 90°C (194°F) in aluminium laminated pouches and cans during the 1988/89 season are given in Fig. 4.4.

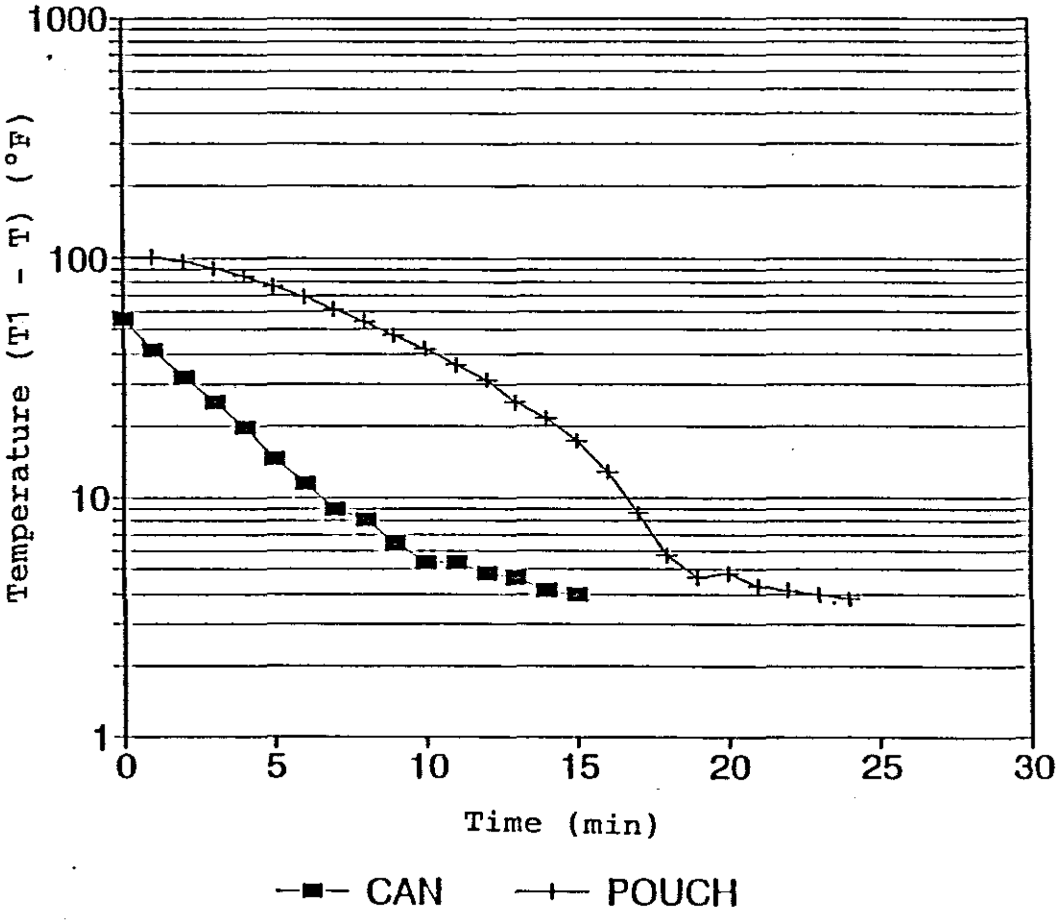

Fig. 4.4 Logarithmic plot of the difference between processing temperature (T1) and fruit center temperature (T) in °F over time, for apricots processed in aluminium laminated pouches and cans at 90°C (194°F) during the 1988/89 season.

At 90°C (194°F) apricots processed in aluminium laminated pouches required 23 min to reach the desired temperature, while fruit in cans required only 15 min (Fig 4.4).

Heat penetration studies performed on peaches processed at 100°C (212°F) during the 1988/89 season are given in Fig.4.5.

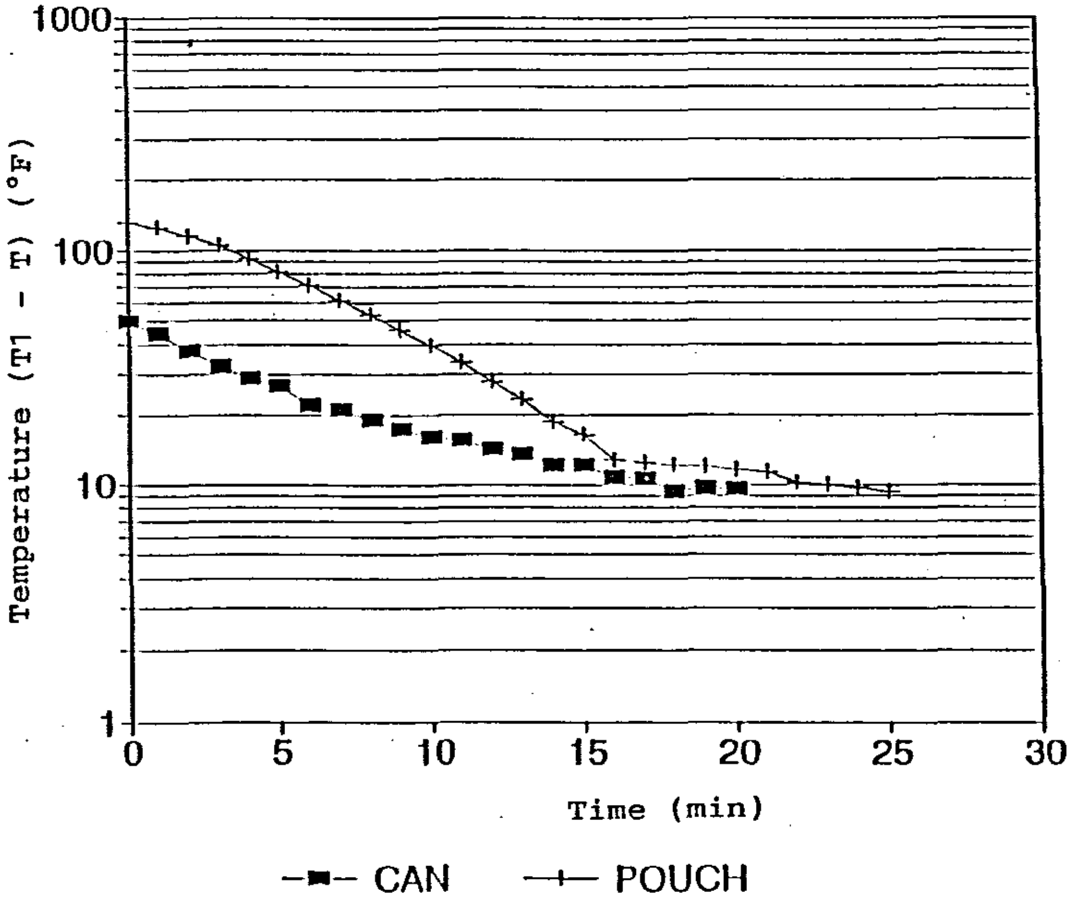

Fig. 4.5 Logarithmic plot of the difference between processing temperature (T1) and fruit center temperature (T) in °F over time, for peaches processed in aluminium laminated pouches and cans at 100°C (212°F) during the 1988/89 season.

At 100°C (212°F) peaches processed in aluminium laminated pouches required 25 min to reach the desired temperature, while fruit in cans required only 20 min (Fig 4.5).

4.4.2 **Tabulated Studies**

During the 1989/90 season apricots processed in aluminium laminated pouches at 90°C (194°F) reached the same process value[49] as fruit processed in cans after 20 min. Fruit in cans required 15 min (Fig. 4.6).

At 100°C (212°F) apricots processed in aluminium laminated pouches will reach the same process value after ± 7½ min.

At 100°C (212°F) peaches processed in aluminium laminated pouches required 29 min to reach the same process value as the fruit in cans. The fruit in cans only required 20 min (Fig. 4.7).

The results of the difference of retort temperature minus fruit temperature in °F compared at one min intervals with lethal rate values obtained from Patashnik's (1953) tables for apricots are shown in Fig. 4.6.

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[49] If temperature readings are taken at equal time interval, process values can be obtained by tabulating the lethality value (F/t) for each equal-time-interval temperature reading and making a summation thereof. The product of this sum and the equal time interval gives the process value (Patashnik, 1953).

These apricots were processed at 194°F (90°C) and 212°F (100°C). The results for peaches processed at 212°F (100°C) are shown in Fig. 4.7.

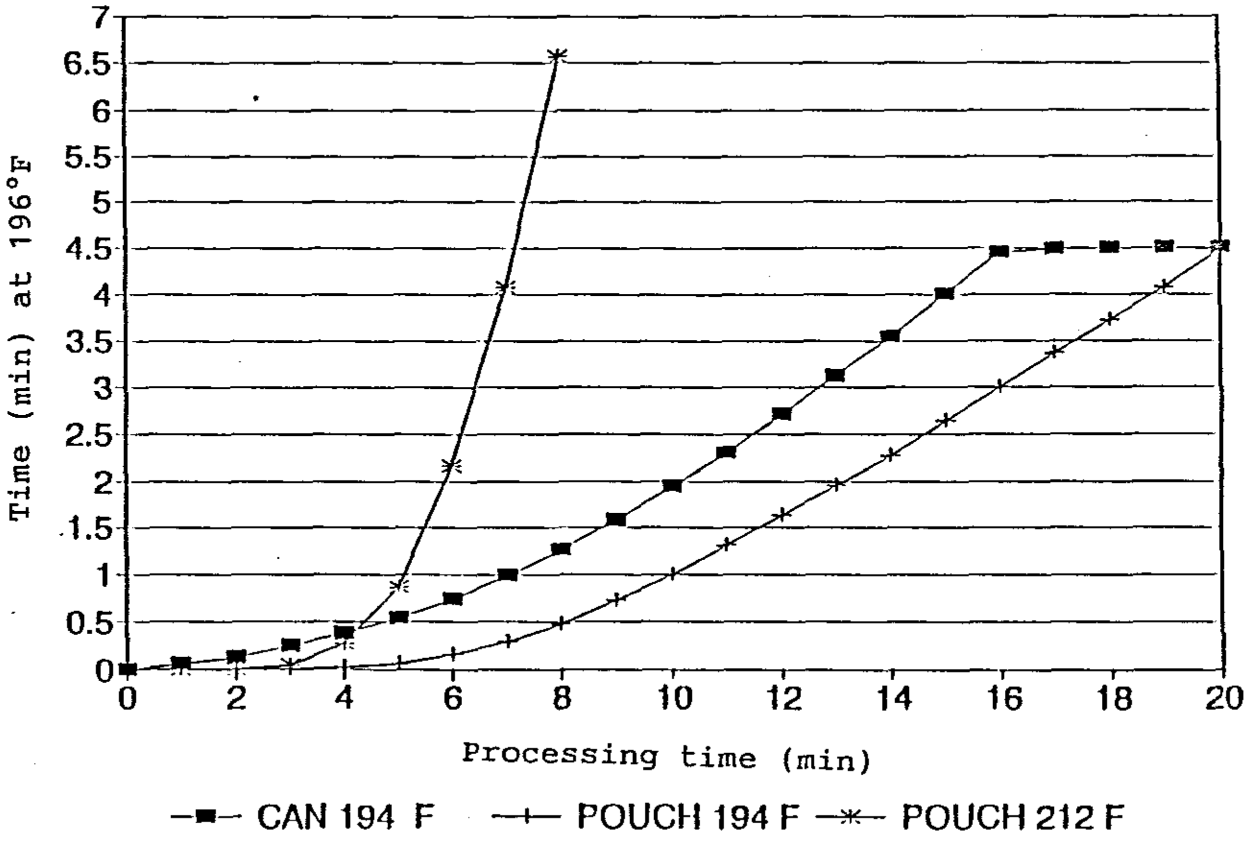

Fig. 4.6 Effective time (min) at 196°F using Patashnik's (1953) tables for apricots processed in pouches at 194°F (90°C) and 212°F (100°C) and cans at 194°F during the 1989/90 season.

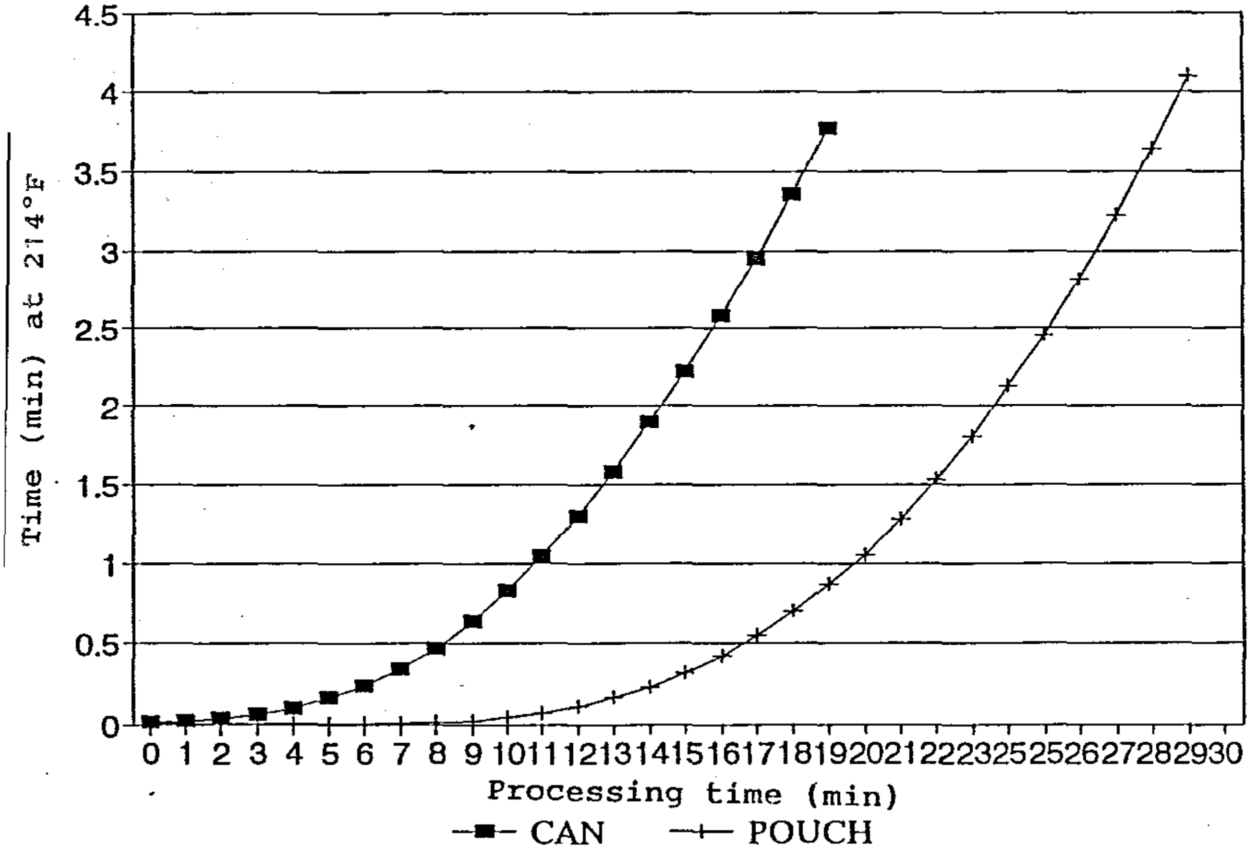

Fig. 4.7 Effective time (min) at 214°F using Patashnik's (1953) tables for peaches processed in pouches and cans at 212°F (100°C) during the 1989/90 season.

4.5 Tests For Discoloration

4.5.1 Aluminium Laminated Pouches Versus Cans

The degrees of browning of apricots and peaches processed in different containers of the 1989/90 season after different storage times are given in Table 4.10.

Table 4.10 Browning[50] of apricots and peaches packed in different containers and processed under different conditions during the 1989/90 season.

Fruit	Container	Temperature (°C)	Processing time (min)	Storage time (months)		
				3	6	12
Apricot	Pouch[51]	80	20	0	+	+++
			24	0	0	+++
	Pouch[50]	90	20	0	0	+++
			24	0	0	+++
	Can	90	15	0	0	0
Peach	Pouch[50]	100	19	0	0	0
			21	0	0	0
			23	0	0	0
			25	0	0	0
	Can	100	20	0	0	0

The apricots processed in aluminium laminated pouches showed a dark brown discoloration after 12 months storage.

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[50] Degree of browning:
0 = no discoloration.
+ = slight discoloration.
++ = brown.
+++ = dark brown.

[51] Aluminium laminated pouches.

4.5.2 Colour Measurements

Colour measurements after 12 months storage at ambient temperature for apricots and peaches processed in different containers during the 1990/91 season are given in Table 4.11 and Table 4.12 respectively.

Table 4.11 Means of colour readings[52] on apricots processed at different temperatures and in different containers with or without the addition of 200mg/l $CaCl_2$ after 12 months storage during the 1990/91 season[53].

Container	Temp	Tristimulus colour values[54]					
	(°C)	Lh	ah	bh	L*	a*	b*
Can	90	$51,5^{a}$	$13,7^{a}$	$31,6^{a}$	$58,5^{a}$	$15,6^{b}$	$64,5^{a}$
Pouch[55,56]	90	$50,5^{ab}$	$14,5^{a}$	$30,5^{bc}$	$57,6^{ab}$	$16,5^{a}$	$61,2^{cd}$
Pouch[55]	90	$49,7^{b}$	$14,2^{a}$	$29,9^{c}$	$56,8^{b}$	$16,2^{ab}$	$60,3^{d}$
Pouch[54,55]	100	$50,8^{ab}$	$13,8^{a}$	$31,0^{ab}$	$57,9^{ab}$	$15,7^{ab}$	$63,2^{ab}$
Pouch[55]	100	$50,1^{b}$	$14,2^{a}$	$30,5^{bc}$	$57,2^{b}$	$16,2^{ab}$	$62,3^{bc}$
LSD[57]		1,25	0,87	0,75	1,22	0,93	1,30

[52] Means of 9 readings per sample.

[53] Means in a column followed by the same letter do not differ significantly at P = 0,05.

[54] Tristimulus colour values:
Hunter scale.
Lh = +100 (white) to -100 (black).
ah = +a (green) to -a (red).
bh = +b (blue) to -b (yellow).
CIELAB scale.
L* = +100 (white) to -100 (black).
a* = +a (green) to -a (red).
b* = +b (blue) to -b (yellow).

[55] 200g Syrup with 200mg/l $CaCl_2$ added.

[56] Aluminium laminated pouch.

[57] LSD = Least significant difference at P=0.05.

In relation to the Lh and L* values fruit in cans did not differ significantly ($p>0,05$) with fruit processed in pouches to which $CaCl_2$ was added but differed significantly ($p<0,05$) with fruit in pouches without $CaCl_2$. No significant ($p>0,05$) difference in Lh and L* values between the different processes for apricots processed in pouches was obtained.

No significant differences ($p>0,05$) in relation of the ah values for the apricots processed in different containers and under different conditions were found. No significant difference ($p>0,05$) in a* values was found between fruit processed in pouches. Fruit processed in pouches at 90°C with the addition of $CaCl_2$, differed significantly ($p<0,05$) from the fruit processed in cans. Fruit in cans did not differ significantly ($p>0,05$) from the other fruit in pouches.

The bh and b* values of apricots processed in cans did not differ significantly ($p>0,05$) with fruit processed in pouches at a 100°C to which $CaCl_2$ was added but differed significantly ($p<0,05$) to the other fruit in pouches.

At 90° as well as at 100°C fruit processed in pouches, with or without the addition of $CaCl_2$, did not differ significantly ($p>0,05$) from each other. Fruit processed in pouches at 90°C also did not differ significantly ($p>0,05$) from fruit processed in pouches at 100°C. In the case of b* values fruit processed in pouches with the addition of $CaCl_2$ at 90°C did not differ significantly ($p>0,05$) from fruit processed at a 100°C without the addition of $CaCl_2$.

Table 4.12 Means of colour readings[58] on peaches processed at 100°C in different containers after 12 months storage during the 1990/91 season[59].

Container	Time	Tristimulus colour values[60]					
	(min)	Lh	ah	bh	L*	a*	b*
Can	20	60,2^a	11,7^a	36,4^a	66,7^a	12,8^a	69,0^a
Pouch[61]	25	65,4^a	13,1^b	35,5^b	66,0^a	14,3^b	66,8^b
LSD[62]		1,31	1,31	0,52	1,20	1,42	1,95

The peaches processed in the different containers did not differ significantly ($p>0,05$) in Lh and L* values but differed significantly ($p<0,05$) in the other values.

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[58] Means of 9 readings per sample.

[59] Means in a column followed by the same letter do not differ significantly at P = 0,05.

[60] Tristimulus colour values:
Hunter scale.
Lh = +100 (white) to -100 (black).
ah = +a (green) to -a (red).
bh = +b (blue) to -b (yellow).
CIELAB scale.
L* = +100 (white) to -100 (black).
a* = +a (green) to -a (red).
b* = +b (blue) to -b (yellow).

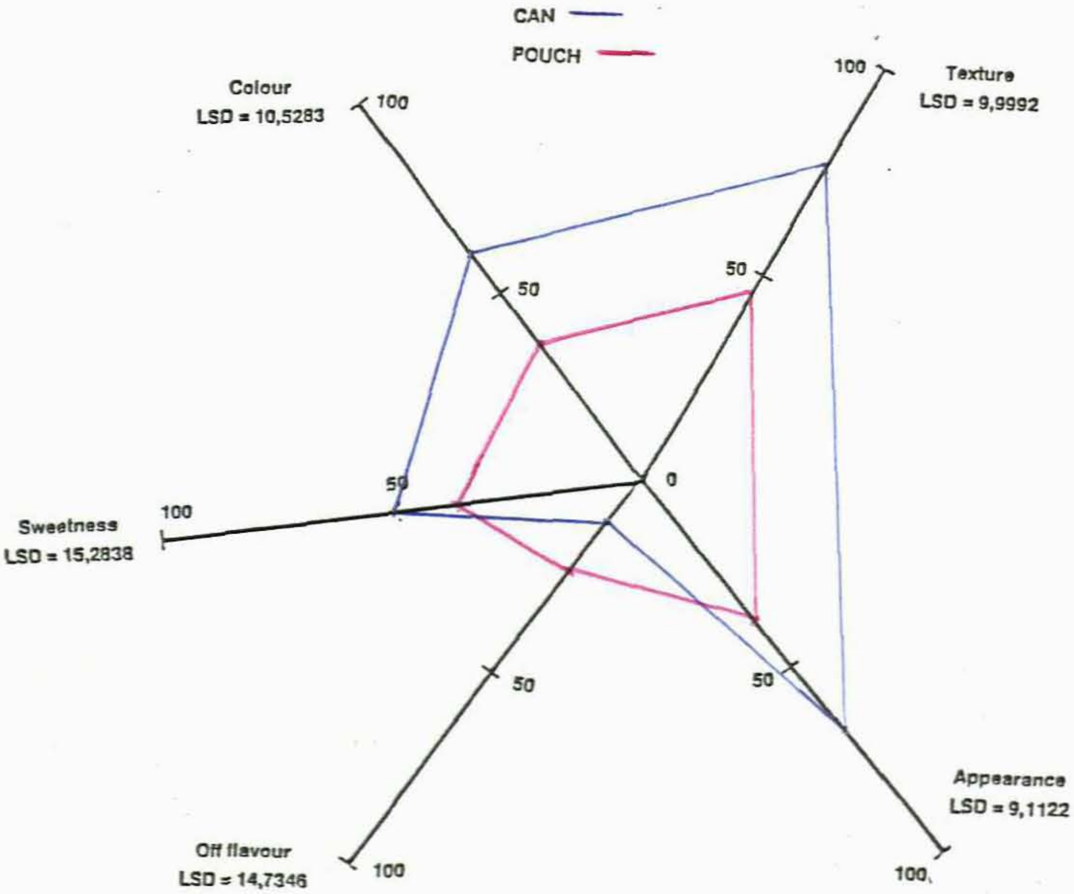
[61] Aluminium laminated pouch.

[62] LSD = Least significant difference at P=0.05.

4.6 Sensory Evaluation

4.6.1 Descriptive Analyses

The results of the Descriptive analyses of peaches processed in pouches and cans during the 1990/91 season are given in Fig. 4.8.



Scale 0 to 100%

Fig. 4.8 Descriptive analyses of peaches processed in pouches and in cans during the 1990/91 season.

The peaches processed in cans had a significant ($p<0,05$) better general appearance, colour and texture than the fruit processed in pouches. No significant difference ($p>0,05$) in sweetness or off-flavor was found.

5 DISCUSSION

5.1 Preliminary Trials

The discoloration of the fruit showed that the transparent pouches were not suitable for packing of fruit. This may be due to the poor oxygen barrier properties of the LDPE and PET/PP used (The Institute of Packaging (SA), 1989).

It was essential that some of the factors causing discoloration of fruit heat processed in transparent pouches and stored for 4 weeks were investigated.

Discoloration of fruit is caused by oxidation of carbohydrates (Basson, 1989) Discoloration does not normally occur in canned fruit. Residual oxygen in the headspace reacts with the tin plate in unlaquered cans (Gotz, 1989).

Oxygen can also move into the fruit by diffusion through the container material (The Institute of Packaging (SA), 1989). According to Davis (1971) the movement of gases through packaging materials is due to the diffusion, because of pores or to a solution-diffusion process whereby the gas or vapour dissolves in one surface of the film, diffuses through and evaporates on the other side.

Discoloration of fruit in this study can probabably be attributed to the poor oxygen barrier properties of the LDPE and PET/PP used (The Institute of Packaging (SA), 1989).

Aluminium laminated pouches exhibit extremely good oxygen barrier properties (Yoell, 1991). Data on oxygen diffusion rates are shown in Table 5.1.

Table 5.1 Oxygen barrier properties of two different pouch laminates.

Pouch material	Oxygen ($cc/m^2/d/atm./25°C$)
PET/PP[1]	36-40
PET/Al/PP[2]	0,5-1,3

The lack of discoloration of fruit heat processed in aluminium laminated pouches during the 4 week storage trials can be attributed to these good barrier properties.

There was no visible difference in the degree of browning between fruit, heat processed in transparent pouches, stored in the dark and those exposed to normal day light during storage. These results on the degree of browning showed that light was not an important factor. This was in

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1 PET/PP = polyethylene terephtalate/polypropelene.
2 PET/AL/PP = polyethylene terephtalate/aluminium foil/polypropelene.

contrast with the findings of Igawa (1970) who states that vitamins, unsaturated fatty acids and pigments are easily destroyed in products packed in LDPE and PP leading to a dark discoloration. This discoloration did not occur when the products were packed in acrylic co-polymer. Unfortunately he did not state the product packed or the storage time. It is presumed that he was not referring to fruit because few fruit contains significant amounts of unsaturated fatty acids. Paul & Southgate (1978) refer to fat in apricots and peaches to be present in traces.

These results led to the decision to use only aluminium laminated pouches for all subsequent experiments.

5.2 Analyses

5.2.1 Moisture, Total Solids

The mean moisture contents of both the fresh apricots and peaches are significantly ($p<0,05$) lower compared to the values published by Paul & Southgate (1978). These differences may be due to the fact that their values are mean values from various cultivars (Paul & Southgate, 1978) and the fruit was not grown under South African conditions.

The fresh experimental fruit was also transported over long distances and was put into cold storage until heat processing could take place. Considerable moisture losses are reported during cold storage and a loss of 3,2% after one week storage is reported (van Rhyn, 1987).

Fruit is a living organism which continues with respiration even after harvesting (Berk, 1976) and this may explain the lower moisture content.

No comparison of the moisture content of the heat processed fruit with the values of Paul & Southgate (1978) could be made because their values refer to fruit and syrup while this study's values refer only to the fruit.

The higher moisture content of products in pouches can partly be explained on the basis of a mass balance (Toledo, 1980). In the case of cans 365 g syrup and for pouches 200 g syrup were added. The same syrup concentrations were used for both aluminium laminated pouches and cans. The syrup had a higher TSS content than the fruit and consequently elevated the equilibrium TSS of the product. As less syrup was added to the pouches the elevation in TSS was less. Consequently products in pouches exhibited a higher moisture content.

The higher moisture content also adversely affected the TS content.

5.2.2 Total Soluble Solids

The fluctuating TSS values of the fresh fruit obtained over the different seasons can possibly be attributed to differences in climate and growing conditions. The mean values differ significantly ($p<0,05$) with those published by Paul & Southgate (1978).

The significantly ($p<0,05$) lower TSS content of the heat processed fruit in pouches compared with cans is due to the relative ratios of fruit to syrup used as explained in 5.2.1.

No comparison between the heat processed fruit and the values of Paul & Southgate (1978) could be made as explained in 5.2.1.

5.2.3 Ascorbic Acid Content

The ascorbic acid contents of both the fresh apricots and peaches are significantly ($p<0,05$) lower than the values published by Paul & Southgate (1978). The published values were converted to the same moisture content as that of the fresh fruit. The reason can be that different cultivars were used to obtain these values. It also depends on the analysis method.

According to Deutsch (1967) there was no official assay for the analysis of reduced ascorbic acid in foods nor for the determination of total anti-scorbutic activity in any product. The official, final action for ascorbic acid, 2,6-dichloroindophenol (DCP) titration method (Williams, 1984) is easily utilized but its application is limited. This method cannot be used to determine vitamin C in products containing an appreciable quantity of basic substances or a significant amount of dehydroascorbic acid. In the case of the microfluorometric method (Williams, 1984) the ascorbic acid is oxidized to dehydroascorbic acid. This together with the dehydroascorbic acid already present in the fruit react with o-phenylenediamine to produce fluorophor. The fluorescence intensity is proportional to the total concentration of ascorbic and dehydroascorbic acid. This method is now successfully used at the Stellenbosch Institute for Fruit Technology.

Paul & Southgate (1978) state that their values for ascorbic acid are based on a variety of methods and for some foods only the reduced form was determined. They do not state which methods were used for apricots and peaches and this may explain the difference in ascorbic acid values.

Van Rhyn (1987) found that the ascorbic acid contents of both apricots and peaches decreased rapidly during storage.

He also found that there was a difference in ascorbic acid content between cultivars and fruit grown in different areas.

As stated the fruit used in this study underwent cold storage and this may be the cause of the lower ascorbic acid content.

The tendency to lower ascorbic acid contents of fruit heat processed in aluminium laminated pouches (not significant $p>0,05$) (Table 4.2) were unexpected. In fact higher values for ascorbic acid would be expected because less syrup was used implying that less ascorbic acid should leach out of the fruit.

Ascorbic acid losses in pouches can probably be attributed to higher levels of oxygen in the product due to incomplete removal of oxygen.

Chen & George (1981) have reported a higher loss of ascorbic acid for green beans heat processed in pouches, compared with those heat processed in cans. They found that during the first week of storage the degradation of the ascorbic acid of the beans in pouches was higher than those in cans.

Oxygen is known to oxidise ascorbic acid (Berk, 1976). It is almost impossible to completely remove oxygen during vacuum sealing as boiling of the syrup leeds to syrup losses and is thus undesireable. Diffusion of external oxygen through the pouch material during storage can also contribute to oxidation of ascorbic acid.

No comparison of the ascorbic acid values with the values of Paul & Southgate (1978) could be made as explained in 5.2.1.

5.2.4 Mineral Content

The mineral contents (Table 4.3) of the fresh fruit differ significantly ($p<0,05$) from the values given by Paul & Southgate (1978). This may be due to the fact that different cultivars were used and different growing and fertilizing procedures were employed.

No comparison of mineral content of the heat processed fruit with the results of Paul & Southgate (1978) could be made as explained in 5.2.1

The significant ($p<0,05$) higher iron content of fruit heat processed in cans, can possibly be explained by the fact that the fruit in cans had gained iron from the tin plate. Elkins (1979) stated that it is possible to get an increase in mineral content with green beans heat processed in cans. He attributed this to the fact that minerals are present in the syrup and that certain minerals, present in the plain tin can, can migrate into solution and thus into the can contents.

Contrary to results reported by Elkins (1979) no significant ($p>0.05$) loss of copper was found in the fruit heat processed in cans. He stated that this loss was due to the plating out of copper on the bare tin plate.

5.2.5 Drained Mass

According to South Africa (1977) there is an upper (14 g) and lower (7 g) filling mass limit when packing fruit in an A2½ can because it is almost impossible to use exactly 450 g fruit and 365 g syrup.

It is generally assumed that fruit and syrup reach equilibrium after about 3 months storage (Cruess, 1958). At this stage the TSS content or osmotic pressure of the fruit and syrup will be in equilibrium. Directly after heat processing considerable differences in osmotic pressure will exist between the fruit and the syrup, with fruit exhibiting the lower osmotic pressure. Fruit will tend to lose moisture and gain syrup. The diffusivity of molecules is proportional to their size. Thus the migration of water from the fruit would tend to be the dominating factor. The result would be shrinkage. Consequently even at equilibrium the fruit would weigh less than their initial mass. In the case of pouches with a smaller proportion of syrup, less water would have to migrate from the fruit to obtain equilibrium with consequent less shrinkage and a higher fill mass retention. This may be the reason for the tendency (nonsignificant) ($p>0,05$) to a higher drained mass of the fruit heat processed in pouches.

Stiekema *et al.* (1960) found that the drained mass of Bulida apricots also depends on the maturity. They also found that the more mature the fruit is, the lower the drained mass will be.

Smit *et al.* (1961) found that more matured Kakamas peaches had a higher drained mass than immature fruit. They also found that the drained mass was influenced by the growing area.

5.2.6 Cut-out Brix

The significant ($p<0.05$) lower cut-out Brix values of the fruit heat processed in aluminium laminated pouches can be explained by the same factors as in 5.2.1.

5.2.7 Texture

The texture in this section was not determined by people but by the use of a Instron Texture meter. deMan *et al.*

(1976) state that the physical property which is determined in this way is called hardness.

Difficulty was experienced to determine the correct heat processing conditions for pouches. Chisholm (1985) reports a saving of processing time of 40-60% while Steffe *et al.* (1980) report a saving of 30-70% compared with heat processing in cans. It was decided to start with $^1/_3$ of the time used for cans. After evaluation of the texture of the heat processed products modifications were made (Appendix A Table 4).

The apricots heat processed in cans during the 1987/88 season were significantly ($p<0,05$) softer than those heat processed in pouches because the standard processig conditions for cans were changed from 15 min at 90°C (Van Rhyn & Hansmann, 1987) to 10 min at 95°C.

The peaches heat processed in aluminium laminated pouches were significantly ($p<0.05$) harder than those in cans due to a too short processing time or too low processing temperatures (Table 4.7).

Heat processing of apricots for periods determined by heat penetration studies during the 1988/89 season resulted in too soft products and texture determinations were not possible.

Softening of apricots is a common problem and Chitarra *et al.* (1989) investigated this softening with "Paterson" apricots to determine if cell wall pectin solubilisation was the cause. It is known that calcium plays an important role in the firmness of fruit (Mohammadzadeh-Khayat & Luh, 1968). French *et al.* (1989) added 3 to 30 mM $CaCl_2$ to the fruit and a $CaCl_2$ concentration of 200 mg/l was added to the apricots during the 1989/90 season.

The time range from the penetration studies for peaches is due to the fact that they have a firmer texture. The differences in maturity also influenced the heat penetration values. Cruess (1958) stated that peaches in contrast to apricots are not easily influenced by over processing. A temperature of 90°C was also considered in an effort to save energy.

The peaches processed in aluminium laminated pouches for 25 and 30 min at 100°C did not differ significantly ($p<0.05$) from the fruit heat processed in cans. The peaches heat processed in pouches for 25 and 30 min at 90°C were significantly ($p>0.05$) harder than the fruit heat processed in cans.

The unacceptable soft texture of apricots during the 1989/90 season can possibly be explained by the fact that all the fruit had pit burn (Kotzé & Bothma, 1989). No hardness determinations could be done and the influence of the $CaCl_2$ could not be determined. It was therefore decided to repeat the experiments with $CaCl_2$ during the 1990/91 season.

The peaches heat processed at 100°C for 21 and 23 min in pouches did not differ significantly ($p>0.05$) from the fruit processed in cans and it seems as if peaches can successfully be heat processed in aluminium laminated pouches under these conditions. These conditions were repeated during 1990/91 over a wider time range to confirm these findings.

Apricots can be successfully heat processed in aluminium laminated pouches at 100°C for 10, 13 and 15 min. Energy costs could possibly be saved if this higher (100°C), compared with 90°C, heat processing temperature was implemented because the heat processing time is shorter.

$CaCl_2$ can successfully be used with apricots to give a harder product if heat processed for 10 min at 90°C and 15 min at 100°C.

The reason why the hardness of the apricots, with or without the addition of $CaCl_2$ heat processed for 10 min at 90°C did not differ significantly ($p>0.05$) from each other can possibly be attributed to the fact that the fruit did not have enough time to react with the $CaCl_2$. In apricots heat processed for 15 min at 100°C the better firmness through the addition of $CaCl_2$ seems to be counteracted by the softening caused by the stringent heat process and no significant ($p>0,05$) difference in hardness was found between the 2 processes.

The reason for the firmer peaches heat processed in pouches for 20 min at 100°C during the 1990/91 season was that the processing time was probably too short.

It seems therefore that in relation to hardness peaches can be successfully heat processed in aluminium laminated pouches if they are heat processed for 21 to 30 min at 100°C. This confirmed the results obtained during the 1989/90 season.

5.3 Microbiological Determinations

Brennan *et al.* (1976) state that it is not necessary for a heating operation to eliminate all viable organisms from the material. Sound cans of food frequently contain viable organisms which are unable to grow in the can due to unfavourable conditions. It is essential that the product should be acceptable for the consumer and safe to eat at the end of a predetermined storage period under defined conditions. This form of sterility is called commercial sterility (Ball & Olsen, 1957).

During the 1987/88 season the Most Probable Number method (Harrigan & McCance, 1976) was used. The growth of microorganisms even to the 10^{-10} dilution (Harrigan & McCance, 1976) in all treatments of fruit was the reason that no useful results were obtained. The organisms were possibly yeasts and some bacteria which were able to survive the heat process. The inoculation of container method (Stumbo, 1973) was used during the next season.

Clostridium butyricum (Clark & Dehr, 1947) can cause problems with apricots, peaches and pears (Townsend, 1939). Therefore it was decided to use this organism for the determination.

One way to prevent the growth of this organism is by acidification of the syrup with citric acid to a pH< 4,0 (Townsend, 1939) while Spiegelberg (1940) recommends a pH< 4,4.

The isolation of 1500 CFU, in both pouches and cans, after heat processing of apricots at 90°C can possibly be explained by an inadequate processing temperature/time relationship and the fruit in the containers did not reach a high enough temperature. The spores of *Cl. butyricum* are activated by exposing them to a heat shock of ± 80°C for a few min or 65°C for a few hours (Stanier *et al.*, 1977).

In apricots heat processed in pouches at 100°C the processing conditions were stringent enough to inactivate these spores and no CFU were found. This was also the reason why no CFU were isolated from peaches heat processed in pouches and cans.

5.4 Computerized Heat Penetration Studies

Most of the heat penetration data in the literature refer to the Fahrenheit scale (Stumbo, 1973, Ball & Olson, 1957). The reason is that when °F is used, the processing temperature range for apricots and peaches is from 32°F to 212°F. When these data are plotted on semi-log paper three log cycles can be used instead of two when the °C scale is used. Measurement of °F scale is also smaller than the °C scale and therefore it is more accurate. Most parametric values for thermal process estimation are based on °F (Stumbo, 1973). Hayakawa & Downes (1981) published values based on °C.

5.4.1 Graphical Studies

The shortening of the heat processing time for apricots during the 1988/89 season for cans was a result of a different heat processing step added. The fruit in the cans underwent a 10 min exhausting process at 90°C which elevated the fruit temperature to ± 70°C (± 158°F) before they were placed in the retort. This elevation of the fruit temperature before heat processing, shortened the heat processing time to 15 min.

The fruit in the aluminium laminated pouches only had a temperature of ± 25°C (± 77°F) when they were placed in the retort and it took ± 8 min before the fruit reached the starting temperature of the fruit in the cans. The heat processing time of 23 min for pouches affected the texture of the apricots and alternative studies were undertaken with $CaCl_2$ to counter these effects (5.3.6).

Peaches in pouches also took ± 8 min to reach the same retort starting temperature as for the fruit in cans. The 25 min heat processing cycle determined was used as a basis for peach heat processing in aluminium laminated pouches during the 1989/90 and 1990/91 seasons. Good heat processed products were obtained.

5.4.2 Tabulated Studies

During the 1988/89 season the apricots in pouches were heat processed for 23 min, but the finished products had a too soft texture. This was possibly due to over processing.

From the 1989/90 season's results it was evident that apricots can be heat processed in pouches at 100°C for half the time of the conventional heat processing method implemented for cans.

The tabulated studies confirmed that the peaches heat processed in pouches needed a longer time to reach the same process value as fruit heat processed in cans. This explained the good texture of peaches heat processed in aluminium laminated pouches for 30 min.

5.5 Tests For Discoloration

5.5.1 Aluminium Laminated Pouches Versus Cans

The brown discoloration in apricots stored for 12 months probably occurred due to residual oxygen (Basson, 1989). The apricots heat processed in aluminium laminated pouches at 80°C for 20 min showed a slight discoloration after 6 months storage probably because the heating process was not stringent enough if compared with the other processes. It is possible that all the enzymes were not denatured at 80°C and that this resulted in enzymatic browning. No discoloration occurred with peaches because they were heat processed at 100°C and it was assumed that all the enzymes were denatured.

The good barrier properties for oxygen of tin cans were confirmed by the fact that no discoloration occurred in the canned apricots or peaches after 12 months storage.

5.5.2 Colour Measurement

Colour measurements were done after 12 months storage. No colour measurements were done on the fresh fruit because the different heat processes of the apricots and peaches were done on the same day. The fresh fruit was randomly (Snedecor & Cochran, 1987) selected and the colour variation would comply to the normal distribution curve (Snedecor & Cochran, 1987) and it was assumed that if colour differences were determined after storage this would be due to the storage period.

It was expected that differences would occur between apricots heat processed in aluminium laminated pouches and cans (Table 4.10) because browning was already visually observed the previous season. Only the apricots heat processed at 90°C with the addition of $CaCl_2$ showed a significant difference ($p<0,05$) with the fruit heat processed in cans in the white and black field. No significant difference ($p>0,05$) was obtained in the green and red field. Most of the significant ($p<0,05$) differences occurred in the blue and yellow field. This implies that the yellow color has faded and moved more to the grey side causing a darker colour.

The significant difference ($p<0,05$) in both the green and red as well as the blue and yellow field between peaches heat processed in aluminium laminated pouches and cans was unexpected (Table 4.11), because no significant browning was visually observed. Possibly this was not due to browning but to a fading of the colour. If the discoloration was browning it could be the result of small amounts of residual oxygen or oxygen in the air that can still move through the aluminium layer. Cans possess an oxygen scavenger in the form of free steel (Cronshaw, 1933), but pouches do not have this activity and browning occurred after heat processing due to oxidation (Basson, 1989).

5.6 Sensory Evaluation

Appearance is a very complex factor. The fruit in the pouches was flatter than the fruit in cans due to the fact that they are not protected by a rigid container, the fruit therefore was squeezed together. This may be the reason for the significant differences (p<0,05) in general appearance and texture. The use of an outer carton (The Institute of Packaging (SA), 1989) could possibly improve the general appearance and texture. The significant difference (p<0,05) in colour between peaches heat processed in cans and pouches can be attributed to a fading of the yellow colour or to oxidation (Basson, 1989).

The peaches in cans were specially heat processed with a syrup with a lower strength to give a specific cut-out Brix, after 3 months storage, comparable with the fruit heat processed in pouches. This was done because a difference in sweetness can be very easily detected. The mean °B of the fruit in cans was 15,6 while that of the fruit in pouches was 15,5. The fact that no significant difference ($p>0,05$) in sweetness was detected is therefore not very important. The only important fact is that the cut-out Brix after 3 months storage can be accurately calculated.

No panel member detected any plastic after-taste. A small difference between the 2 containers was that some of the assessors detected a slight caramel (burned) flavor in the fruit heat processed in pouches but this was not statistically significant (for $P=0.05$).

6 CONCLUSIONS AND RECOMMENDATIONS

Aluminium laminated pouches can be used to heat process apricots and especially peaches.

The ideal processing conditions for apricots and peaches in aluminium pouches are; 10 to 15 min at 100°C and 21 to 30 min at 100°C respectivily.

The concentrations of some nutrient elements of fruit processed in aluminium laminated pouches did not differ significantly ($P>0,05$) from that of the fruit heat processed in cans with the exception of iron.

Sensory evaluation of peaches showed that the fruit processed in aluminium pouches had a inferior general appearance, texture and colour.

Microbiologically speaking the heat processing conditions employed, provided a safe product.

The hardness of apricots processed in aluminium laminated pouches can successfully be improved by the use of $CaCl_2$.

Discoloration was observed with fruit after 12 months storage which can be attributed to the presence of oxygen (Basson, 1989). It should be possible to produce excellent processed fruit for a shorter storage period, viz. 6 months.

The clear pouch materials employed cannot be successfully used for processing fruit, due to the fast discoloration of the heat processed fruit.

7 SUGGESTED FUTURE RESEARCH

Laminates with better oxygen barrier properties than those used for the experiments are presently available. These laminates are more expensive but further experiments to see if discoloration can be prevented, may be advisable.

The use of oxygen scavengers as reported by Shorter (1982) could also be investigated.

Other methods, than a vacuum chamber, to evacuate the air from the pouches as described by Lampi (1977) should be investigated. Other sealing methods as reported by Lampi (1977) and Madhwaraj *et al.* (1992) should also be investigated.

The use of an outer carton should be beneficial for both the general appearance and texture.

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9 APPENDIXES

9.1 Contents

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9.5 APPENDIX D

9.2 APPENDIX A

Table 1 Lethal ratio (F/t[1]) values at 196°F for z = 18.

T Temp. (°F.)	F/t Lethal Ratio	T Temp. (°F.)	F/t Lethal Ratio	T Temp. (°F.)	F/t Lethal Ratio	T Temp. (°F.)	F/t Lethal Ratio
196	1,00	178	0,100	160	0,0100	142	0,00100
195	0,88	177	0,088	159	0,0088	141	0,00088
194	0,77	176	0,077	158	0,0077	140	0,00077
193	0,68	175	0,068	157	0,0068	139	0,00068
192	0,60	174	0,060	156	0,0060	138	0,00060
191	0,53	173	0,053	155	0,0053	137	0,00053
190	0,46	172	0,046	154	0,0046	136	0,00046
189	0,41	171	0,041	153	0,0041	135	0,00041
188	0,36	170	0,036	152	0,0036	134	0,00036
187	0,32	169	0,032	151	0,0032	133	0,00032
186	0,28	168	0,028	150	0,0028	132	0,00028
185	0,25	167	0,025	149	0,0025	131	0,00025
184	0,22	166	0,022	148	0,0022	130	0,00022
183	0,19	165	0,019	147	0,0019	129	0,00019
182	0,17	164	0,017	146	0,0017	128	0,00017
181	0,15	163	0,015	145	0,0015	127	0,00015
180	0,13	162	0,013	144	0,0013	126	0,00013
179	0,11	161	0,011	143	0,0011	125	0,00011

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[1] (F/t) = Lethal ratio at a given temperature is the time in min (F) required to reduce a given number of organisms to some prescribed safe level at 196°F, to the time in min (t) to accomplish the same reduction at any other temperature.

Table 2 Lethal ratio (F/t[2]) values at 214°F for z = 18.

T Temp. (°F.)	F/t Lethal Ratio	T Temp. (°F.)	F/t Lethal Ratio	T Temp. (°F.)	F/t Lethal Ratio	T Temp. (°F.)	F/t Lethal Ratio
214	1,00	196	0,100	178	0,0100	160	0,00100
213	0,88	195	0,088	177	0,0088	159	0,00088
212	0,77	194	0,077	176	0,0077	158	0,00077
211	0,68	193	0,068	175	0,0068	157	0,00068
210	0,60	192	0,060	174	0,0060	156	0,00060
209	0,53	191	0,053	173	0,0053	155	0,00053
208	0,46	190	0,046	172	0,0046	154	0,00046
207	0,41	189	0,041	171	0,0041	153	0,00041
206	0,36	188	0,036	170	0,0036	152	0,00036
205	0,32	187	0,032	169	0,0032	151	0,00032
204	0,28	186	0,028	168	0,0028	150	0,00028
203	0,25	185	0,025	167	0,0025	149	0,00025
202	0,22	184	0,022	166	0,0022	148	0,00022
201	0,19	183	0,019	165	0,0019	147	0,00019
200	0,17	182	0,017	164	0,0017	146	0,00017
199	0,15	181	0,015	163	0,0015	145	0,00015
198	0,13	180	0,013	162	0,0013	144	0,00013
197	0,11	179	0,011	161	0,0011	143	0,00011

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[2] (F/t) = Lethal ratio at a given temperature is the time in min (F) required to reduce a given number of organisms to some prescribed safe level at 214°F, to the time in min (t) to accomplish the same reduction at any other temperature.

Table 3 Syrup Brix values to obtain the desired cut-out Brix of fruit processed in an A2½ can[3].

Fresh°Brix	Syrup Brix values	
	Apricots (19,5°B)	Peaches(18,5°B)
10	31,21	28,98
10,5	30,60	28,36
11	29,98	27,75
11,5	29,36	27,13
12	28,75	26,51
12,5	28,13	25,90
13	27,51	25,28
13,5	26,90	24,66
14	26,28	24,05
14,5	25,66	23,43
15	25,05	22,82
15,5	24,43	22,20
16	23,82	21,58
16,5	23,20	20,97
17	22,58	20,35

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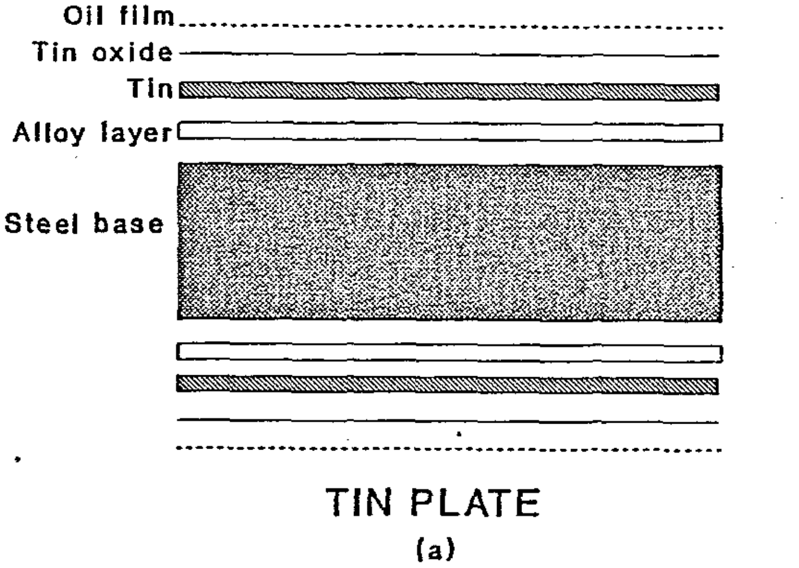
[3] Source Fruit and Fruit Technology Research Institute (1989).

Table 4 Processing times and temperature combinations used for fruit processed in aluminium laminated pouches during the different seasons.

Season	Apricot		Peach	
	Time (min)	Temp. (°C)	Time (min)	Temp. (°C)
1987/88	5	95	7	80
			7	85
			7	90
			7	95
1988/89	23	90	25	90
			25	100
			30	90
			30	100
1989/90	20	80	19	100
	25	80	21	100
	20	90	23	100
	25	90	25	100
1990/91	10	90	20	100
	15	90	25	100
	23	90	30	100
	10	100		
	13	100		
	15	100		

9.3 APPENDIX B



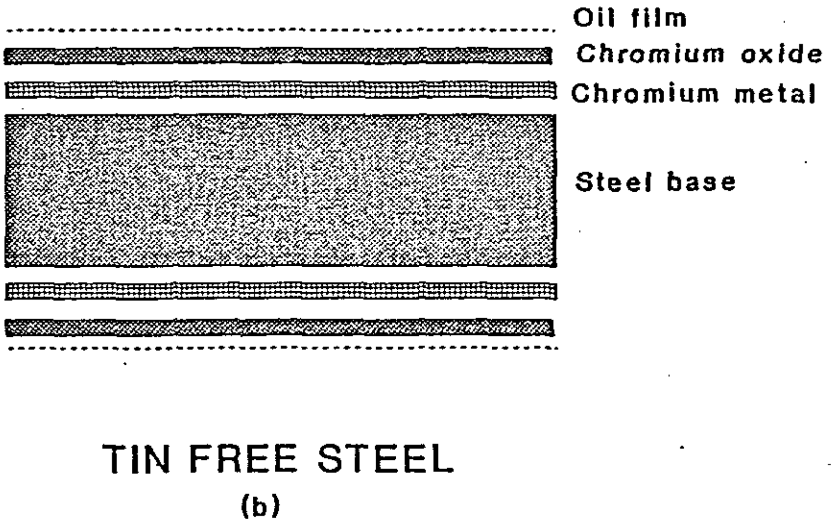


Fig. 1 Cross section comparison of tin plate and tin free steel (Patrick, 1989).

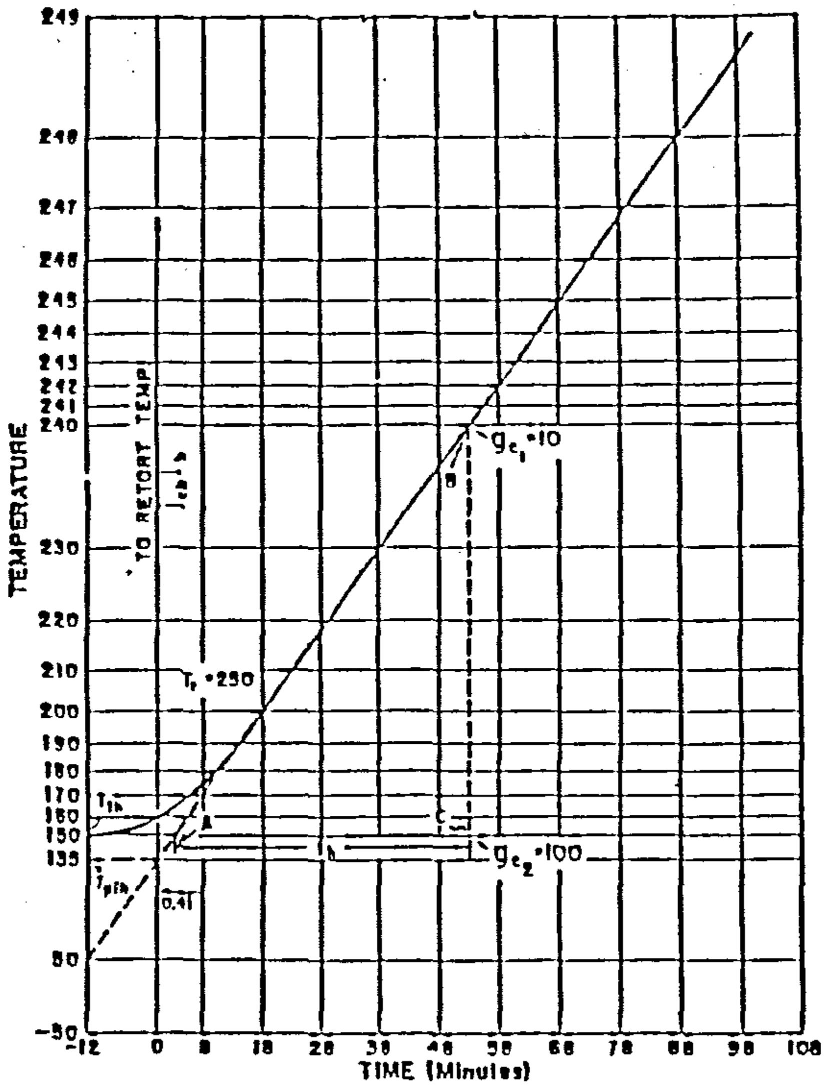


Fig. 2 Semilog plot of heating curve[4] (Stumbo, 1973).

---

[4] (T_{ih}) = Initial temperature (°F).
(T_r) = Retort temperature (°F).
(l) = Come-up time (min).
(B) = *Process time (min).*
(I_h) = Difference between retort- and initial food temperature (°F).
(T_{pih}) = Pseudo-initial temperature heating (°F).
(j_{ch}) = Heating lag factor (min).
(f_h) = Time, (min), required for the straight line portion of the heat penetration curve to traverse one log cycle.
(g) = The difference between the retort temperature and the maximum temperature reached by the food (°F).

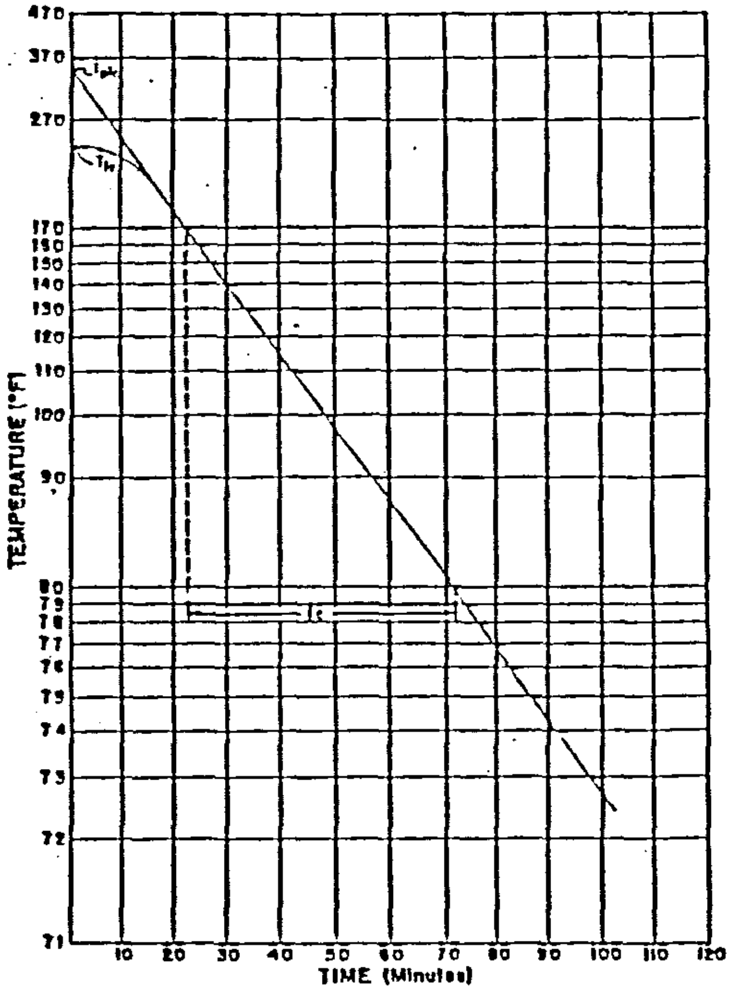


Fig. 3 Semilog plot of cooling curve[5] (Stumbo, 1973).

---

[5] (T_{ic}) = Initial temperature of the food before cooling starts (°F).
(T_w) = Cooling water temperature (°F).
(I_c) = Difference between cooling water and food temperature (°F).
(T_{pic}) = Pseudo-initial temperature - cooling (°F).
(j_{cc}) = Cooling lag factor (min).
(f_c) = Time, (min) required for the straight line portion of the cooling curve to traverse one log cycle.

9.4 APPENDIX C

Formula 1. General equation of the survivor curve (Stumbo, 1973).

$$t = D(\log a - \log b)^{6}$$

Formula 2. Temperature conversion if the initial temperature stays the same but the retort temperature changes[7] (Stumbo, 1973).

$$T'_c = T'_r \frac{T'_r - T_i}{T_r - T_i} (T_r - T_c)$$

Formula 3. Temperature conversion if the retort temperature stays the same but the initial temperature changes[3] (Stumbo, 1973).

$$T'_c = T_r \frac{T_r - T'_i}{T_r - T_i} (T_r - T_c)$$

---

[6] t = Time (min) of heating at a constant temperature.
D = Time (min) to kill 90% of the cell population.
a = Initial number of viable cells in the population.
b = Number of viable cells in the population after time t.

[7] (T_r) = Original retort temperature (°F).
(T'_r) = New retort temperature (°F).
(T_i) = Initial temperature (°F).
(T'_i) = New initial temperature (°F).
(T_c) = A can temperature (°F) of the original set.
(T'_c) = A new can temperature (°F) corresponding to T'_r.

Formula 4. Equation for products for which the semilog heating curve is one straight line (Stumbo, 1973).

$$B^{[8]} = f_h \log \frac{j_{ch} I_h}{g_c}$$

---

[8] (B) = Process time (min), when no time is required to bring the retort to processing temperature.

(f_h) = Time (min), required for the straight-line heating curve to traverse one log cycle.

(j_{ch}) = Heating lag factor.

(I_h) = Temperature (°F) difference between retort temperature and initial food temperature.

(g_c) = Difference (°F) between retort temperature and the maximum temperature reached by the food at the geometrical center of the container.

9.5 APPENDIX D

Example of the sensory evaluation form used for the sensory evaluation of heat processed peaches.

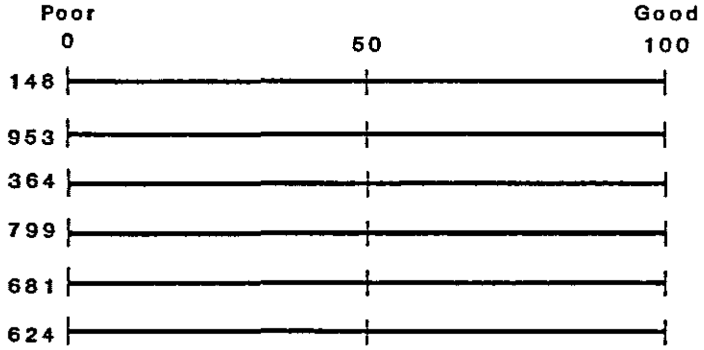
SENSORY EVALUATION OF HEAT PROCESSED PEACHES

NAME:_____________

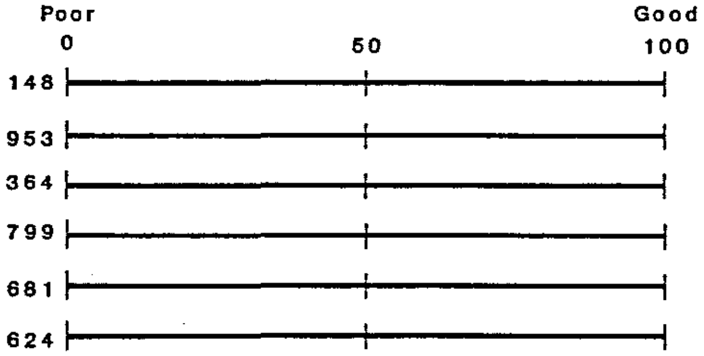
DATE:______________

Evaluate the sample for each of the under-mentioned characteristics by drawing a vertical line on the scale of 0 to 100%

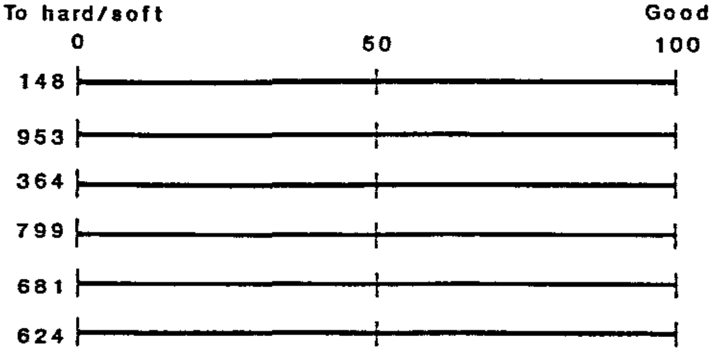
GENERAL APPEARANCE



COLOUR



TEXTURE



SWEETNESS

Too little/much good

0 50 100

148

953

364

799

681

624

OFF FLAVOR

No Strong

0 50 100

148

953

364

799

681

624