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Title: Thiamin and Ascorbic Acid Retention and Visual and Textural Qualities in Thermally Processed and Stored Green Beans and Royal Ann Cherries Packed in Pouches and Cans

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Thiamin and ascorbic acid content and retention were determined in raw, blanched, pouched and canned green beans immediately after processing and after storage for four months at room temperature or at 37.8°C. Ascorbic acid was also determined in raw, pouched and canned Royal Ann cherries immediately after processing and after storage for six months at room temperature. Five replicates of green beans and three replicates of cherries were assayed. Compared to the raw green beans, the blanched green beans were higher in apparent thiamin and lower in ascorbic acid. There was significantly more thiamin and ascorbic acid in the pouched green beans and more ascorbic acid in the pouched cherries than in the canned ones. There were no significant losses in these two vitamins in the pouched and canned products after four months storage at room temperature. These vitamins, however, were significantly lower

in the pouched and canned products after four months' storage at 37.8°C. The liquid portions of the pouched products had significantly higher concentrations of these water soluble vitamins than the canned ones. However, the total amount of liquid portion was lower in the pouched than in the canned products, leading to smaller total vitamin losses in the pouched products. Canned green beans were yellower and lighter in color than pouched green beans. Pouched cherries were significantly darker red than the canned cherries. The pouched products were firmer in texture than the canned. Results of this study demonstrate that pouched green beans and cherries have a better nutritional value, color and texture than the canned ones.

Thiamin and Ascorbic Acid Retention and Visual and Textural Qualities in Thermally Processed and Stored Green Beans and Royal Ann Cherries Packed in Pouches and Cans

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DEDICATED WITH LOVE ...

to my father, my mother, and Ramzey who have given me all the love, support and help I needed. I am truly fortunate for having had such wonderful people in my life to help me achieve my aspirations.

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I. INTRODUCTION

Nutritional losses due to thermal processing are a concern of food manufacturers. Bender (1978) recently reviewed the effect of food processing on the retention of several vitamins. He concluded that the loss of ascorbic acid is inevitable in almost every type of food processing and, although it may be minimized by good manufacturing practices, the losses of this vitamin may still be considerable. Bender also stated that, after ascorbic acid, thiamin is the next most labile of the vitamins. Both thiamin and ascorbic acid are water soluble and heat labile.

Recently, a growing interest in nutrition labeling of foods has drawn attention to the nutritional value of foods and the stability of nutrient during processing. The public is exerting pressure on the food industry to improve the nutritional quality of food.

Improved packaging materials, containers and methods are continually being developed in order to obtain better quality products. The retort pouch, a new kind of container, has been approved by the Food and Drug Administration and the United States Department of Agriculture in 1977 (Lopez, 1981). The retort pouch is usually made from a laminated flexible

material consisting of two plastic films with aluminum foil in between.

It is expected that there will be a higher retention of heat labile and water soluble nutrients in foods processed in pouches than in cans. One reason is that pouches have a flat rectangular shape which favors rapid heat transfer. This reduces the time necessary to reach commercial sterilization at the center of the pouch. The retention of water soluble nutrients is also expected to be higher in pouched foods because less syrup or brine is used in processing fruits and vegetables. Furthermore, it is expected that the texture and color of fruits and vegetables processed in pouches will be more desirable than of those processed in cans. Chen and George (1981) compared the ascorbic acid retention in green beans processed in retort pouches and cans. They observed lower ascorbic acid values for the pouched green beans than for the canned ones. They attributed this to overprocessing of green beans in the pouches.

More studies on nutrient retention during pouching are needed. In the study reported in this thesis, the effect of pouching and canning was determined on the retention of thiamin and ascorbic acid in green beans, and on the retention of ascorbic acid in cherries. The effect of storage on the retention of thiamin and ascorbic acid was also investigated. This study also compares the color and texture of green beans and cherries processed in institutional-sized retortable pouches (30.5 x 38.1 x 3.8 cm) and in No. 10 cans.

II. REVIEW OF LITERATURE

The Retort Pouch

The retort pouch is a flexible, three-ply laminate which can be thermally processed like a can. It is composed of an outer layer of polyester, a middle layer of aluminum foil, and an inner layer of modified polyolefin (Norman, 1979). The material for retort pouches must provide superior barrier properties for a long shelf-life, seal integrity, toughness and puncture resistance. It must also withstand thermal processing (Pintauro, 1978). The polyester film is used for high temperature resistance, toughness, protection and printability; it is laminated to the aluminum foil by a thermosetting adhesive system. The aluminum foil protects the product from oxygen and light as well as loss of volatile components. The inner layer of modified polypropylene provides heat-sealable integrity, even during thermal processing up to 121°C, and cooling (Norman, 1979).

There are two major markets for the retort pouch: the retail market for pouches containing 170-450 g of food and the institutional market with pouches holding around 2,240-2,940 g, which is approximately equivalent to the capacity of a No. 10 can.

Certain characteristics of pouches should favor the retention of nutrients, color and texture of the foods present in them. Compared to the tin can, the pouch has a thin profile (Fig. 1) which provides for rapid heat transfer during processing. This

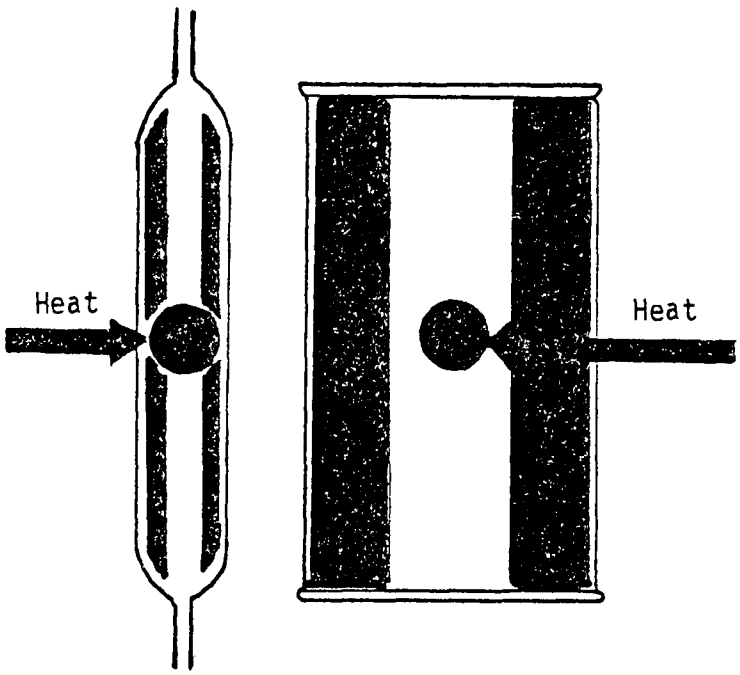


FIGURE 1. Heat conduction in the retort pouch and in a cylindrical can.

permits the required amount of heat to reach the critical point with minimal overcooking and loss of heat labile nutrients. Cylindrical containers, on the other hand, have a relatively large diameter and a relatively small surface area compared to volume. These characteristics of the can are responsible for a relatively low rate of heat transfer to the critical point. This can cause losses of heat labile nutrient and quality due to over-processing.

Another feature of the pouch which favors the retention of water-soluble nutrient is that the amount of brine and syrup required to process vegetables and fruits in a pouch is less than that required for processing in a can. Some fruits can even be processed in a pouch without any added syrup. Research on the effect of pouching on vitamin retention will be discussed later. The need for less brine or syrup for processing also reduces the cost and waste of the liquid portion in pouched products.

Pouches have some other advantages (Lopez, 1981; Mermelstein, 1976): (a) The shelf-life of food processed in a retort pouch is similar to that processed in a can; refrigeration or freezing is not required; (b) Due to the shape of the pouch, pouched products can be heated in a few minutes by immersing the pouch in boiling water. When used for "boil-in-the-bag" types of foods, it competes with frozen foods rather than canned; (c) The pouch is easily opened and is disposable.

Disadvantages of the retort pouch (Lopez, 1981; Mermelstein, 1976) are: (a) A major capital investment is required for

equipment to fill and close this containers; (b) Filling is slower and more complex than for conventional containers; (c) Thermal processing for pouches is more complex and procedures have to be established for each product in the particular type and size of container; (d) Not only may pouches be punctured easily, but the detection of leakage is difficult in the flexible container; (e) Getting the trade and the consumers used to properly handling the pouched products may be difficult.

Thiamin

Chemical and Physical Properties

Thiamin occurs naturally in foods and other biological materials, either in the free or in a combined form as a protein complex, a phosphorus-protein complex, or a pyrophosphoric acid ester (Freed, 1966).

Thiamin is composed of a pyrimidine and a thiazole moiety. Its structure, seen in Figure 2, is a 3-(2'-methyl-4'-amino-5'-pyrimidylmethyl)-5-(2-hydroxyethyl)-4-methyl-thiazole (Fennema, 1976). The empirical formula of thiamin is $C_{12}H_{18}ON_4SCl_2$ and its molecular weight is 337.26. One gram of the thiamin hydrochloride can dissolve in 1 ml of water. Thiamin is soluble in alcohol and is practically insoluble in ether, benzene, hexane and chloroform (Windholz et al., 1976).

Temperature, time of heating, storage and pH are important

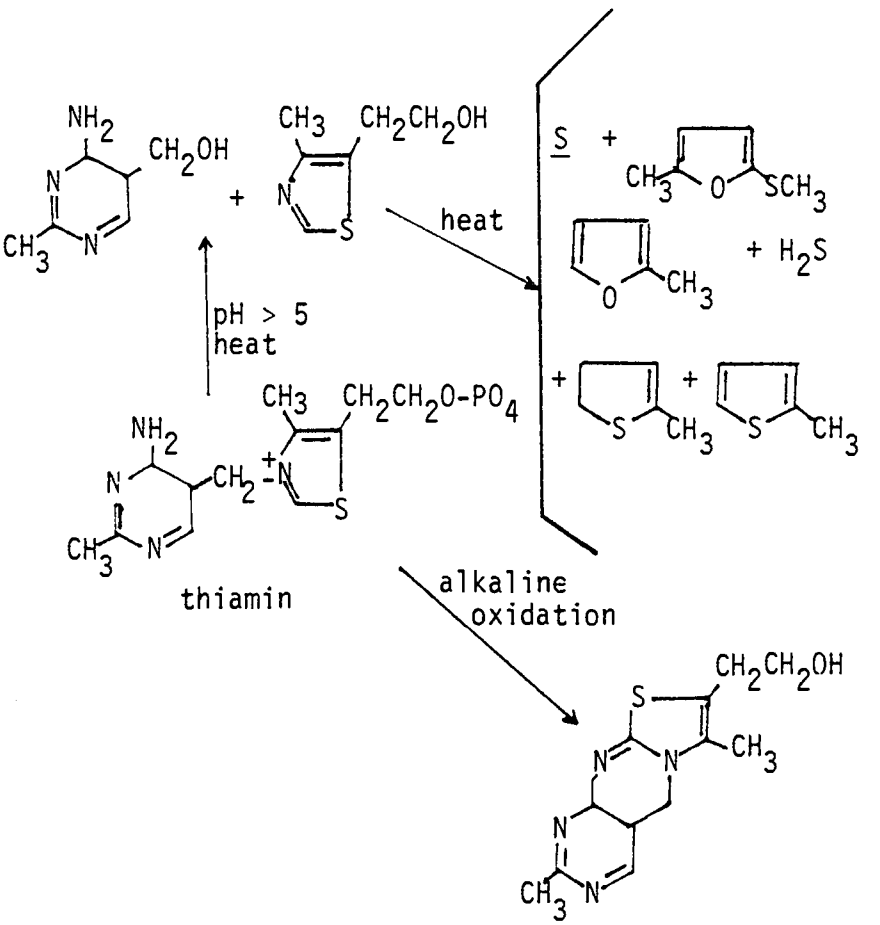


FIGURE 2. Degradation of thiamin and formation of Thiochrome (adapted from Fennema, 1976).

factors leading to losses of thiamin in foods (DeRitter, 1976). The reactions for thermal and alkaline destruction of thiamin are presented in Figure 2. Thiamin is destroyed at elevated temperatures at pH 5 or above. At pH 7 and above, thiamin rapidly loses its biological activity. In an alkaline solution thiamin is oxidized to form the fluorescent compound, thiochrome. This reaction is widely used for the detection and quantitation of this vitamin. Thiochrome is soluble in alcohol, ether, chloroform and acetone, and moderately soluble in water. Thiochrome exhibits a blue fluorescence, which is intensified when extracted with isobutanol. Thiochrome is physiologically inactive (Windholz et al., 1976).

Method of Determining Thiamin in Foods

The various chemical, microbiological and animal methods for determining thiamin in foods were reviewed by Gÿorgy and Pearson (1967). Among the chemical methods, the thiochrome one is most commonly used for foods (Joslyn, 1970). Thiamin is extracted into an acid medium, in which it is stable. Since thiamin in a phosphoric acid ester is not available for measurement by the thiochrome method, enzyme treatment is needed to liberate this vitamin. Various enzymes such as Takadiastase, Diastase, Mylase, Clarase and Polidase which possess both diastatic and phosphorolytic activities can be used. The phosphatase hydrolyses the phosphoric acid ester of thiamin, and the diastase facilitates the liberation

of the vitamin from starch. Following hydrolysis, thiamin is isolated by passing the solution containing the vitamin through a cation-exchange column of Decalso (The Permutit Company, 330 West 42nd Street, New York, New York), a synthetic zeolite. After the thiamin is eluted from the Decalso, it is oxidized to thiochrome by an alkaline oxidizing agent. The thiochrome, which is extracted into isobutanol, is determined by fluorometry at 365 nm (activation) and 435 nm (fluorescence).

Since Decalso and clarase or mylase P are no longer available, Ellefson et al. (1981) recently evaluated four ion exchange resins and nine enzyme preparations for use in the thiochrome method. These enzymes were tested for their effectiveness in releasing thiamin from its phosphate, and their ability to produce similar results as clarase. Rhozyme S (Rohm and Haas Company, Independence Mall West, Philadelphia, Pennsylvania) showed 90-100 percent effectiveness in both of these respects. Among the ion exchange resins tested, Ellefson et al. found that the best recovery of thiamin was from Bio-Rex 70 (Bio-Rad Laboratories, Richmond, California).

Other chemical methods for measuring thiamin include formaldehyde-diazotized sulphanilic acid, diazotized p-aminoacetophenone and bromthymol blue.

The most popular microbiological method for measuring thiamin uses Lactobacillus viridescens as the assay organism. This microorganism requires the intact thiamin molecule for growth;

thiazole and pyrimidine as well as their respective phosphorylated forms are not active (Goodhart and Shils, 1980).

Animal assay, the so-called growth method, permits evaluation of the actual results in that the weight gain of animals responding to samples containing varying amounts of thiamin is measured. Although this method is cumbersome and time-consuming, it serves as a reference standard to evaluate and correlate other faster methods (Freed, 1966).

Ascorbic Acid

Chemical and Physical Properties

The chemical and physical properties of L-ascorbic acid were reviewed by Joslyn (1970). Ascorbic acid is a colorless crystalline substance having an empirical formula of $C_6H_8O_6$ (Fig. 3) and a molecular weight of 176. Ascorbic acid contains a dienol group conjugated with a carbonyl in a lactone ring. This structure not only gives ascorbic acid its reducing ability, but also its acidic properties. In solution, the hydroxyl group on C-3 ionizes rapidly (pK_1 = 4.04 at 25°C), while the one C-2 is more resistant to ionization (pK_2 = 11.4). Ascorbic acid is soluble in water, and is insoluble in organic solvents. Ascorbic acid is readily oxidized in an alkaline medium. It is stable as dry crystals and fairly stable in acid solutions.

In the presence of oxygen and a suitable catalyst, ascorbic

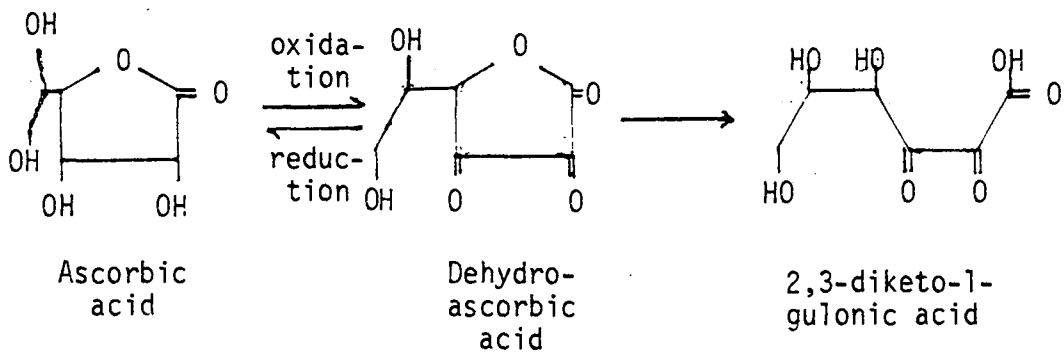


FIGURE 3. Oxidation of L-ascorbic acid.

acid is oxidized to dehydroascorbic acid, which is fairly stable below pH 4.0. Mills, Damron and Roe (1949) reported that dehydroascorbic acid still has 75 percent of the vitamin activity of reduced ascorbic acid. Dehydroascorbic acid undergoes further conversion to 2,3-diketo-l-gulonic acid formed by the opening of the lactone ring of dehydroascorbic acid. Diketogulonic acid has no demonstrable antiscorbutic activity. These reactions are presented in Figure 3.

Since ascorbic acid is soluble in water, it is readily lost via leaching. In processed foods, however, the most significant losses after processing result from chemical degradation. In foods high in ascorbic acid, losses are usually associated with nonenzymatic browning (Fennema, 1976). Factors which can influence the nature of the degradation are temperature, salt and sugar concentration, pH, oxygen, oxidative enzymes, metal catalysts, amino acids, and oxidants or reductants. The scheme in Figure 4 shows the degradation of ascorbic acid beyond diketogulonic acid.

Method of Determining Ascorbic Acid in Foods

There are a variety of methods for estimating ascorbic acid in foods. These were reviewed by Freed (1966), Gÿorgy and Pearson (1967) and Deutsch and Weeks (1965).

Among the methods used to measure ascorbic acid, the chemical

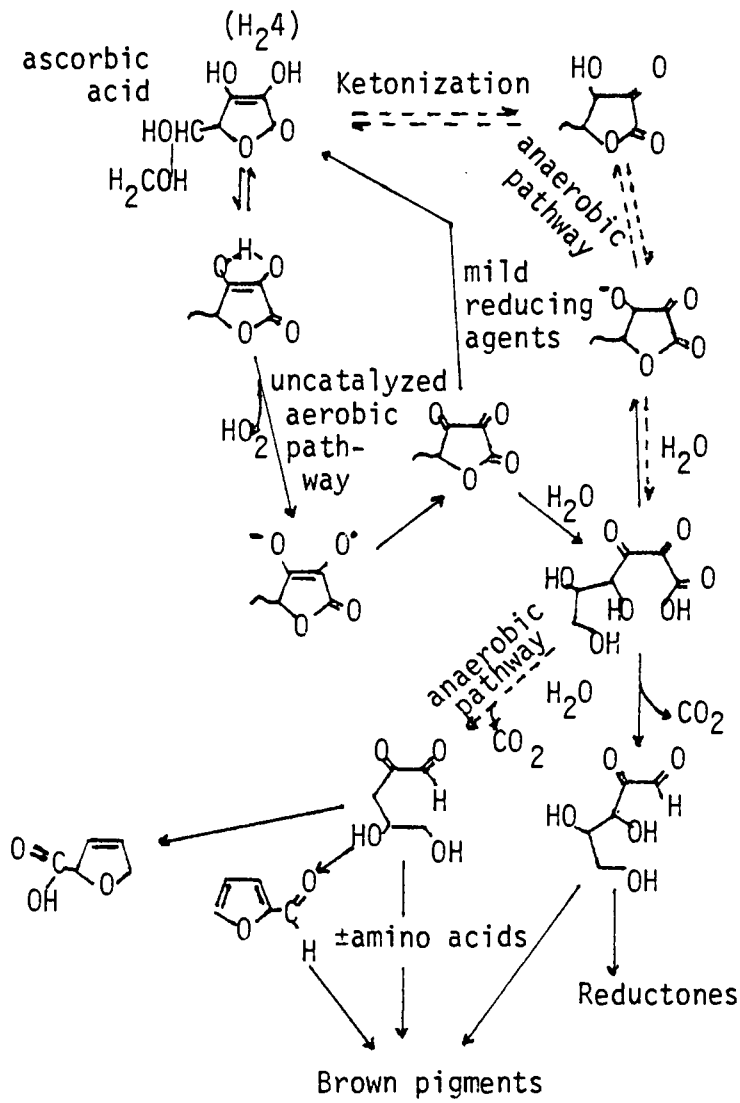


FIGURE 4. Degradation of ascorbic acid (adapted from Fennema, 1976).

ones are the most practical. These are based on oxidative properties of the loosely bound H atoms on C-2 and 3 of ascorbic acid, or reduction of the oxygen at the dienol group of the dehydroascorbic acid (Gÿorgy, 1967).

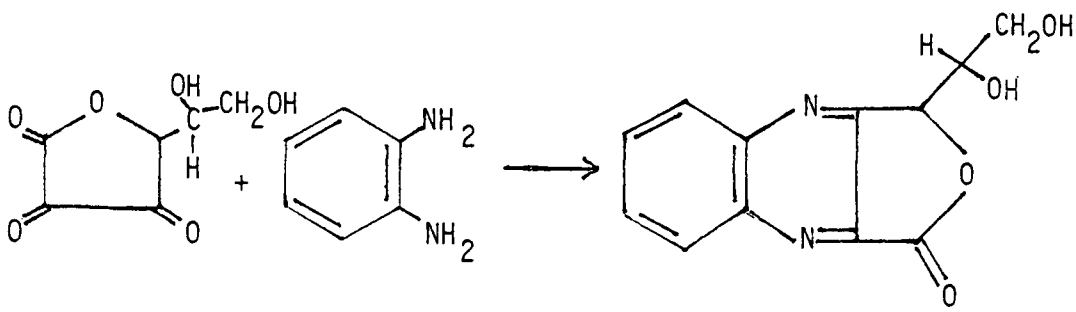
The dye method is based on the extent to which the reduced ascorbic acid decolorizes a solution of 2,6-dichlorophenol indophenol. Since ascorbic acid reduces the dye almost instantaneously and interfering substances reduce the dye more slowly, determination of the decrease in color intensity with time permits correction for the reduction of the dye by substances other than ascorbic acid. This procedure does not take into account dehydroascorbic acid, which also has ascorbic acid activity. This method also lacks specificity, since any substance that has a reduction potential lower than that of the dye indicator is a possible source of interference (Gÿorgy, 1967).

In the dinitrophenylhydrazine method ascorbic acid is mildly oxidized, forming dehydroascorbic acid. The latter compound undergoes spontaneous transformation to diketogulonic acid in a neutral or mildly acidic solution and rapidly in an alkaline medium. Dehydroascorbic and diketogulonic acids couple rapidly with 2,4-dinitrophenylhydrazine in sulfuric acid forming a brownish-red derivative of bis-2,4-dinitrophenylhydrazine. This procedure is obviously susceptible to errors introduced by the presence of compounds with similarly reactive carbonyl groups

which have no ascorbic acid activity. Furthermore, if incubation temperature is not controlled, other interfering substances might be formed (Gÿorgy, 1967; Freed, 1966).

The fluorometric determination of ascorbic acid is also based on the oxidation of ascorbic acid. The vitamin, which is extracted with a metaphosphoric acid-acetic acid solution, is oxidized to the dehydroascorbic acid with acid-washed charcoal. The reaction of dehydroascorbic acid with o-phenylenediamine gives a fluorescent quinoxaline compound (Fig. 5) which has activation and fluorescence maxima at 350 nm and 430 nm, respectively. The development of the fluorescent derivative of the vitamin is prevented by forming a boric acid-dehydroascorbic acid complex prior to the addition of the o-phenylenediamine solution. This provides a means of differentiating between the fluorescence from the vitamin and that from possible interfering substances. This method shows a higher degree of specificity, and measures dehydroascorbic acid, which is found in processed and stored food (Mills, Damron and Roe, 1948). Dehydroascorbic acid has ascorbic acid activity. This is a rapid, straightforward procedure giving results statistically equivalent to those obtained by established methods (Deutsch and Weeks, 1965).

Although bioassays are time-consuming, expensive and lack precision, they measure the true activity of the vitamin. The bioassays have been used largely for establishing the specificity of chemical methods.



Dehydro-ascorbic acid

o-phenylenen-diamine

Quinoxaline (fluorescent)

FIGURE 5. Formation of the fluorescent compound, quinoxaline

Nutritional Retention in Canned and Pouched Foods

Thermal processing of canned foods is conventionally done by heating the food container in a pressurized steam or water retort at a prescribed combination of time and temperature. Processing time is chosen to result in a sufficient reduction in bacteria to produce a safe, shelf-stable product. Associated with thermal processing is the degradation of nutrients in foods. Bender (1982) stated that ascorbic acid and thiamin are by far the most labile of the nutrients. A number of reports indicate damage done to these two nutrients in thermal processing.

Mayfield and Richardson (1939) examined the vitamin content of cooked, stored, canned green string beans. Raw cut green beans that had been cooked uncovered in boiling water for 45 minutes were packed in No. 2 tin cans. Each can was filled with boiling brine, sealed and processed for 30 minutes at 115.6°C. Thiamin was determined by rat assay, and ascorbic acid by guinea pig assay. Cooking for 45 minutes resulted in no loss in thiamin and 30-40 percent loss in ascorbic acid. Mayfield and Richardson presented no information on the effect of canning (before storage) on the retention of thiamin and ascorbic acid. Canned green beans that had been stored for six months lost 40 percent of its thiamin, and 80-85 percent of its ascorbic acid.

Farrell and Fellers (1941) also investigated the influence of canning on the thiamin and ascorbic acid content of green snap

beans. The beans were blanched for two minutes in boiling water, placed in No. 2 tin cans, and processed at 115.6°C for 20 minutes. Thiamin was measured by rat assay and ascorbic acid by the 2,6-dichlorophenolindophenol method. Farrell and Fellers observed that blanched green beans were higher in thiamin than raw green beans. Expressing their results as µg of thiamin per 100 g wet weight and 100 g dry weight, respectively, Farrell and Fellers found that the raw beans contained 63 and 699 µg of thiamin, while the blanched green beans contained 77 and 996 µg. The content in canned green beans was 54 and 825 µg of thiamin. The loss in thiamin in canned green beans was 17 percent, based on yhr values of the blanched green beans. They also observed that the thiamin content of the fresh (raw) beans decreased with maturity. The concentration of thiamin in the liquid portion of the canned green beans was 21 µg per 100 g sample, thus about 30 percent of the thiamin in the canned product was present in the liquid portion. Farrell and Fellers found that raw, blanched and canned green beans contained, respectively, 26.5, 14.5 and 4.5 mg of ascorbic acid per 100 g of wet sample, and 283, 188 and 71 mg per 100 g of dry sample. Farrell and Fellers calculated a 75 percent loss of ascorbic acid in the canned beans and a 50 percent loss of ascorbic acid in the liquid portion.

Elkins (1979) investigated the nutrient content of raw and canned green beans. The beans were blanched for two minutes at 79.4°C and packed into No. 303 cans with hot brine and processed

for nine minutes at 68.5°C. Ascorbic acid was determined by 2,6-dichloroindophenol method and thiamin by the thiochrome method. The analyses showed that 100 g of raw and canned green beans contained, respectively, 50 and 16 µg of thiamin, and 14.8 and 4.0 mg of ascorbic acid.

The retention of ascorbic acid and thiamin is affected more markedly by temperature of storage than by the period of storage. Guerrant et al. (1948) investigated the retention of thiamin and ascorbic acid in 11 different canned foods stored for 4, 8, 12, and 24 months at 10°, 18.3° and 26.7°C. Both time and temperature of storage had an adverse effect on the vitamin content, the degree of effect depending on the particular food and on the specific vitamin. Canned foods stored at 10°C showed better retention of vitamins than canned foods stored at higher temperatures.

Lee, Massey and Van Buren (1982) examined the effect of post-harvest handling and processing on the vitamin contents of peas. Ascorbic acid was determined by the photometric method of the indophenol-xylene extraction technique and thiamin content by the thiochrome method. The results were reported on the dry weight basis. Raw, blanched and canned peas contained, respectively, 137.2, 114.4 and 78.9 mg of ascorbic acid per 100 g, and 14.28, 13.73 and 9.11 µg thiamin per 100 g. Lee et al. also compared the vitamin retention of peas packed in No. 303 and No. 10 cans. Peas in No. 303 cans were processed at 127°C for 12.2 minutes and those in No. 10 cans at 124°C for 24.5 minutes. The results

showed that the peas canned in No. 10 cans were lower in ascorbic acid and thiamin content than those packed in No. 303 cans. Lee et al. concluded that these differences in nutrient content were due to longer heat exposure in No. 10 cans than No. 303 cans.

The retort pouch, a new development in food preservation, may be a coming form of packaging, replacing the conventional can. A few reports are available on the retention of nutrients in model system or foods packed in retort pouches.

Ohlsson (1980) studied the time-temperature relationship of nutrient retention in colloid foods packed in flat containers of various thicknesses. Thiamin retention and peroxidase activity were calculated. Ohlsson concluded that retortable pouches reduce the deterioration of sensory and nutritional qualities during heat sterilization. Pouches which are flat and rectangular have a geometrical shape that favors rapid heat transfer to the central point.

Castillo et al. (1980) developed a theoretical model for the prediction of nutrient retention in food packed in retortable pouches and sterilized by thermal conduction. The validity of the model was verified experimentally on a simulated food mixture of corn starch, carboxymethyl cellulose, and thiamin in a pH 6.0 buffer solution. Thiamin was determined by the thiochrome method. The fraction of thiamin retained, predicted and experimentally determined, after thermal processing in a 6.35 x 17.78 cm pouch at 118.9°C for 27.5 minutes was 0.878 and 0.929; at 115°C for 57.0 minutes was 0.747 and 0.719; at 120.3°C for 46.9 minutes was

0.737 and 0.767. The prediction of the fraction of nutrient retained at the end of processing compared favorably to the fraction obtained experimentally, and they were within the 90 percent confidence intervals of the experimental fractions.

Chen and George (1981) determined the retention of ascorbic acid, using the 2,6-dichlorophenol-indophenol titration method, in green beans retorted in pouches under home canning conditions. The green beans were blanched in hot (82°C) water for two minutes and cooled rapidly. The retort pouches were processed at 115.6°C for 12 minutes and the cans were processed at the same temperature for 25 minutes. The ascorbic acid content in raw, blanched, canned and pouched green beans was 15.56, 9.43, 3.48, and 3.18 mg per 100 g wet weight. Compared to raw, the percent retention of ascorbic acid in blanched, canned and pouched green beans was 60.0, 22.4, and 20.4 percent, respectively. Chen and George attributed the low retention of ascorbic acid in the pouched beans to over-processing.

Huerta-Espinosa (1981) compared the ascorbic acid content in cut green beans thermally processed in institutional-sized retort pouches and No. 10 cans stored at room temperature for 10 months. The retort pouches were processed for 12, 20, or 24 minutes at 121°C, the ascorbic acid was 2.02, 1.62, and 1.01 mg per 100 g wet basis, respectively. The No. 10 can was processed for 18 minutes at 121°C, the ascorbic acid was 0.61 mg per 100 g wet basis. Huerta-Espinosa concluded that, although the pouched beans were over-processed, they showed a higher concentration of ascorbic acid than did

the canned sample. So far, however, there has been inadequate information comparing the nutritional retention among raw, blanched, canned and pouched products that have not been over-processed.

Color of Green Beans and Cherries

The quality and acceptability of foods is generally based on color, flavor, texture and nutritive value. These factors are considered differently in assessing overall quality. Color of a food is due to natural pigments present, except in cases where colorants have been added.

The primarily green color of beans is due to chlorophyll A and B,carotene and xanthophyll (Duckworth, 1966). Chemically, the chlorophylls may be altered in many ways, but in food processing the most common alteration is pheophytinization (Mackinney and Weast, 1940). Pheophytinization is the replacement of the central magnesium of chlorophyll A or B by hydrogen, with the consequent formation of the dull olive brown pheophytin (A or B).

Anthocyanins are the primary natural pigment in cherries (Duckworth, 1966). Since the flavylium nuclei of anthocyanins are highly reactive, these compounds readily undergo undesirable structural and color changes under the variety of conditions employed in the processing and storage of fruit products. Anthocyanin destruction is pH dependent, being greater at higher pHs

and is apparently proportional to the amount of pigment that exists in the form of its colorless carbinol base. Higher temperatures markedly decrease anthocyanin stability (Chichester, 1972).

Texture

Blanching, cooking, and canning are drastic treatments which often cause extensive changes in the texture of foods. Usually these alterations are desirable, although in some cases they may be undesirable. This is especially true of canning, where the high temperatures and relatively long times required for sterilization frequently yield foods with sub-optimal texture characteristics (Matz, 1962).

The most important early happening in the alteration of texture by heat applied to food is the destruction of the selective permeability of cell membranes (Crafts, 1944). As soon as the selective permeability of the cell is lost, the internal pressure is permanently reduced. Some cell distension may still be present; however, crispness and similar textural properties will no longer exist.

III. MATERIALS AND METHODS

The pouched and canned products used in this research project were supplied by Truitt Bros., Salem, Oregon. This canning company has been experimenting with pouched products in their pilot plant.

Sample Collection and Processing of Green Beans

The retention of thiamin and ascorbic acid as well as texture and color was determined in pouched and canned cut snap green beans (variety 290). These nutrients were determined in raw and blanched green beans, as well as pouched and canned green beans, immediately after processing and after storage for four months at room temperature or at 37.8°C. Processing temperatures and times for the pouched and canned green beans are presented in Table 1. Five replications were done in duplicate according to the scheme in Figure 6a.

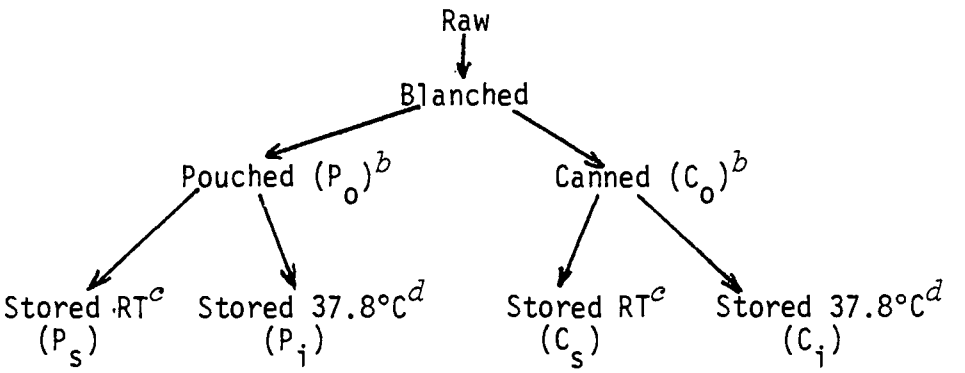
Raw, blanched, pouched and canned variety 290 green beans were obtained from Truitt Bros., Salem, Oregon, in 1981 on August 4, 10, 13, 17, and 24. Raw and blanched green beans were selected randomly from the trough and production line, respectively, placed in plastic bags and stored on ice until prepared for analysis upon return the same day to the Foods and Nutrition Department at Oregon State University. For each replication a No. 10 can of green beans was selected randomly from the production line; pouched

TABLE 1. Processing information for institutional-sized pouched and canned[a] green beans and cherries.

Product	Blanching		Holding	Processing		Brine	Syrup	
	Time (min)	Temp. (°C)	Time (min)	Time (min)	Temp. (°C)	Wt. (gm)	Wt. (gm)	% Brix
Green beans								
Pouched	1.75	79.4	--	12.00	122.2	255.15	--	
Canned	1.75	79.4	17.00	19.00	122.8	1304.10	--	
Cherries								
Pouched	--	--	--	12.00	100.0	--	--[b]	--
Canned	--	--	--	20.60	98.9	--	1077.3	24.0

[a]Pouch size was 30.5 x 38.1 x 3.8 cm and can size was No. 10.

[b]Processed without syrup.



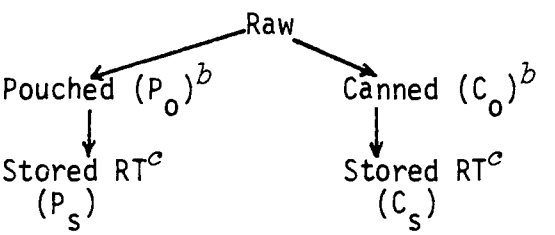
[a]Five replicates, each done in duplicate.

[b]Analyzed immediately after processing.

[c]Analyzed after four months of storage at room temperature.

[d]Analyzed after four months of storage at 37.8°C.

FIGURE 6a. Scheme for the determination of thiamin and ascorbic acid in cut snap green beans.[a]



[a]Three replicates, each done in duplicate.

[b]Analyzed immediately after processing.

[c]Analyzed after six months of storage at room temperature.

FIGURE 6b. Scheme for the determination of ascorbic acid in Royal Ann cherries.[a]

products (size of pouch, 30.5 x 38.1 x 3.8 cm) were obtained from the pilot plant. In each replication, pouched and canned green beans were assayed immediately, or after storage at room temperature and 37.8°C for four months. These processed products assayed immediately after processing are referred to as P_0 (pouched zero) and C_0 (canned zero). Those stored for four months at room temperature are designated as P_s for pouches and C_s for cans; those stored for four months at 37.8°C are referred to as P_i and C_i (i = incubation).

Sample Collection and Processing of Cherries

The analyses on the cherries were done in triplicate according to the scheme presented in Figure 6(b). Each replicate was done in duplicate. The same scheme was used for assaying Royal Ann cherries as for the green beans, except that only ascorbic acid was determined and there were no blanched cherries or cherries stored at 37.8°C. The three replicates of Royal Ann cherries were obtained in 1981 on July 6, 9, and 14. Processing time and temperature for cherries are presented in Table 1.

Pouched and canned cherries analyzed immediately after processing are referred to, respectively, as P_0 and C_0; those after six months of storage at room temperature as P_s and C_s.

Other Foods Assayed

Ascorbic acid and thiamin were also measured in frozen cut green beans, as well as in pouched green beans with tomato sauce. The latter also were stored for six months at room temperature and at 37.8°C. In addition, ascorbic acid was determined in raw, blanched, canned and pouched pears; and thiamin was measured in raw, canned and pouched plums.

Sample Preparation

On the day when each replicate of green beans or cherries was obtained, the raw products were washed, drained and stored overnight at -20°C. The blanched green beans were also frozen at this time. The following day, the canned and pouched products were drained and the weights of the drained and liquid portions were determined. The liquid portions from the green beans and cherries were stored in glass bottles at -20°C for analysis later. Around 20 g of brine or syrup were used for thiamin and ascorbic acid determination.

The drained portions along with the frozen raw and blanched green beans were chopped into small pieces, cooled further in liquid nitrogen, and ground in a blender to a fine powder. Portions of the pulverized products were weighed immediately for ascorbic acid (10 g) and thiamin (10 g) determinations. A portion of the powdered samples was placed in plastic vials and stored

at -20°C for moisture determination later.

Procedure

A. Thiamin Determination

Thiamin was determined according to the AOAC (1980) thiochrome method 43.024-30. After acid hydrolysis the samples were hydrolyzed with Clarase 40,000 (Miles Laboratories, Enzyme Products Division, Elkhert, IN 46515) at a 5 percent concentration. After the enzyme treatment, which was done on the same day as the ascorbic acid determinations, the sample extract was stored at 2.2°C overnight under a layer of toluene. The following day, the hydrolyzed sample was applied to a column of Decalso (The Permutit Company, 330 West 42nd Street, New York, N.Y.), a cation exchanger, which will retain thiamin along with other cations. The standard containing 0.16 µg of thiamin hydrochloride per ml was also applied to a Decalso column. Thiamin in the effluent collected from the chromatographic columns was oxidized to thiochrome by an alkaline solution of potassium ferricyanide. The thiochrome was measured fluorometrically in an Aminco-Bowman spectrofluorometer (8030 Georgia Avenue, Silver Spring, Maryland 20910) at 365 nm (activation) and 465 nm (fluorescence). The sensitivity of the instrument was set at 50 with a solution of quinine sulfate (0.0375 µg/ml in 0.1N H_2SO_4). The thiamin values were expressed in µg of thiamin per 100 g of green beans (net weight).

B. Ascorbic Acid Determination

Ascorbic acid was determined by the fluorometric method outlined by AOAC (1980) in section 43.061-67. This method measures reduced ascorbic acid as well as dehydroascorbic acid. In this procedure, ascorbic acid is converted into dehydroascorbic acid by treatment with acid-washed charcoal. The α-diketo group of dehydroascorbic acid reacts with o-phenyldiamine to form a quinoxaline which was measured with an Aminco-Bowman spectrofluorometer (8030 Georgia Avenue, Silver Spring, Maryland 20910) at 350 nm (activation) and 430 nm (fluorescence). Sensitivity of the instrument was set at 50 with quinine sulfate (0.0375 µg/ml in 0.1N H_2SO_4) solution.

C. Orange Juice Control

Orange juice was used as a control for the thiamin and ascorbic acid assays. It was assayed each time along with the green beans, cherries or other foods. Frozen concentrated orange juice was diluted with distilled water and mixed according to the directions on the label. Approximately 60 ml of reconstituted orange juices were dispensed into 90 ml glass bottles, capped, and stored at -20°C. Before each assay a bottle was removed from the freezer and thawed. The amounts of thiamin and ascorbic acid values, respectively, found in 100 g of the first orange juice control sample were 62.2 ± 6.3 µg and 47.09 ± 1.7 mg for 15 and 9 assays (done in summer, 1981) and 45.7 ± 1.3 and 43.4 ± 0.6

(done in winter, 1982) for two assays; those for the second orange juice control sample were 60.7 ± 4.2 μg and 40.4 ± 0.9 mg, respectively, for 14 and 11 assays done winter, 1982.

D. Moisture Determination

Samples of powdered green beans or cherries weighing 10 ± 1.2 g were placed in aluminum weighing dishes of 8.5 cm in diameters (VWR Scientific, Inc., San Francisco, CA) that had been dried to a constant weight.

The samples were dried in a vacuum oven (Model 58301, National Appliance Company, Portland, Oregon) to constant weight at 60°C at a pressure of ≤ 100 mm Hg. After drying, the samples were cooled in a desiccator for 20 minutes and reweighed. The difference in weight over the original weight multiplied by 100 was expressed as percent moisture. Moisture of each sample was determined in triplicate.

E. Percent Retention

The percent retention of each vitamin was calculated as follows:

$$\frac{\text{μg or mg nutrient / g dry solids after process}}{\text{μg or mg nutrient / g dry solids before process}} \times 100$$

Color Determination

A Hunterlab Colorimeter Model D25P-2 (Hunter Associates Laboratory, Inc., Fairfax, Virginia) was used to determine color. The

sample was placed in a 4-cm rectangular glass cell. Readings were taken using the reflective mode of the instrument, which was standardized against a standard white tile No. 122 where L = 94.02, a = -0.9, and b = 1.2. With the "L," "a," and "b" system, the color specimens may be visually interpreted. With these scales, it is possible to represent colors by position in a three-coordinate system. The term "L," the vertical axis, measures lightness. The "a" and "b" scales are the chromaticity coordinates. A plus value for "a" indicates redness; a minus value, greenness. A plus value for "b" indicates yellowness; a minus value, blueness. Black is when "L" equals zero, white when "L" equals 100 and gray falls in between those two (Fig. 7).

The color of the sample was measured in three different places and the average values of "L," "a," and "b" were reported.

Texture Determination

The texture of the processed green beans and cherries was measured with an Allo-Kramer Model 52 HE shear press (Precision Metals Engineering Corporation, Rockville, Maryland). A sample of 100 g of drained green beans or cherries was placed in the shear-compression cell. The range of the shear press was set at 5 for the green beans and at 2 for the cherries, which gave a full scale of 45.4 kg and 113.4 kg, respectively. The force rate was 23.0 kg/cm for the green beans and 57.7 kg/cm for the cherries.

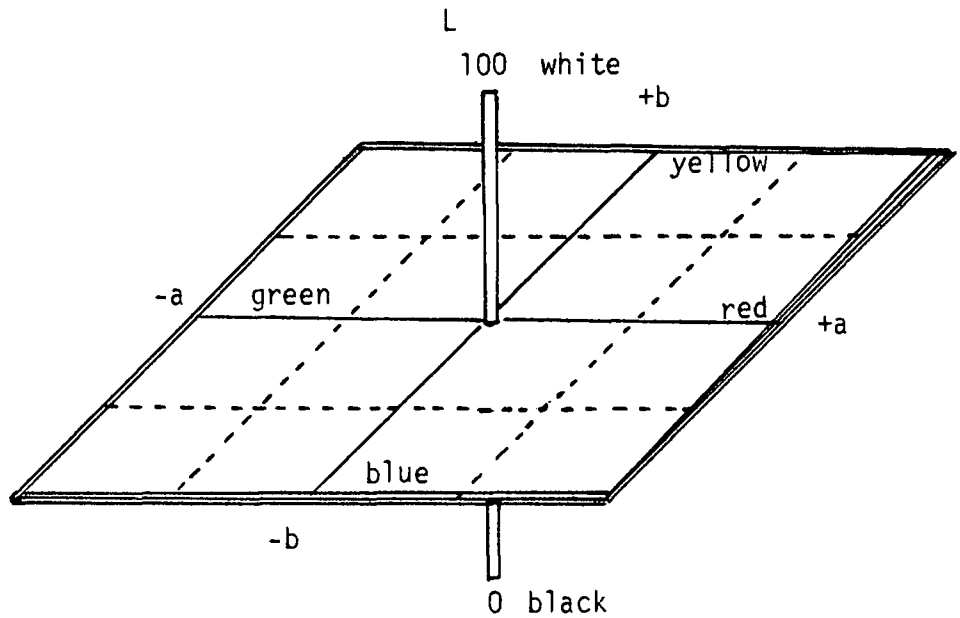


FIGURE 7. The Hunter and Munsell solids.

The work due to compression was calculated by multiplying the area obtained from the recording chart by the force rate. The data were expressed in kg x cm.

Statistical Analysis

The statistical analyses were done at the O.S.U. Computer Center. Means and standard deviations were computed. The analysis of variance was done using randomized complete block design. Five blocks were analysed for green beans using (2x3)+2 factorial. Newman-Keuls comparison was utilized to compare storage at different levels. Differences at five percent or lower probability were considered significant.

IV. RESULTS AND DISCUSSION

The analyses of variance for thiamin and ascorbic acid content and retention, moisture, block variation, color and texture of pouched and canned green beans and cherries are presented in the Appendix. Comparisons among treatments using the Newman-Keuls method are also included in this Appendix.

The weights of the drained and liquid portions of the canned and pouched green beans and cherries are reported in Table 2. The liquid portion accounted for approximately 20 percent of the total weight of the pouched products and approximately 40-45 percent of the canned ones.

Thiamin and Ascorbic Acid in Green Beans

Table 3 presents the moisture, thiamin and ascorbic acid content and retention in raw, blanched, pouched and canned drained green beans analyzed immediately after processing and after storage for four months at room temperature and at 37.8°C. These results are also presented graphically in Figures 8 to 11.

With blanching, the amount of apparent thiamin (Fig. 8) in green beans increased while that of ascorbic acid (Fig. 9) decreased significantly ($P \leq 0.05$) (Table 3). These results are in agreement with those reported by Farrell and Fellers (1941) who also observed that thiamin is higher and ascorbic acid is lower in blanched than in the raw green beans. An apparent

increase in vitamin content after heating is possible when bound forms of vitamins are liberated (Bender, 1978). Thiamin occurs in foods as a protein complex, as a phosphorus-protein complex, or as thiamin pyrophosphate or diphosphothiamin (Joslyn, 1970). In some instances the apparent increase in vitamin content could be due to the greater difficulty of extracting the nutrient from the raw material than from the heated food. During heating there may also be an apparent loss or gain in substances interfering in the assay (Bender, 1978).

There is no information on the form in which ascorbic acid occurs in foods. The loss in ascorbic acid with blanching is most likely due to water leaching and the heat instability of the vitamin (DeRitter, 1976). Mayfield and Richardson (1939), Chen and George (1981) also found that ascorbic acid is lower in the blanched than in the raw green beans.

The pouched drained green beans are significantly higher than the canned ($P \leq 0.01$) in both thiamin (Fig. 8) and ascorbic acid (Fig. 9) (Table 3). This difference may be due to the fact that the canned green beans were heated longer (Table 1) and were processed with more brine (Table 2) than the pouched vegetables. Both nutrients are water soluble and heat labile. In addition, the loss of these vitamins may be higher in the canned than in the pouched green beans due to the inbibition and disintegration of the cell structure during the longer thermal processing (Lee et al., 1982) of the canned than the pouched products. The texture

of pouched and canned green beans in this study will be discussed later.

The results of this study disagree with those obtained by Chen and George (1981) who observed that canned green beans contained more ascorbic acid than pouched ones. This discrepancy in results is most likely due to the differences in the size of pouch as well as time and temperature of heating. Chen and George heat-processed their pouches (14.0 x 43.2 cm) for 12 minutes and their cans (303 x 406) for 25 minutes at 115.6°C. In the present study, the pouches were larger (30.5 x 38.1 x 3.8 cm) and they were processed at 122.2°C for 12 minutes and the No. 10 cans at 122.8°C for 19 minutes.

Compared to storage at room temperature, storage at 37.8°C for four months resulted in a significantly greater loss of thiamin (Fig. 8) and ascorbic acid (Fig. 9) in both pouched and canned green beans (Table 3). For both nutrients, there was no statistically significant difference between time zero (immediately measured after processing) and storage at room temperature for four months. These results are in agreement with those obtained by Guerrant et al. (1948) who also observed that thiamin and ascorbic acid were affected more markedly by temperature of storage than by the storage time.

Based on per g of solids, the amount of thiamin, but not ascorbic acid, in green beans showed significant ($P \leq 0.01$) variation among the five replications (Table 4a). This variation in

thiamin did not follow a pattern. It may be due to different weather or growing conditions, or time of harvesting and processing, etc.

The concentration and total amount of thiamin and ascorbic acid in the brine of pouched and canned green beans are summarized in Table 5. Compared to the brine from the canned green beans, the brine from the pouched vegetables had a significantly higher ($P \leq 0.01$) concentration of thiamin and ascorbic acid. The total amount of brine, however, was lower in the pouched than in the canned product (Table 2).

As the volume of the brine increased, the water soluble nutrient losses were increased via leaching. At zero time (Table 6), the brine of the pouched green beans contained 19 percent and 17 percent of the total thiamin and ascorbic acid, respectively; the brine from the canned product, on the other hand, contained 40 percent and 30 percent of the total thiamin and ascorbic acid. Table 6 also shows that the total amount of thiamin and ascorbic acid in the drained pouched and canned beans decreased with time and temperature of storage and that the total amount of these nutrients in the brine increased concomitantly. Furthermore, the total amount of thiamin and ascorbic acid of the drained beans and brine combined decreased with time and temperature of storage. This decrease is due to the degradation of thiamin and ascorbic acid (Fennema, 1976) (Figs. 2 and 4). Farrell and Fellers (1941) found a lower concentration of thiamin

in the brine than that obtained in this investigation; they reported a 30 percent loss via leaching. Leaching of ascorbic acid in the pouched and canned green beans as reported by Chen and George (1981) was 10 percent and 40 percent, respectively. In the present study there was no process and storage interaction. The mode of processing was independent from storage.

According to Bender (1978), ascorbic acid is more labile than thiamin. The results obtained in this study also showed that the percent retention of ascorbic acid is lower than that of thiamin in the pouched and canned products (Table 3; Figs. 10a, 10b, and 11).

Ascorbic Acid in Royal Ann Cherries

The ascorbic acid content and percent retention as well as the moisture content of raw, pouched and canned cherries are summarized in Table 7. These data are presented graphically in Figures 12 and 13.

Ascorbic acid content (Fig. 12) and percent retention (Fig. 13) are significantly higher ($P \leq 0.01$) in pouched cherries than in the canned ones. Ascorbic acid in cherries showed no significant difference among replications (Table 4b). The loss in ascorbic acid after six months of storage at room temperature was not significant. These results on the effect of pouching vs. canning and of storage at room temperature on

ascorbic acid are similar to those obtained with green beans (discussed in the preceding section).

The total ascorbic acid content of the syrup of pouched and canned cherries is summarized in Table 8. On the basis of 100 g syrup, the pouched cherries had a higher concentration of ascorbic acid than the canned ones. Since the canned cherries had a higher volume of syrup than the pouched (Table 2), there was more leaching of ascorbic acid in the canned than in the pouched; 35.5 percent vs. 15.2 percent, immediately after processing (Table 6).

There was a tremendous decrease in the ascorbic acid content of the canned cherry syrup stored for six months (Table 6). Examining the data more closely, there was a wide variation among syrup samples. Since only three replications of cherries were analyzed, the variation among replications had a wide effect on the results. As the time of storage increased, the percent of drained cherries decreased and the percent of syrup increased, thus increasing the loss via leaching. Some of the loss in fact was not only due to leaching of ascorbic acid, but to its degradation as well.

Color and Texture of Pouched and Canned Green Beans and Cherries

Color was determined in the pouched and canned green beans and cherries, respectively, that had been stored at room

temperatures for three and four months. The Hunter values for these products are presented in Table 9. There was a significant ($P \leq 0.05$) difference for "b" and "L" values between pouched and canned green beans. A higher positive "b" value of the canned green beans than of the pouched indicates that the canned vegetable was paler (yellower) than the pouched ones (Fig. 7). Furthermore, the higher "L" value of the canned green beans indicates a lighter color. The change in color in green beans from green to yellow involves the loss of magnesium from the chlorophyll molecule (Mackinney and Weast, 1940). Almost any type of food processing, alone or combined with storage, will cause some deterioration of the chlorophyll pigments (Fennema, 1976). Since the canned product was heated longer than the pouched (Table 1), there was a greater loss of chlorophyll pigment in the canned than in the pouched green beans.

The Hunter "a" value for cherries was significantly ($P \leq 0.05$) higher for the pouched cherries than for the canned ones (Table 9). Since positive "a" value measures redness (Fig. 7), pouched cherries have a significantly darker red color than the canned ones. The anthocyanin pigment is responsible for the red color in cherries. The reactions which involve decoloration of these pigments depend on pH and temperature (Chichester, 1972). Thus, with increased heating, there was a loss of red color in the cherries. Since the pouched product is heated for a shorter

period of time, heat-sensitive pigments are retained better.

The texture of the processed green beans and cherries was also measured after three and four months of storage at room temperature, respectively. The texture of pouched and canned green beans and cherries is reported in Table 10. The pouched green beans and cherries have significantly ($P \leq 0.01$) higher shear press compression work than the canned products. Since pouched green beans were heated for a shorter time, they were not held after blanching, and consequently their texture was firmer than the canned green bean. As shown in Table 1, the canned green beans were held for 17 minutes at 79.4°C after blanching. Holding is necessary to activate pectin-esterase in vegetable tissues to make them firmer and to prevent sloughing (Doesburg, 1965).

It is suggested for future research to measure the color of raw as well as pouched and canned green beans and cherries on the day of their processing and after storage at room temperature and higher temperatures. Increase in time and temperature of storage enhance the degradation of natural pigments (Fennema, 1976). It is also suggested that the texture of pouched and canned products be studied on the day they are processed and after storage at room and at higher temperatures. Increase in time and temperature of storage changed the solid and liquid proportions of pouched and canned products (Table 2), which may affect their texture.

Other Foods

Table 11 presents the amount of ascorbic acid or thiamin or of both nutrients in some other foods.

Thiamin and ascorbic acid content in green beans with tomato sauce decreased with storage for four months at room temperature and further decreased with storage at 37.8°C for the same length of time. This decrease was also seen in the total thiamin and ascorbic acid content in the tomato sauce which was analyzed separately. These results are similar to those obtained with the green beans which were discussed in a preceding section.

The cooked frozen green beans were higher in apparent thiamin than the uncooked ones (Table). This was also seen in the blanched green beans when compared to raw ones in Table 3.

The ascorbic acid content was higher in pouched pears and syrup than the canned. Similarly, the thiamin content in pouched plums and syrup was higher than the canned ones. The results are similar to those obtained for pouched and canned green beans and cherries (Tables 3, 5, 7 and 8).

TABLE 2. Weights of drained solids and liquid, in grams, of pouched and canned[a] green beans and cherries.

Storage	Pouched		Canned	
	Drained	Brine	Drained	Brine
Green Beans[b]				
None	1516 ± 11.	368 ± 12.	1678 ± 76.	1273 ± 67.
4 months at RT[c]	1488 ± 9.	395 ± 11.	1673 ± 56.	1283 ± 51.
4 months at 37.8°C[d]	1488 ± 11.	396 ± 13.	1685 ± 56.	1273 ± 45.
Cherries[e]				
	Pouched		Canned	
	Drained	Syrup	Drained	Syrup
None	1817 ± 64.	397 ± 61.	1885 ± 101.	1233 ± 129.
6 months at RT[f]	1619 ± 61.	598 ± 54.	1797 ± 64.	1327 ± 69.

[a]Size of pouches (30.5 x 38.1 x 3.8 cm) and No. 10 cans.

[b]Values obtained from five replications

[c]Storage for four months at room temperature.

[d]Stored for your months at 37.8°C.

[e]Values obtained from three replications.

[f]Storage for six months at room temperature.

FIGURE 8. Thiamin content of raw, blanched, pouched and canned drained green beans analyzed immediately after processing and after storage for four months at room temperature (RT) and at 37.8°C. The values obtained are the means from five replications, each done in duplicate. The total length of the bars for the pouched and canned green beans represent the thiamin content in beans analyzed immediately after processing; the horizontal lines plus open bars represent thiamin content after storage of the vegetable for four months at room temperature; and the open bars represent thiamin content after storage of green beans for four months at 37.8°C.

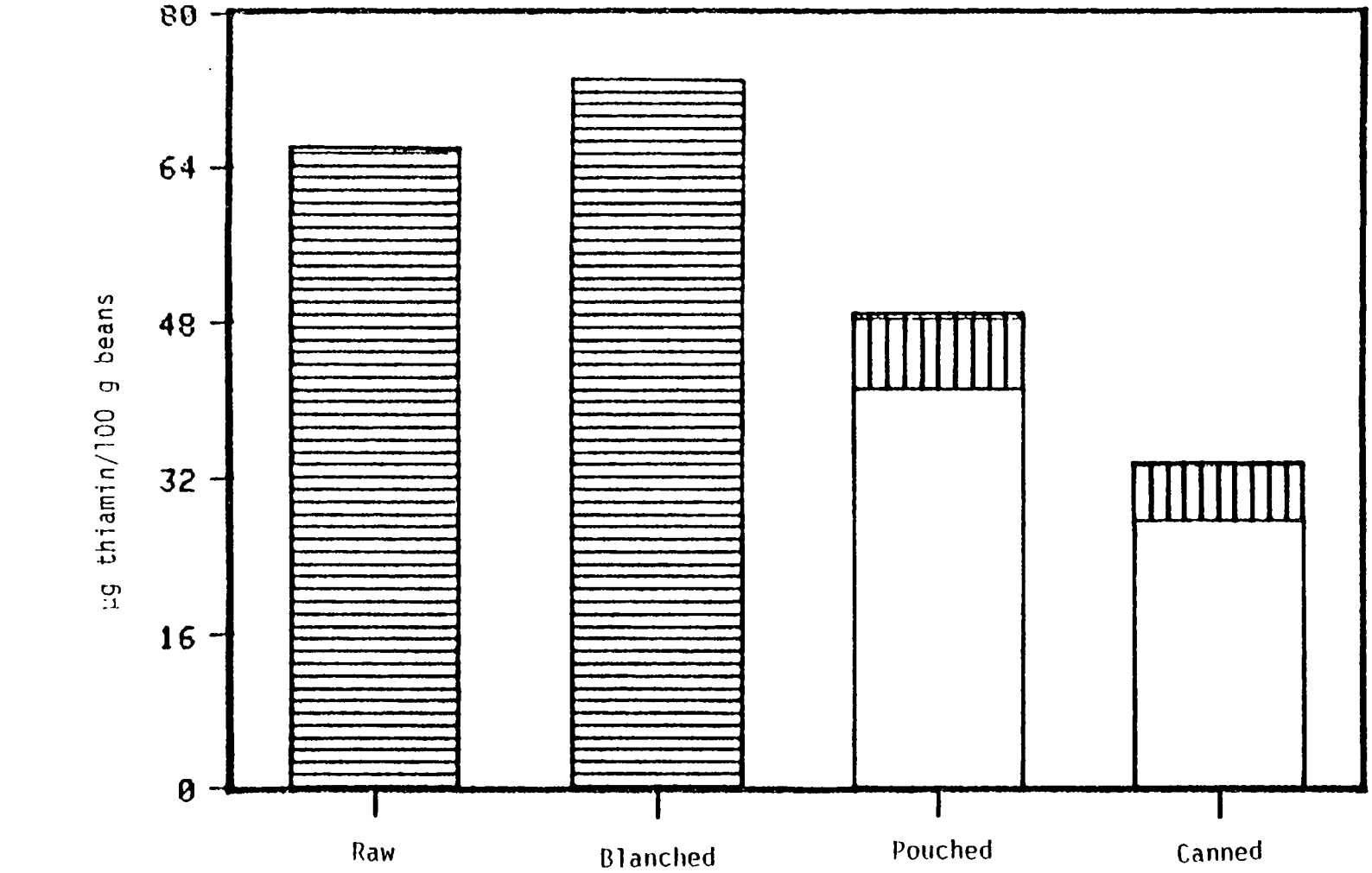
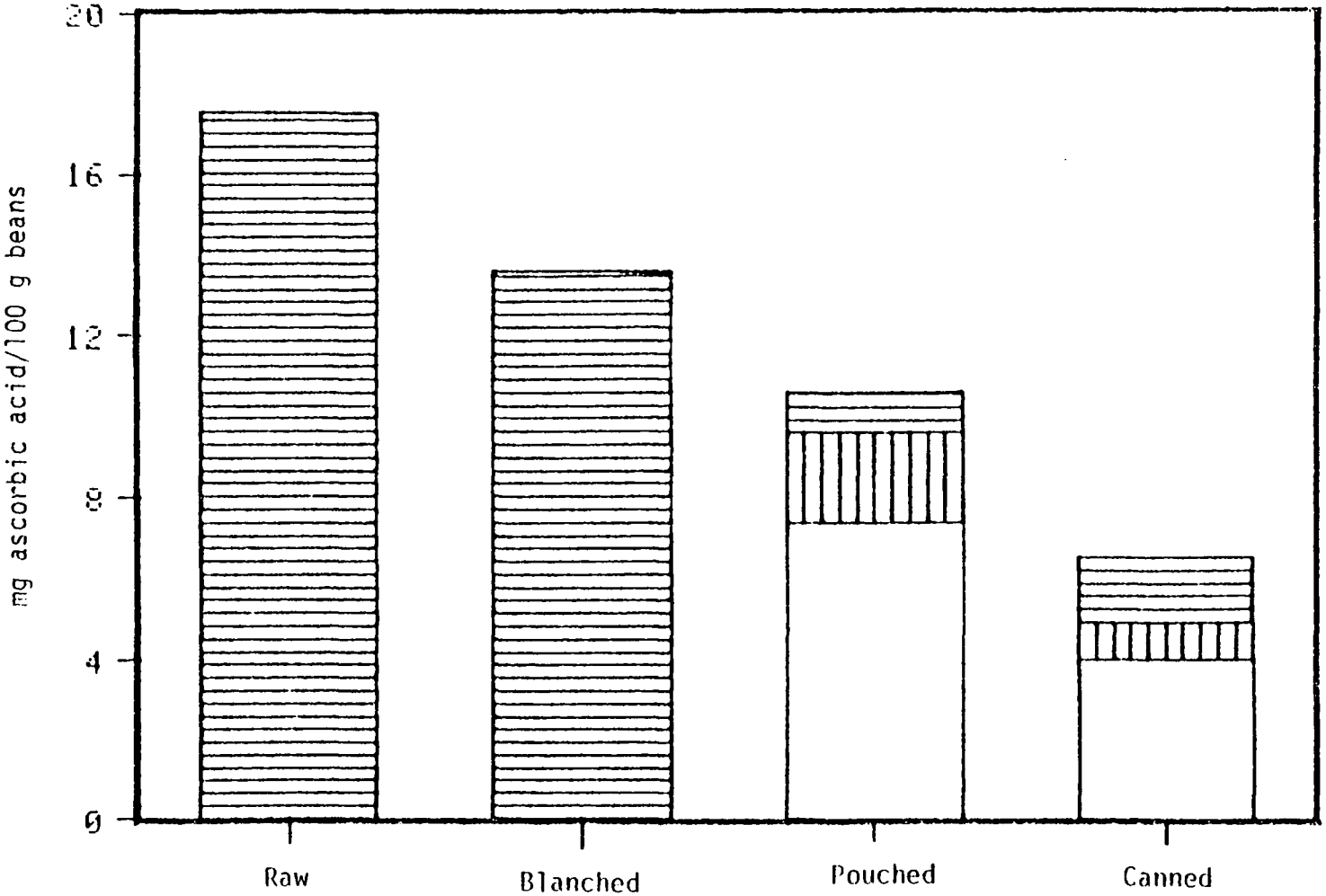

80
64
48
32
16
0
µg thiamin/100 g beans
Raw
Blanched
Pouched
Canned
Samples
• No storage
• Stored at RT
• Stored at 37.8°C

FIGURE 8

FIGURE 9. Ascorbic acid content of raw, blanched, pouched and canned drained green beans immediately after processing and after storage for four months at room temperature (RT) and at 37.8°C. The values obtained are the means from five replications, each done in duplicate. The total length of the bars for the pouched and canned green beans represent the ascorbic acid content in beans analyzed immediately after processing; the horizontal lines plus open bar represent ascorbic acid content after storage of the vegetable for four months at room temperature; and the open bars represent ascorbic acid content after storage of green beans for four months at 37.8°C.



. No storage
. Stored at RT
. Stored at 37.8°C

FIGURE 9

TABLE 3. Moisture, thiamin and ascorbic acid content of and retention in raw, blanched, pouched and canned[a] drained green beans immediately after processing and stored for four months at room temperature and 37.8°C.

Sample	Moisture (%)	Thiamin (wet weight) (µg/100 g)	Ascorbic acid (wet weight) (mg/100 g)	Thiamin retention based on Raw (%)	Thiamin retention based on Blanched (%)	Ascorbic acid retention based on raw (%)
Raw	88.9 ± 1.9[b]	65.9 ± 10.5	17.5 ± 3.9	--	--	--
Blanched	89.7 ± 1.4	73.1 ± 7.6	13.6 ± 2.4	122.4 ± 25.9	--	86.4 ± 20.3
Pouched						
P_0[c]	89.7 ± 1.0	49.0 ± 4.7	10.6 ± 1.6	82.0 ± 17.9	67.4 ± 8.6	68.0 ± 19.6
P_s[d]	89.7 ± 1.3	48.4 ± 3.1	9.6 ± 1.9	80.1 ± 10.9	66.8 ± 10.0	59.9 ± 10.6
P_l[e]	89.7 ± 1.3	41.3 ± 5.2	7.4 ± 1.2	66.4 ± 13.0	55.8 ± 8.6	45.2 ± 8.8
Canned						
P_0[c]	91.9 ± 0.8	33.7 ± 3.3	6.5 ± 1.0	71.4 ± 13.3	58.6 ± 3.0	53.2 ± 16.0
P_s[d]	91.7 ± 1.3	33.3 ± 2.4	4.9 ± 0.5	69.5 ± 14.1	57.8 ± 10.4	38.4 ± 7.5
P_l[e]	91.7 ± 1.1	27.7 ± 4.9	4.0 ± 1.3	57.7 ± 15.0	47.5 ± 9.3	31.9 ± 10.3
Raw vs. blanched	NS	NS[b]	**[g]	--	--	--
Blanched vs.others	--	--	--	**	--	**
Pouch vs. canned	**	**	**	*[h]	*	**
None vs. RT	NS	NS	NS	NS	NS	NS
None vs. 37.8°C	NS	*	**	*	*	**
RT vs. 37.8°C	NS	*	**	*	*	**

[a]Processed in (30.5 x 38.1 x 3.8 cm) pouches and No. 10 cans.

[b]Means ± SD obtained from five replications, each done in duplicate.

[c]Analyzed immediately after processing.

[d]Stored for four months at room temperature.

[e]Stored for four months at 37.8°C.

[f]Non-significant.

[g]Significant at ($P \leq 0.01$).

[h]Significant at ($P \leq 0.05$).

TABLE 4a. Thiamin and ascorbic acid content in each replication of green beans.

Replications[a]	Thiamin[b] µg/g solids	Ascorbic acid mg/g solids
1	4.9 ± 1.1[c]	0.9 ± 0.4
2	4.3 ± 1.4	0.9 ± 0.4
3	4.6 ± 1.2	1.0 ± 0.4
4	4.6 ± 1.4	1.0 ± 0.4
5	5.5 ± 1.5	0.9 ± 0.3

[a]Each replication includes raw, blanched, processed and stored green beans.

[b]Significant ($P \leq 0.01$) difference among replications.

[c]Means ± SD of each replication done in duplicate.

TABLE 4b. Ascorbic acid content in each replication of cherries.

Replications	Ascorbic acid mg/g solids
1	0.3 ± 0.2
2	0.4 ± 0.2
3	0.4 ± 0.2

[a]Each replication includes raw, processed and stored cherries.

TABLE 5. Total thiamin and ascorbic acid content in the brine of pouched and canned green beans.

Samples	Brine	Thiamin	Total thiamin	Ascorbic acid	Total ascorbic acid
	gm/P or C[a]	µg/100 g	µg/P or C	mg/100 g	mg/P or C
Pouched					
P_o[b]	368 ± 12.2[c]	49.4 ± 3.0	181.7 ± 9.0	8.9 ± 1.7[d]	34.5 ± 6.8
P_s[e]	395 ± 11.9	47.9 ± 4.2	189.0 ± 10.6	8.8 ± 1.6[d]	34.5 ± 5.6
P_I[f]	396 ± 13.9	43.3 ± 3.5	170.8 ± 8.5	7.2 ± 1.1[d]	28.4 ± 4.1
Canned					
C_o[b]	1273 ± 67.0	30.4 ± 7.8	382.2 ± 86.2	4.5 ± 2.2	56.9 ± 27.8
C_s[e]	1283 ± 51.0	34.7 ± 3.7	444.7 ± 49.3	4.9 ± 0.7	62.9 ± 10.5
C_I[f]	1273 ± 45.3	30.9 ± 3.8	394.7 ± 26.6	4.2 ± 1.3	58.1 ± 12.6

[a] P = institutional pouch (30.5 x 38.1 x 3.8 cm) and C = No. 10 can.

[b] Analyzed immediately after processing.

[c] Means ± SD obtained from five replications, each done in duplicate.

[d] Significant difference ($P \leq 0.01$) between pouched and canned.

[e] Stored for four months at room temperature.

[f] Stored for four months at 37.8°C.

TABLE 6. Total amount of thiamin and ascorbic acid in the solid and liquid portions of green beans and cherries packed in institutional-sized pouches (30.5 x 38.1 x 3.8 cm) and No. 10 cans.

Storage	Pouches				Cans			
	Total thiamin (µg/pouch)	(%)	Total ascorbic acid (mg/pouch)	(%)	Total thiamin (µg/can)	(%)	Total ascorbic acid (mg/can)	(%)
None								
Beans	742.5 ± 77.4[a]	80.4	159.4 ± 24.7	83.0	561.6 ± 77.0	59.5	108.5 ± 20.9	65.6
Brine	181.7 ± 9.0	19.5	32.7 ± 6.8	17.0	382.2 ± 86.2	40.5	56.9 ± 27.8	30.4
4 months at RT[b]								
Beans	726.1 ± 44.2	79.3	142.3 ± 28.8	80.5	556.8 ± 47.1	55.6	81.0 ± 8.2	56.2
Brine	189.0 ± 10.6	20.7	34.5 ± 5.6	19.5	444.7 ± 49.3	44.4	62.9 ± 10.5	43.8
4 months at 37.8°C[c]								
Beans	556.2 ± 110.5	76.5	109.8 ± 19.4	79.5	464.9 ± 82.8	54.1	68.0 ± 23.0	53.9
Brine	170.8 ± 8.5	23.5	28.4 ± 4.1	20.5	394.7 ± 26.6	45.9	58.1 ± 12.6	46.1
None								
Cherries			188.7 ± 22.7[d]	84.8			91.4 ± 22.5	64.5
Syrup			33.7 ± 8.3	15.2			50.3 ± 28.2	35.5
6 months at RT[e]								
Cherries			129.9 ± 68.0	73.2			43.4 ± 13.0	59.6
Syrup			47.5 ± 19.8	26.8			29.4 ± 6.7	40.4

[a]Means ± SD of five replications, each done in duplicate.

[b]Stored for four months at room temperature.

[c]Stored for four months at 37.8°C.

[d]Means ± SD for three replications, each done in duplicate.

[e]Stored for six months at room temperature.

TABLE 7. Ascorbic acid content and retention in raw, pouched and canned[a] cherries.

Samples	Moisture content	Ascorbic acid wet basis	Retention
	(%)	(mg/100 g)	(%)
Raw	80.3 ± 2.1[b]	12.9 ± 0.8	--
P_o[c]	80.2 ± 1.8	10.4 ± 0.8[d]	80.6 ± 12.6[d]
P_s[e]	79.4 ± 1.5	8.0 ± 3.6[d]	57.2 ± 22.2[d]
C_o	78.9 ± 0.4	4.9 ± 1.2	36.2 ± 14.0
C_s	77.8 ± 1.9	2.6 ± 0.8	18.5 ± 9.9

[a]Pouch size was 30.5 x 38.1 x 3.8 cm and can size was No. 10.

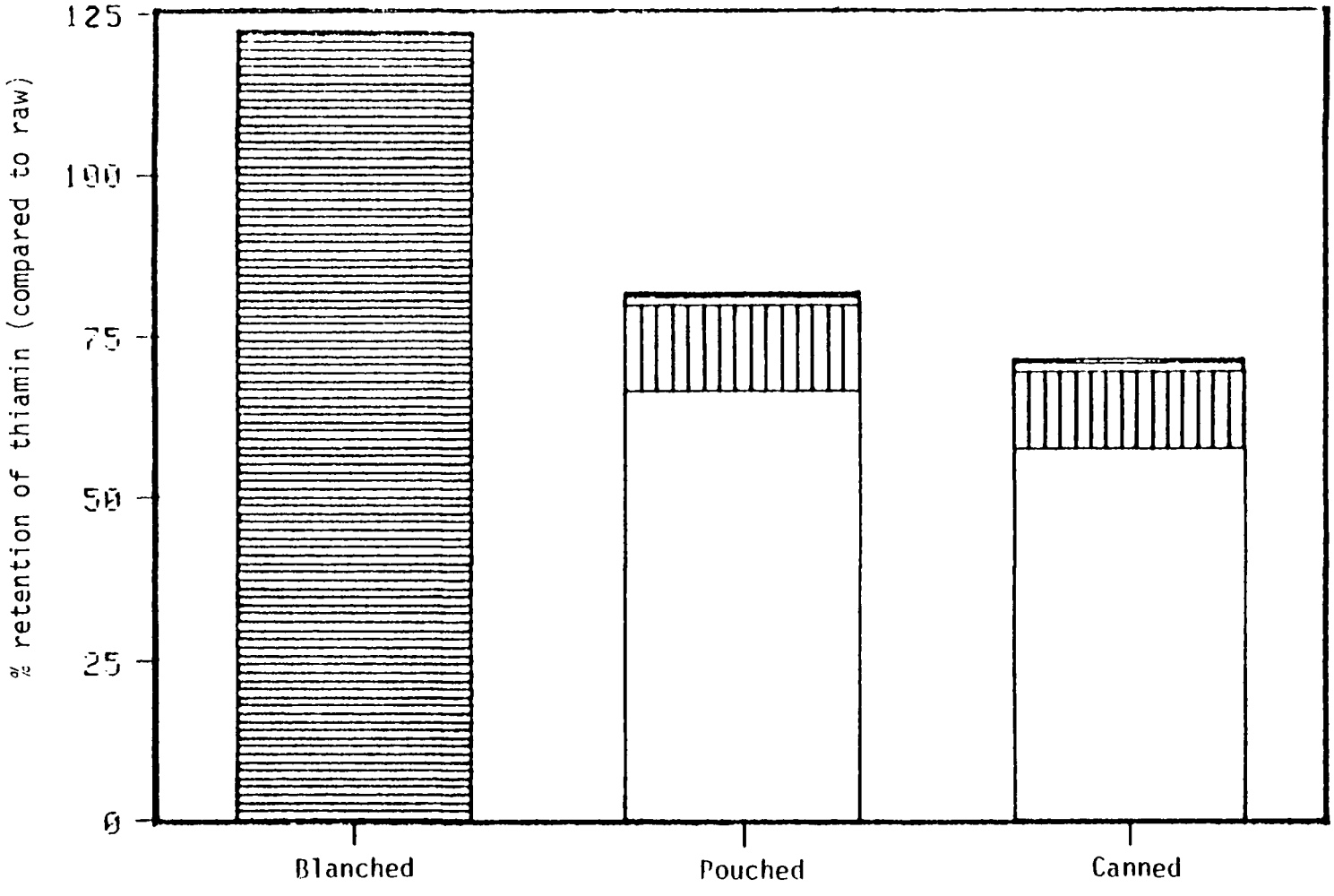
[b]Means ± SD obtained from three replications, each done in duplicate.

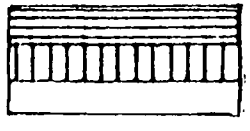
[c]Analyzed immediately after processing.

[d]Significant ($P \leq 0.01$) difference between pouched and canned.

[e]Stored for six months at room temperature.

FIGURE 10a. Percent retention of thiamin in blanched, pouched and canned drained green beans, analyzed immediately after processing and after storage for four months at room temperature (RT) and at 37.8°C, when compared to raw. The values obtained are the means from five replications, each done in duplicate. The total length of the bars for blanched, pouched and canned green beans represent the percent retention of thiamin in those vegetables analyzed immediately after processing; for the pouched and canned green beans, the horizontal lines plus open bars represent the thiamin retention after storage for four months at room temperature; the open bars represent storage of green beans for four months at 37.8°C.

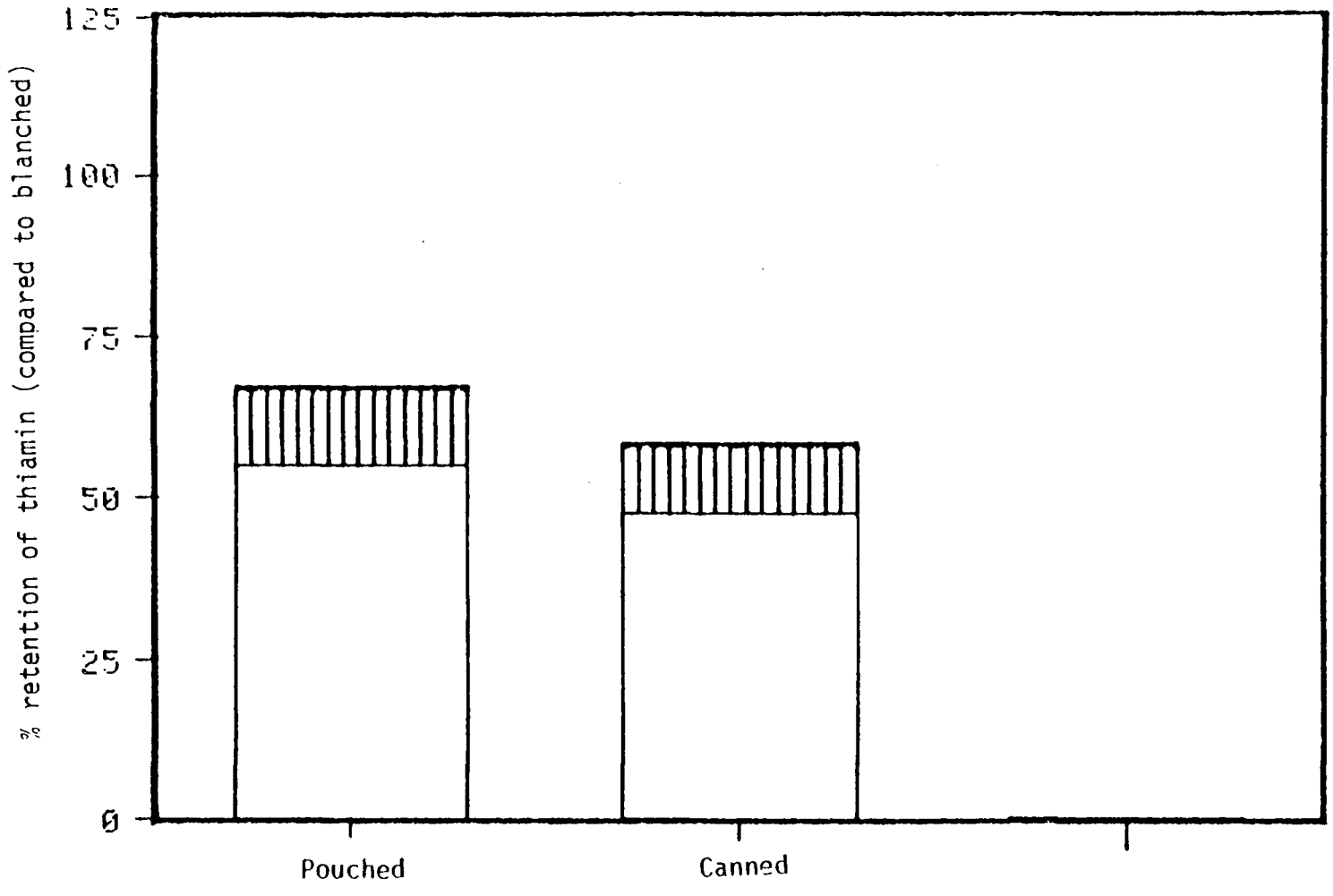


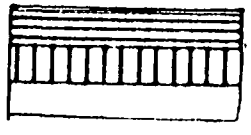


•No storage
•Stored at RT
•Stored at 37.8°C

FIGURE 10a

FIGURE 10b. Percent retention of thiamin in pouched and canned drained green beans, analyzed immediately after processing and after storage for four months at room temperature (RT) and at 37.8°C, when compared to blanched. The values obtained are the means for five replications and done in duplicate. The total length of the bars for pouched and canned green beans represent the percent retention of thiamin in those vegetables analyzed immediately after processing; the horizontal lines plus open bars represent thiamin retention after storage for four months at room temperature; the open bars represent storage of green beans for four months at 37.8°C.

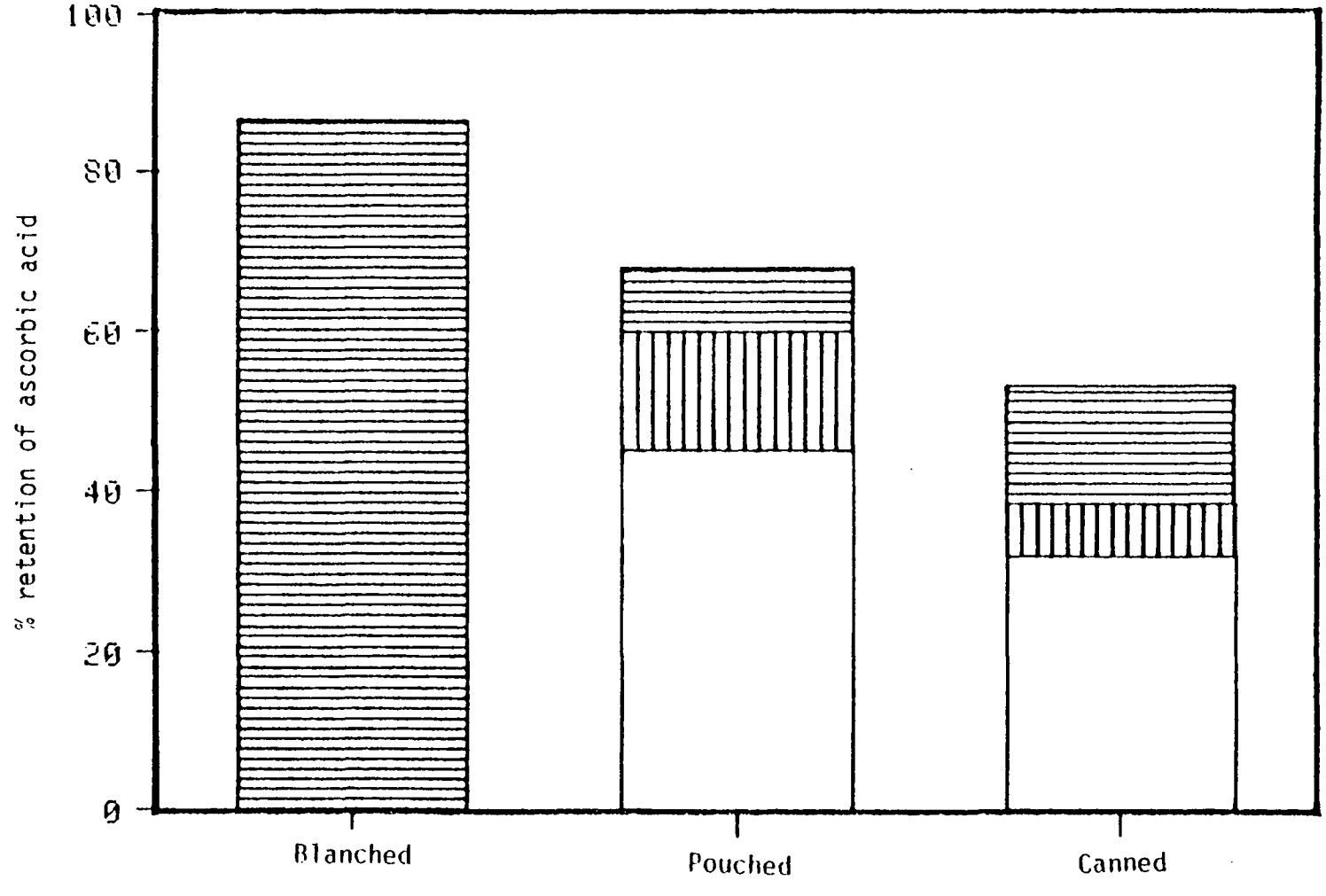


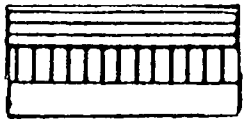


. No storage
. Stored at RT
. Stored at 37.8°C

FIGURE 10b

FIGURE 11. Percent retention of ascorbic acid in blanched, pouched and canned drained green beans analyzed immediately after processing and after storage for four months at room temperature (RT) and at 37.8°C. The values obtained are the means from five replications each done in duplicate. The total length of the bars for pouched and canned green beans represent the percent retention of thiamin in the vegetable analyzed immediately after processing; the horizontal lines plus open bars represent ascorbic and retention after storage for four months at room temperature; the open bars represent storage of green beans for four months at 37.8°C.

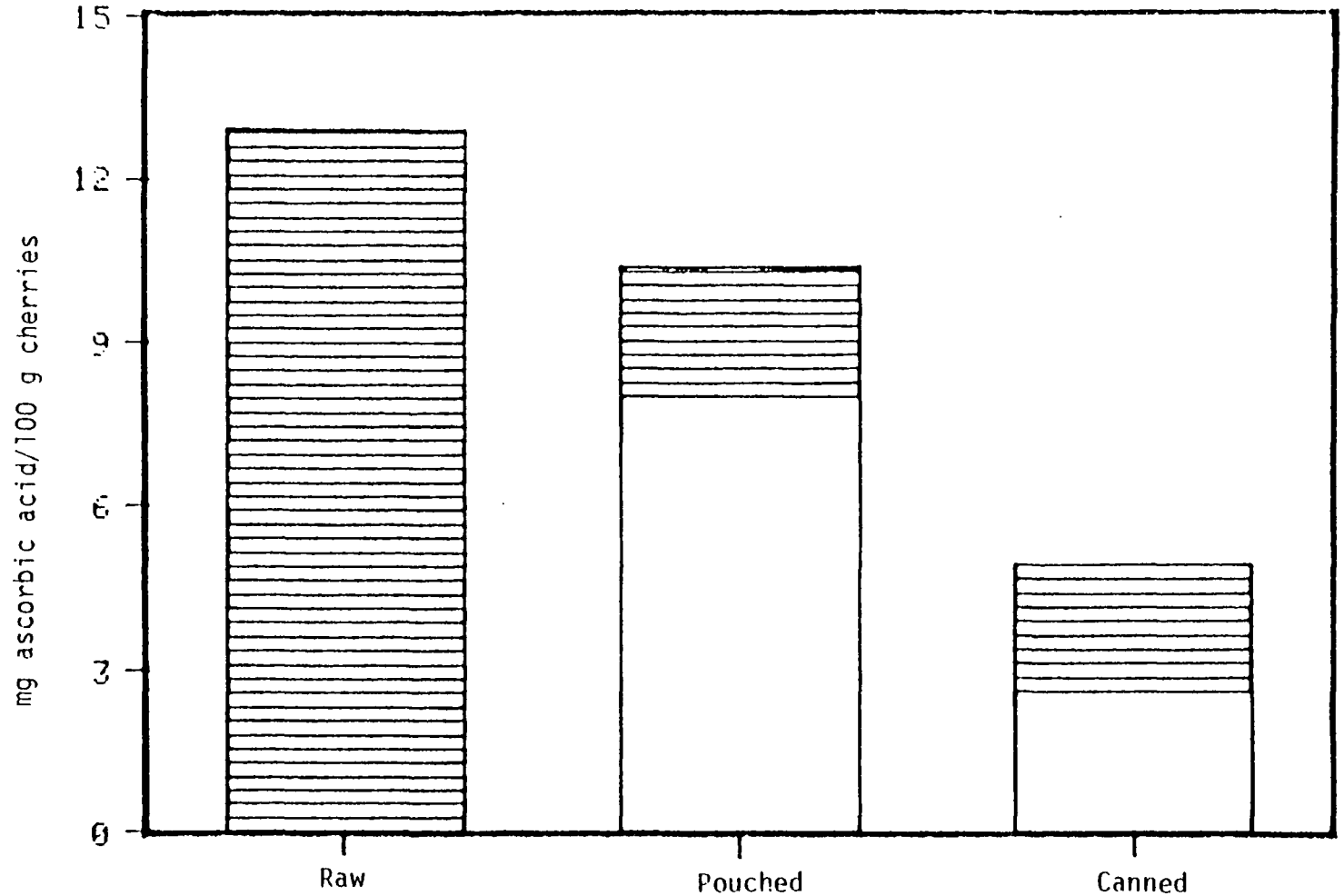




- No storage
- Storage at RT
- Storage at 37.8°C

FIGURE 11

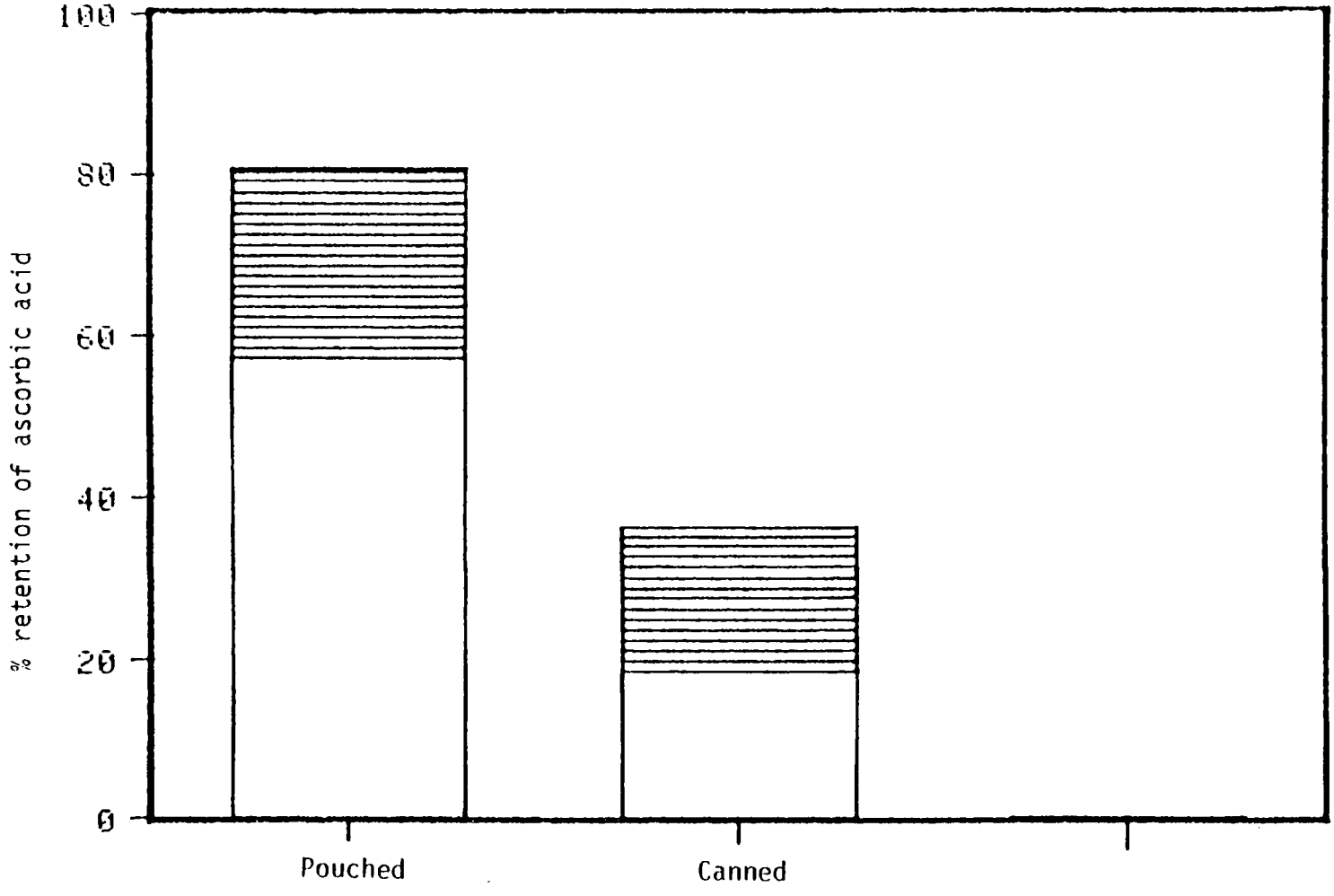
FIGURE 12. Ascorbic acid content of raw, pouched and canned drained cherries analyzed immediately after processing and after storage for six months at room temperature (RT). The values obtained are the means from three replications, each done in duplicate. The total length of the bars in the pouched and canned cherries represent the absorbic acid content in those fruit analyzed immediately after processing; the open bars represent storage of cherries for six months at room temperature.

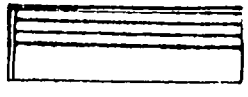


. No storage
. Storage at RT

FIGURE 12

FIGURE 13. Percent retention of ascorbic acid in pouched and canned drained cherries, analyzed immediately after processing and after storage for six months at room temperature (RT). The values obtained are the means from three replications, each done in duplicate. The total length of the bars for pouched and canned cherries represent the percent retention of ascorbic acid in those fruits analyzed immediately after processing; the open bars represent ascorbic acid retention of cherries after storage for six months at room temperature.





• No storage
• Stored at RT

FIGURE 13

TABLE 8. Total ascorbic acid content in the syrup of pouched and canned[a] cherries.

Samples	Syrup	Ascorbic acid	Total ascorbic acid
	(gm)	(mg/100 g)	(mg/P or C)[a]
P_o[b]	397 ± 61.6[c]	8.5 ± 1.4[d]	33.7 ± 8.3
P_s[e]	598 ± 54.6	8.1 ± 3.5[d]	47.5 ± 19.8
C_o[b]	1233 ± 129.9	4.0 ± 1.8	50.3 ± 28.2
C_s[e]	1327 ± 69.5	2.3 ± 0.6	29.4 ± 6.7

[a]Institutional-size pouches (30.5 x 38.1 x 3.8 cm) and No. 10 cans.

[b]Analyzed immediately after processing.

[c]Means ± SD obtained from three replications, each done in duplicate.

[d]Significant ($P \leq 0.01$) difference between pouched and canned.

[e]Stored for six months at room temperature.

TABLE 9. Color determination of green beans[a] and cherries[b] thermally processed in institutional pouches (30.5 x 38.1 x 3.8 cm) and No. 10 cans.

	Hunter values		
	a	b[c]	L[a]
Green beans			
Pouched	+0.3 ± 0.3	+13.8 ± 0.7	+31.7 ± 1.6
Canned	-0.1 ± 0.4	+14.5 ± 0.6	+32.9 ± 0.6
	a[c]	b	L
Cherries			
Pouched	+5.4 ± 0.7	+18.9 ± 1.3	+42.0 ± 2.6
Canned	+4.9 ± 0.6	+18.9 ± 1.0	+41.3 ± 1.5

[a]Stored for three months at room temperature.

[b]Stored for four months at room temperature.

[c]Significant at ($P \leq 0.05$).

[d]Means ± SD of five replications each, done in triplicate.

TABLE 10. Texture measurement of green beans[a] and cherries[b] thermally processed in institutional pouches (30.5 x 38.1 x 3.8 cm) and No. 10 cans.

	Shear press compression work
	(Kg cm/100 g)
Green beans	
Pouched	30.2 ± 2.9[c,d]
Canned	24.2 ± 3.8
Cherries	
Pouched	25.9 ± 5.7[d]
Canned	14.6 ± 2.6

[a]Stored for three months at room temperature.

[b]Stored for four months at room temperature.

[c]Means ° SD of five replications each done in triplicate.

[d]Significant at ($P \leq 0.01$).

TABLE 11. Thiamin and ascorbic acid in other foods.[a]

	Thiamin in solids	Thiamin in liquid	Ascorbic acid in solids	Ascorbic acid in liquid
	(µg/100 g)	(µg/100 g)	(mg/100 g)	(mg/100 g)
Pouched beans with tomato sauce	Beans	Tomato sauce	Beans	Tomato sauce
P_o	49.7	44.8	5.3	3.8
P_s	42.4	44.3	3.7	4.0
P_I	38.3	40.1	2.4	2.4
Frozen green beans				
uncooked	37.3	--	12.5	--
cooked[b]	50.2	--	6.8	--
Pears			Pears	Syrup
raw	--	--	5.6	--
blanched	--	--	4.0	--
pouched	--	--	3.3	2.8
canned	--	--	2.4	1.7
Plums	Plums	Syrup		
raw	20.5	--	--	--
pouched	25.8	27.3	--	--
canned	18.7	18.4	--	--

[a]One replication of each item was analyzed in duplicate.

[b]Steamed for 15 minutes in a steamer.

VI. CONCLUSION AND RECOMMENDATION

Based on the results of the present study, these following conclusions can be drawn. The retention of thiamin and ascorbic acid, as well as color and texture, was higher in green beans and cherries processed in pouches than in cans. These results are attributed to the shorter heating time required to process foods in pouches than in cans. Furthermore, the addition of less liquid to the pouched fruits and vegetables reduces the loss of these two water soluble nutrients. Losses of thiamin and ascorbic acid are higher in green beans stored at 37.8°C than at room temperature for four months.

For future research other heat labile vitamins, such as folic acid and carotene, should be analyzed in fruits and vegetables. Other types of products packed in the pouches, e.g., entrees, should be analyzed as well. A subjective method for measuring the quality, color and texture of products packed in pouches as compared to those in cans would be helpful in knowing the preference of the consumer.

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VII. APPENDIX

TABLE A1. Analysis of variance of the thiamin content in raw, blanched, and drained pouched and canned green beans analyzed immediately after processing and stored for four months at room temperature and 37.8°C.

Source of variation	d.f.	Mean square[a]	F-value
Samples	40	--	
Treatments			
Process	1	3236.942	49.406[b]
Storage	2	294.640	4.497[b]
Process and storage	2	4.232	0.065
Raw vs. blanched	1	261.365	3.989
Others	1	14042.340	214.330[c]
Error	28	65.517	11.332[b]

[a]Values obtained from five replications done in duplicate.

[b]Significant at ($P \leq 0.01$).

[c]Significant at ($P \leq 0.05$).

TABLE A2. Comparisons among type of storage (immediate analysis and storage for four months at room temperature and 37.8°C) using Newman-Keuls method for thiamin in drained green beans.

Storage type	Mean[a]	(a)	$\sqrt{\frac{MSE}{n}}$ x Q(a,d.f.)[b]	Q(a,d.f.)
P_o and C_o[c]	41.34[d]	-	--	--
P_s and C_s[e]	40.86[d,f]	(2)	5.25	2.90
P_I and C_r[g]	37.47[h]	(3)	6.32	3.49

[a]Values obtained from five replications done in duplicate.

[b]MSE = 65.517, n = 20, d.f. = 28.

[c]Analyzed immediately after processing.

[d,f,h]Means with different letter differ significantly.

[e]Stored for four months at room temperature.

[g]Stored for four months at 37.8°C.

TABLE A3. Analysis of variance for moisture of raw, blanched, pouched and canned drained green beans analyzed immediately after processing and stored for four months at room temperature and 37.8°C.

Source of variation	d.f.	Mean square[a]	F-value
Samples	80	--	--
Treatments			
Process	1	109.120	75.842[b]
Storage	2	0.521	0.362
Process and storage	2	0.209	0.145
Raw vs. blanched	1	5.547	3.855
Others	1	43.542	30.263[b]
Error	28	1.439	6.127[c]

[a]Values obtained from five replications done in duplicate.

[b]Significant at ($P \leq 0.01$).

[c]Significant at ($P \leq 0.05$).

TABLE A4. Analysis of variance for the percent retention of thiamin in raw, blanched, pouched and canned drained green beans analyzed immediately after processing and stored for four months at room temperature and 37.8°C, when compared to raw.

Source of variation	d.f.	Mean square[a]	F-value
Block	4	1265.241	12.581[b]
Treatments			
Process	1	745.208	7.410[c]
Storage	2	629.253	6.257[c]
Process and storage	2	2.864	0.028
Blanched vs. other 6	1	11258.454	111.949[b]
Error	24	100.568	

[a]Values obtained from five replications done in duplicate.

[b]Significant at ($P \leq 0.01$).

[c]Significant at ($P \leq 0.05$).

TABLE A5. Analysis of variance for the percent retention of thiamin in raw, blanched, pouched and canned drained green beans analyzed immediately after processing and stored for four months at room temperature and 37.8°C, when compared to blanched.

Source of variation	d.f.	Mean square[a]	F-value
Block	4	185.106	3.433[b]
Treatments			
Process	1	534.505	9.913[c]
Storage	2	434.106	8.051[c]
Process and storage	2	1.656	0.031
Error	20	53.920	

[a]Values obtained from five replications done in duplicate.

[b]Significant at ($P \leq 0.05$).

[c]Significant at ($P \leq 0.01$).

TABLE A6. Analysis of variance of the ascorbic acid content in raw, blanched, pouched and canned drained green beans analyzed immediately after processing and stored for four months at room temperature and 37.8°C.

Source of variation	d.f.	Mean square[a]	F-value
Samples	40	--	--
Treatments			
Process	1	245.633	54.92[b]
Storage	2	39.541	8.84[b]
Process and storage	2	2.385	0.53
Raw vs. blanched	1	77.225	17.27[b]
Others	1	1057.980	236.56[b]
Error	28	4.472	19.78[c]

[a]Values obtained from five replications done in duplicate.

[b]Significant at ($P \leq 0.01$).

[c]Significant at ($P \leq 0.05$).

TABLE A7. Comparison among type of storage (immediate analysis and storage for four months at room temperature and 37.8°C, using Newman-Keuls method for thiamin in drained green beans.

Storage type	Mean[a]	(a)	$\sqrt{\frac{MSE}{n}} \times Q\ (a,d.f.)^b$	Q(a,d.f.)
P_o and C_o[c]	8.52[d]	-	--	--
P_s and C_s[d]	7.21[d,f]	(2)	1.37	2.90
P_I and C_I[e]	5.71[h]	(3)	1.65	3.49

[a]Values obtained from five replications done in duplicate.

[b]MSE = 4.472, n = 20, d.f. = 28.

[c]Analyzed immediately after processing.

[d,f,h]Means with different better differ significantly.

[e] Stored for four months at room temperature.

[g] Stored for four months at 37.8°C.

TABLE A8. Analysis of variance for the percent retention of ascorbic acid in raw, blanched, canned and pouched drained green beans analyzed immediately after processing and stored for four months at room temperature and 37.8°C, when compared to raw.

Source of variation	d.f.	Mean square[a]	F-value
Block	4	1079.905	19.831[b]
Treatments			
Process	1	2044.846	37.550[b]
Storage	2	1218.009	22.367[b]
Process and storage	2	46.875	0.861
Blanched vs. others	1	5861.436	107.635[b]
Error	24	54.457	

[a]Values obtained from five replications done in duplicate.

[b]Significant at ($P \leqslant 0.01$).

TABLE A9. Analysis of variance for the percent retention of ascorbic acid in raw, blanched, pouched and canned drained green beans analyzed immediately after processing and stored for four months at room temperature and 37.8°C, when compared to blanched.

Source of variation	d.f.	Mean square[a]	F-value
Block	4	42.951	0.868
Treatments			
Process	1	2809.717	56.756[b]
Storage	2	1533.682	30.980[b]
Process and storage	2	62.384	1.260
Error	20	49.505	

[a]Values obtained from five replications done in duplicate.

[b]Significant at ($P \leq 0.01$).

TABLE A10. Analysis of variance for the thiamin in brine of pouched and canned drained green beans analyzed immediately and stored for four months at room temperature and 37.8°C.

Source of variation	d.f.	Mean square[a]	F-value
Samples	30	--	--
Treatments			
Process	1	3319.728	115.501[b]
Storage	2	92.036	3.202
Process and storage	2	64.792	2.254
Error	20	28.742	5.667[c]

[a]Values obtained from five replications done in duplicate.

[b]Significant at ($P \leq 0.01$).

[c]Significant at ($P \leq 0.05$).

TABLE A11. Analysis of variance for the ascorbic acid in brine of pouched and canned drained green beans analyzed immediately and stored for four months at room temperature and 37.8°C.

Source of variation	d.f.	Mean square[a]	F-value
Samples	30	--	--
Treatments			
Process	1	212.064	64.878[b]
Storage	2	7.848	2.401
Process and storage	2	2.150	0.658
Error	20	3.269	20.429[c]

[a]Values obtained from five replications done in duplicate.

[b]Significant at ($P \leq 0.01$).

[c]Significant at ($P \leq 0.05$).

TABLE A12. Analysis of variance for ascorbic acid content in raw, pouched and canned drained cherries analyzed immediately after processing and stored for six months at room temperature.

Source of variation	d.f.	Mean square[a]	F-value
Samples	18	--	--
Block	2	19.939	1.798
Treatments			
Process	1	177.670	16.021[b]
Storage	1	33.844	3.059
Process and storage	1	0.020	0.002
Other	2	83.959	7.571[c]
Error	10	11.089	78.587[b]

[a]Values obtained from three replications done in duplicate.

[b]Significant at ($P \leq 0.01$).

[c]Significant at ($P \leq 0.05$).

TABLE A13. Analysis of variance for moisture content of raw, pouched, and canned drained cherries analyzed immediately after processing and stored for six months at room temperature.

Source of variation	d.f.	Mean square[a]	F-value
Samples	36	--	--
Block	2	4.231	0.477
Treatments			
Process	1	17.921	2.018
Storage	1	8.410	0.947
Process and storage	1	0.360	0.040
Other	2	18426.253	2075.327[b]
Error	10	8.879	11.777[b]

[a]Values obtained from three replications.

[b]Significant at ($P \leq 0.01$).

TABLE A14. Analysis of variance table for percent retention of ascorbic acid in raw, pouched and canned drained cherries analyzed immediately after processing and stored for six months at room temperature.

Source of variation	d.f.	Mean square[a]	F-value
Block	2	106.746	.314
Treatments			
Process	1	5167.738	15.207[b]
Storage	1	1268.564	3.733
Process and storage	1	25.136	0.074
Other	1	24.963	0.074
Error	8	339.833	

[a]Values obtained from three replications done in duplicate.

[b]Significant at ($P \leq 0.01$).

TABLE A15. Analysis of variance for the ascorbic acid content in the syrup of pouched and canned cherries analyzed immediately and stored for six months at room temperature.

Source of variation	d.f.	Mean square[a]	F-value
Samples	15	--	--
Block	2	26.460	2.433
Treatments			
Process	1	160.684	14.774[b]
Storage	1	6.720	0.618
Process and storage	1	2.734	0.251
Other	1	3.997	0.367
Error	8	10.876	108.041[b]

[a]Values obtained from three replications done in duplicate.

[b]Significant at ($P \leq 0.01$).

TABLE A16. Analysis of variance for block difference for thiamin per grams solid in green beans.

Source of variation	d.f.	Mean square[a]	F-value
Error	28	.378	
Block	4	1.693	4.483[b]
Treatments	7	7.535	19.951[b]

[a]Values obtained from five replications each done in duplicate.

[b]Significant at ($P \leq 0.01$).

TABLE A17. Analysis of variance for block difference for ascorbic acid per grams solids in green beans.

Source of variation	d.f.	Mean square[a]	F-value
Error	28	0.018	--
Block	4	0.028	1.607
Treatments	7	0.678	38.590[b]

[a]Values obtained from three replications each done in duplicate.

[b]Significant at ($P \leq 0.01$).

TABLE A18. Analysis of variance for block difference for ascorbic acid per gram from solids in cherries.

Source of variation	d.f.	Mean square[a]	F-value
Error	10	0.01100	--
Block	2	0.02910	2.73
Treatments	5	0.39907	37.47[b]

[a]Values obtained from three replications each done in duplicate.

[b]Significant at ($P \leq 0.01$).

TABLE A19. Analysis of variance for "a" Hunter values in pouched and canned green beans.

Source of variation	d.f.	Mean square[a]	F-value
Block	4	.258	.687
Pouch vs. canned	1	1.281	3.405
Sample error	20	0.042	
Block by treatment	4	0.376	8.890[b]

[a]Values from five replications each done in triplicate.

[b]Significant at ($P \leq 0.01$).

TABLE A20. Analysis of variance for "b" Hunter values in pouched and canned green beans.

Source of variation	d.f.	Mean square[a]	F-value
Error	4	0.431	
Treatment	1	4.181	8.830[b]
Error and sample	24	0.474	

[a]Values from five replications each done in triplicate.
[b]Significant at ($P \leq 0.01$).

TABLE A21. Analysis of variance for "L" Hunter values in pouched and canned green beans.

Source of variation	d.f.	Mean square[a]	F-value
Block	4	1.740	
Treatment	1	10.680	7.412[b]
Error and sample	24	1.441	

[a]Values from five replications each done in duplicate.

[b]Significant at ($P \leq 0.05$).

TABLE A22. Analysis of variance for "a" Hunter values in pouched and canned cherries.

Source of variation	d.f.	Mean square[a]	F-value
Block	2	2.521	
Treatment	1	1.620	12.623[b]
Error and sample	14	0.128	

[a]Values obtained from three replications each done in triplicate.
[b]Significant at ($P \leq 0.01$).

TABLE A23. Analysis of variance for "b" Hunter values in pouched and canned cherries.

Source of variation	d.f.	Mean square[a]	F-value
Block	2	0.901	
Treatment	1	0.009	0.006
Error and sample	14	1.386	

[a]Values obtained from three replications each done in triplicate.

TABLE A24. Analysis of variance for "L" Hunter values in pouched and canned cherries.

Source of variation	d.f.	Mean square[a]	F-value
Block	2	13.752	
Treatment	1	2.569	0.711
Error and sample	14	3.615	

[a]Values obtained from three replications each done in triplicate.

TABLE A25. Analysis of variance for compression area of pouched and canned green beans.

Source of variation	d.f.	Mean square[a]	F-value
Block	4	13.595	
Treatment	1	270.000	22.362[b]
Error and sample	24	12.074	

[a]Values obtained from five replications each done in triplicate.
[b]Significant at ($P \leq 0.01$).

TABLE A26. Analysis of variance for compression area of pouched and canned cherries.

Source of variation	d.f.	Mean square[a]	F-value
Block	2	28.262	
Treatment	1	565.631	30.634[b]
Error and sample	14	18.463	

[a]Values obtained from three replications each done in triplicate.
[b]Significant at ($P \leq 0.01$).