THE EFFECTS OF CERTAIN PACKAGING METHODS ON THE QUALITY OF FROZEN ASPARAGUS

by

CELINE MARCELLA SIMON

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Approved by:

Gwendolyn L. Tinklin
Major Professor

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INTRODUCTION

Fresh asparagus is available in abundant quantities for a limited season each year. At other times frozen or canned asparagus may be used. Generally, it is recognized that freezing offers one of the best means for capturing the fresh flavor, color, and appearance of foods. Tinklin et al., 1961, showed commercially frozen asparagus to be significantly ($P = 0.001$) more palatable than the canned product. A homemaker may purchase a commercially frozen product when needed or freeze asparagus at the peak of the season. For home freezing, many types of packaging materials are available, including aluminum foil and plastic films. Some heat sealable films are suitable for boil-in-bag pouches.

In a survey of 600 families in Long Island, New York (Anon., 1966a), homemakers gave quality, convenience, and nutritional value as reasons for the selection of commercially available boil-in-bag vegetables. Despite higher cost, they were chosen in preference to vegetables packed in other ways. Work reporting the home freezing of vegetables without sauce in a heat-sealed bag for use as boil-in-bag pouch was not found in the literature. The present study was designed to investigate and compare, after given intervals of extended storage, the quality of asparagus frozen in a heat-sealed polypropylene-polyethylene laminated film with the quality of that frozen in aluminum foil packages. To study the influence of the packaging material as well as its method of use on the quality of the vegetable cooked after frozen storage, the laminated film was used in two ways: for frozen storage only, the asparagus being removed for cooking; and for frozen storage followed by boiling in the bag for cooking. The aluminum foil packages were used for frozen storage only. Quality factors studied included palatability, color, tenderness, ascorbic acid retention, and cell damage.

REVIEW OF THE LITERATURE

Functions of Packaging Material for Frozen Vegetables

Freezing is recommended as a processing method primarily because of the superior quality of the product that may be produced for out of season use. To produce top quality frozen vegetables, variety, maturity, handling after harvest, and processing and freezing procedures must be controlled (Guadagni, 1960). Unless protected by wrapping or packaging, frozen vegetables will deteriorate rapidly, becoming unsightly and unpalatable. Charlton and DeLong (1956) stated that the package material functions physically to contain the food and to maintain the quality of the food product. The functional properties of the packaging material are important for protection of foods against oxidation, loss of moisture, microbial contamination, and flavor changes (Toof, 1966). For satisfactory performance the material must be impermeable to odor, oxygen, moisture, and microorganisms. In addition, it must be strong, flexible, and economically practical (Cruess, 1958; Luh and de la Hoz, 1964; Tressler and Evers, 1957). The material itself must not have an odor to impart to the contents nor should chemical action take place between the contents and the packaging material (Barail, 1954; Klein, 1966). The package material should be of such a shape as to use a minimum of space in the freezer (Cruess, 1958; Carlton, 1941; Desrosier, 1963).

The basic problem with frozen food is to keep moisture in the food and package. Contact with air should be prevented or kept at a minimum (Pennington, 1941). This involves the use of material with an adequate moisture vapor barrier and proper application methods (McCoy et al., 1946). Matz (1965) explained that sublimation of ice crystals in the surface layers of foods with loss of water to the atmosphere is the cause of freezer burn. The resistance of any package to moisture vapor transfer is affected by the permeability of the material making up the package, the efficiency of the heat seal or other closure, and the mechanical strength of the wrap, that is, the extent of loss of barrier properties at bends, creases, and folds. The inherent permeability of the film is usually the controlling factor (Matz, 1965). Two mechanisms by which permeation takes place are explained by Charlton and DeLong (1956): the solution of gases or water vapor in the film or its plasticizers, with subsequent migration through the sheet and reevaporation from the opposite side, and the escape of the vapor or moisture through pores or interstices in the film itself.

Aluminum foil for packaging is economical and readily available. Foil of an appropriate density, 0.0015 in. thick, is essentially pinhole free and therefore is impermeable to gas and water vapor (Charlton and DeLong, 1956; Matz, 1965). It has a high degree of moisture and gas resistance, is opaque and impervious to light, is nontoxic, does not rust, and is light in weight (Crane, 1965; Toof, 1966). Work at Kansas State University has shown aluminum foil to be a suitable packaging material for frozen vegetable products (Tinklin, 1963).

A laminated film consisting of a Saran-coated heat-set oriented polypropylene material has excellent moisture and oxygen barrier properties; it is combined with polyethylene to yield strong heat seals (Shaw, 1966). This film can endure subzero to boiling temperature; therefore, it can be used as a boil-in-bag pouch as well as a packaging material for storage. The Saran serves as an excellent gas barrier (Dulmage, 1965). Oriented polypropylene has extremely high strength and is heat set to enhance its mechanical properties. Also, it has the basic characteristics of low water-vapor transmission and medium gas permeability (Anon., 1966b; Winters, 1965). Polyethylene is a strong plastic film in a range of temperature extremes, from -60°F to 230°F. It is resistant to fresh and salt water, acids and alkalies, does not become brittle under normal conditions of use, is nontoxic, tasteless, and odorless (Barail, 1954; Flood and Phelps, 1965).

Historical Development of Frozen Food Packaging

As a commercial process for the retail market, freezing of foods began in 1930 when the General Foods Corporation developed and marketed the Birds Eye line of frozen foods (Carlton, 1941;

Desrosier, 1963; Duncan, 1942; Hampe and Wittenberg, 1964). The frozen food industry had to wait upon the improvement of mechanical refrigeration, and it was not until the 1940's that frozen foods became important competitors to other consumer-type preserved foods (Desrosier, 1963; Duncan, 1942). Clarence Birdseye (1953) had recognized in 1930 that quick freezing called for transparent, moisture-vapor proof, wet-strength, tasteless, and odorless wrapping materials, but none had been developed. He tried using waxed paper, vegetable parchment, paraffined parchment, and an uncoated cellophane imported from France. Finally, a workable moisture-vapor proof cellophane was developed by Dupont.

When packaging materials were scarce during World War II, the use of paraffin coatings was important (Woodroof and DuPree, 1943). In 1948 Gortner et al. wrote that packaging materials for frozen products included glass jars especially designed for freezing, tin cans, cellophane, and laminated wrapping papers. Cellophane needed an outer wrap or paperboard carton. The laminated wrapping papers included various combinations of paper, metal foil, glassine, cellophane, and rubber latex sheets bonded together. Shelor and Woodroof (1954) stated that for most commercially packed fruits and vegetables, a semirigid Peter's type carton with a moisture-vapor proof overwrap was the leading type of container. In 1964 a review by Anderson included rigid plastic containers and flexible pouches as modern frozen food packaging materials.

A new product is frequently one offered in some form in which a major change has been made to give the consumer added value and/or convenience. It does not necessarily involve a complete change in product identity (Mottern and Johnson, 1964). Vegetables frozen for use as boil-in-bag products are such a new product. As early as 1946 Carley (1965) recognized that a boilable pouch for frozen products was needed both for the convenience of reheating and for flavor preservation. However, the only plastic films available at that time would shatter like glass when frozen or give off flavors when heated. Not until 1955 did the packaging industry develop a commercially acceptable film that would withstand the temperature range of subzero to 212°F. Two years more elapsed before the first line of boil-in-bag frozen prepared vegetables in sauces was introduced (Carley, 1965). In early 1964 other manufacturers began to market boil-in-bag vegetables in sauces (Anon., 1965b). Polyester, nylon, and oriented polypropylene-polyethylene are among materials currently used both commercially and in developmental quantities for boil-in-bag pouches (Mathias and Russo, 1966; Sacharow, 1966). Available for use by the homemaker is a food packaging set complete with heat sealer for freezing and packaging foods in a boilable polyester film (Anon., 1965a).

PROCEDURE

Asparagus Used

California 500 asparagus, grown and harvested by the Kansas State University Department of Horticulture, was used in the study.

Sufficient asparagus of similar size and maturity for one replication was harvested and held overnight at 35°F until processed. All of the asparagus was obtained between May 3 and May 21, 1966.

Packaging Materials Used

Asparagus was packaged for freezing in two types of material: aluminum foil of 0.0015 in. thickness and in laminated film of Saran coated polypropylene-polyethylene. Enough asparagus was packaged in the laminated film for the film to be used in two ways (Table 1): as a packaging material for frozen storage only and as a packaging material during frozen storage and for use afterwards as a boil-in-bag pouch. The aluminum foil packaging was used only for frozen storage.

Sampling, Packaging, and Freezing

Sufficient asparagus was processed for all replications of each measurement to be made in the 4 evaluation periods (Table 1; Form 1, Appendix). The asparagus was cut to 5-in. lengths, washed, and dried; the spears were randomly distributed for packaging in lots of 100 g. After blanching in boiling water followed by immediate cold dipping and drying, the product to be frozen was packaged in single layers in randomly assigned aluminum foil or laminated film bags. Optimum blanching time, which ranged from 2 to 2½ min, was fixed by testing for the adequacy of blanch by determining peroxidase activity (Tressler and Evers, 1957). The aluminum foil packages were closed using the confectioner's

Table 1. Asparagus required for various stages of the study.

Evaluation period	Packaging material	Number of 100 g samples/replication
Fresh		12
1 month	Foil	6
	Laminated film	11
3 months	Foil	6
	Laminated film	11
5 months	Foil	6
	Laminated film	11

wrap; the laminated film bags were heat sealed at 250°F for 10 sec (Fig. 1). All packages were placed in direct contact with the freezer shelf. After freezing 24 hr the packages were assembled and stored at approximately -15°F until evaluated.

Evaluation

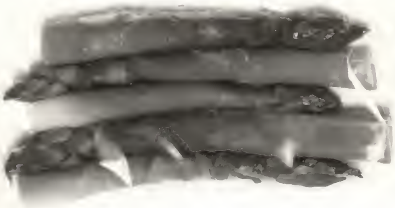
The asparagus was evaluated as indicated in Form 1, Appendix, when fresh, and after 1 month, 10 weeks, and 5 months of frozen storage. Preliminary work indicated that 90 min defrosting in an incubator at 21°C was satisfactory for spears used to measure the shear value. Optimum cooking time for 100 g samples of asparagus in 140 ml water was 8 min for fresh spears; 6 min for blanched, fresh spears; and 7 min for blanched, frozen spears. Frozen spears were placed in boiling water, and a timer was started when the water returned to the boil.

Fig. 1. Packaging methods.

1 = Laminated film bag, heat-sealed.

2 = Aluminum foil package with confectioner's closure.

2



1

Frozen samples for histological work were fixed in Craf's solution.

Palatability. A panel of 7 experienced judges scored under the Macbeth skylight the general appearance of cooked asparagus spears from each packaging treatment. Each judge scored a spear from each treatment for aroma, flavor, texture, and acceptability (Form 2, Appendix).

Color. A homogenate of cooked asparagus was prepared for evaluation of color and total solids. A 100 g sample of asparagus was blended with 50 ml distilled water at speed 100 for 3 min in a Waring Blendor connected to a Powerstat variable transformer. Color difference was measured with a Gardner Color Difference Meter. Rd (reflectance), a- (greenness), and b+ (yellowness) values were determined on duplicate samples of asparagus homogenate. Four readings were taken for each sample; between readings the sample was turned through a 90° angle. The average of the 4 measurements was considered the color value for the sample. The instrument was standardized using a tile known to have values of Rd 45.8, a- 17.8, and b+ 8.2. Color was expressed as a/b, the degree of greenness.

Shear Value. The shear value was measured 4 in. from the tip of each spear, on spears from a 100-g lot using the 25 lb dynamometer of the Warner-Bratzler shearing apparatus.

Total Solids. Total solids were calculated from the percentage total moisture as determined with the C. W. Brabender Semi-Automatic Moisture Tester. Duplicate 10 g samples of asparagus homogenate were subjected to a temperature of 121°C for 40 min.

Percentage of solids and moisture in any one sample was assumed to be 100 (Woolsey, 1965). Since the asparagus homogenate had added water the calculation for total solids was:

$$\frac{(10)\ (0.01)\ (100\% - \%\ \text{total moisture})}{6.67} \times 100 = \%\ \text{total solids.}$$

The numerator (weight of sample in pan) (conversion factor for percentage to decimal) (% solids in pan) was weight in g of the solids in the pan after drying and the denominator

$$\left(\frac{100\ \text{g asparagus}}{100\ \text{g asparagus} + 50\ \text{g water}}\right)10$$ was the weight in g of the asparagus in the pan before drying.

Histological work. Histological work was conducted on fresh, fresh-blanched and blanched frozen asparagus to study the changes that took place in cell wall surfaces and intercellular spaces. Sections were prepared for viewing by cutting a cross section about 3/8 in. thick 4 in. from the tip of each spear. Sections were cut from 2 spears of each treatment at each evaluation period. These sections were fixed in Craf's solution until dehydration in a tertiary butyl alcohol series. Following dehydration and infiltration in paraffin, the sections were embedded in paraffin blocks. The blocks were cut with a rotary microtome to a thickness of 12 microns and the tissue was mounted on a microscope slide using Haupts' adhesive. Subsequent staining in a safranin, fast-green, orange G series preceded fixation of a cover glass.

Ascorbic Acid. On cooked asparagus the total ascorbic acid and the dehyroascorbic plus diketogulonic acid fraction were measured according to a modification of the method of Schaffert and Kingsley (1955); the value for the reduced ascorbic acid fraction was obtained by subtraction. A 100 g sample of asparagus was blended with approximately 100 ml 5% metaphosphoric acid at speed 100, for 5 min in a Waring Blendor. The solution was made up to volume in a 500 ml flask with 5% metaphosphoric acid. Analysis for total ascorbic acid was done following dilution of the filtered extract (20 ml to 50 ml) with 5% metaphosphoric acid and shaking for 1 min with approximately ½ teaspoon Norit.

Experimental Design and Analyses of Data

A completely randomized design with 5 replications of each treatment was followed for processing and evaluating the asparagus. Data for each measurement used to evaluate the asparagus was subjected to analyses of variance as follows:

The following plan for analysis was used to compare the fresh asparagus with the fresh-blanched:

Source of Variation		D/F
Treatment		1
Error		8
	Total	9

For determining the effects of storage time and the effects of certain packaging methods a 3 x 3 factorial arrangement of treatments with 2 way classification with interaction was used:

Source of Variation		D/F
Storage time (T)		2
Packaging methods (P)		2
T x P		4
Error		36
	Total	44

The data also were analyzed to compare the following: (1) fresh-blanched asparagus and that packaged by each of the 3 methods after 1 month's storage (2) fresh-blanched asparagus and that packaged by each of the 3 methods after 10 weeks' storage (3) fresh-blanched asparagus and that packaged by each of the 3 methods after 5 months' storage (4) fresh-blanched asparagus and that packaged in foil at each of the 3 storage times (5) fresh-blanched asparagus and that packaged in laminated film for use in frozen storage only at each of the 3 storage times and (6) fresh-blanched asparagus and that packaged in laminated film for use as a boil-in-bag pouch at each of the 3 storage times. The following analysis was used:

Source of Variation		D/F
Treatment		3
Error		16
	Total	19

RESULTS AND DISCUSSION

Average palatability scores and values for objective tests for each replication appear in Appendix, Tables 6-17. The analyses of variance also appear in Appendix, Tables 18-24. Throughout the discussion, packaging methods refers to the use of aluminum foil for frozen storage (F), the use of laminated film for frozen storage only (S), and the use of laminated film for frozen storage and for a boil-in-bag pouch (B). Fig. 2 and 3 are photographs of the asparagus at various stages in the study.

Fresh Asparagus

Since all the asparagus evaluated after frozen storage had been subjected to the blanching process, the changes that took place in the blanching of fresh asparagus were studied. No significant differences between the fresh asparagus and the fresh-blanched were noted except for shear value (Table 2).

Table 2. Average values for palatability and objective measurements for fresh and fresh-blanched asparagus.

Factor	Treatment		
	Fresh		Fresh-blanched
Palatability scores[a]			
Appearance: color	5.6		5.6
Appearance: shape	6.2		6.0
Aroma	6.2		6.2
Flavor	5.6		6.0
Texture	5.5		5.6
Objective values			
Shear (lb)	9.1	***	3.2
Color: reflectance (Rd)	19.5		20.3
Color: degree of greenness (a/b)	.659		.626
Total solids (%)	6.9		7.1

[a]Range: 7 (very desirable) to 1 (inedible).
***, P = 0.001.

Fig. 2. Fresh asparagus.

1 = Raw

2 = Blanched

3 = Cooked

Fig. 3. Frozen and defrosted asparagus.

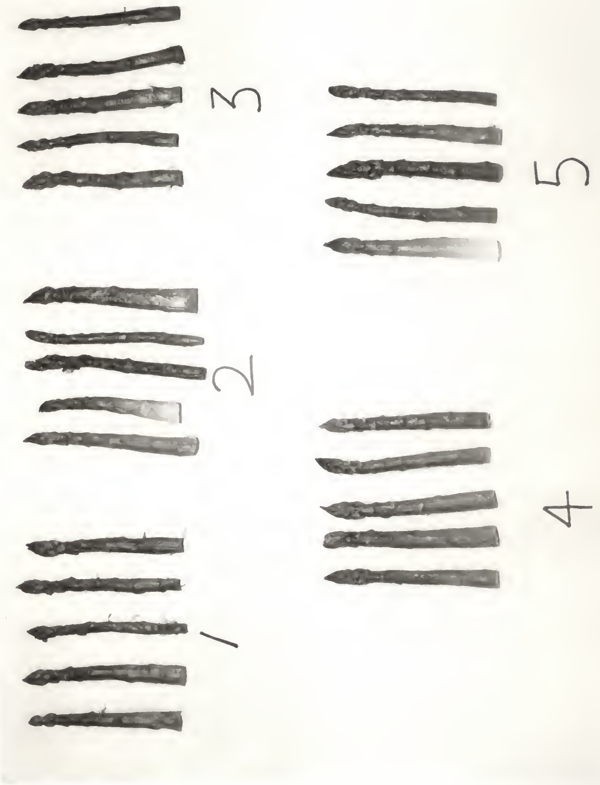
1 = Cooked spears from laminated film package used for frozen storage only

2 = Cooked spears from laminated film package used for frozen storage and boil-in-bag pouch.

3 = Cooked spears from aluminum foil package used for frozen storage only.

4 = Uncooked, defrosted spears from laminated film package.

5 = Uncooked, defrosted spears from aluminum foil package.


3
5
2
4
1

Although all the samples initially presented to the palatability panel were considered acceptable (Table 3), the overall quality of the asparagus ranged from "moderately desirable" to "desirable" (Table 2, Form 2, Appendix). A significant (P = 0.001) difference in shear value between the fresh and fresh-blanched asparagus indicated that softening of the tissue took place in the blanching process.

Frozen and Stored Asparagus

Appearance: color and shape. In general, average scores for appearance of frozen asparagus were similar to those for the fresh-blanched product (Table 3). Freezing for extended periods and freezing in 2 different packaging materials, one of which was used in 2 ways, did not alter significantly the scores for color or shape (Table 4).

Objective color measurement. An objective measurement of color was made with the Gardner Color-Difference Meter. Average reflectance (Rd) values (Table 3) were lower after frozen storage than immediately after blanching. The lower values indicate that the frozen sample absorbed more light. A significant (P = 0.05) reduction in Rd (Table 5) was shown between storage of 1 month and 10 weeks, but no significant reduction occurred with further storage nor between 1 and 5 months' storage. At storage for 10 weeks the asparagus packaged by all 3 methods had significantly (P = 0.05) lower Rd values (Table 4) than the fresh-blanched, whereas after 5 months only that frozen in F

Table 3. Average palatability scores and objective values for fresh-blanched and frozen asparagus.

Factor	FB	Packaging[a] F	S	B
Palatability scores				
Appearance: color				
Initial	5.6			
1 month		5.8	5.5	5.1
10 weeks		5.2	5.4	5.4
5 months		5.7	5.9	5.5
Appearance: shape				
Initial	6.0			
1 month		5.3	5.1	5.8
10 weeks		5.2	5.5	5.4
5 months		5.6	5.6	5.7
Aroma				
Initial	6.2			
1 month		5.4	5.4	5.0
10 weeks		5.6	5.4	5.4
5 months		5.7	5.8	5.5
Flavor				
Initial	6.0			
1 month		4.8	5.3	4.8
10 weeks		5.2	4.8	4.2
5 months		4.7	4.8	4.5
Texture				
Initial	5.6			
1 month		4.8	4.7	4.9
10 weeks		5.2	4.8	5.1
5 months		4.9	4.9	4.9
Acceptability, %				
Initial	100.0			
1 month		75.3	81.3	81.3
10 weeks		88.8	76.9	72.1
5 months		82.5	79.8	79.3

Table 3. (cont'd)

Factor	FB	Packaging[a] F	S	B
Objective values				
Reflectance (Rd) values[b]				
Initial	20.3			
1 month		18.5	18.2	20.1
10 weeks		16.3	16.1	16.5
5 months		17.9	17.0	18.1
Degree of greenness (a/b) values[c]				
Initial	0.626			
1 month		0.624	0.663	0.571
10 weeks		0.646	0.642	0.374
5 months		0.666	0.680	0.581
Shear[d]				
Initial	3.2			
1 month		4.0	5.2	5.3
10 weeks		5.5	5.3	5.6
5 months		6.3	6.7	7.3
Total solids[e]				
Initial	7.1	7.3	8.2	7.6
10 weeks		7.7	8.3	7.6
5 months		7.3	7.1	7.9
Total ascorbic acid[f]				
Initial	24.2			
1 month		17.8	19.2	24.2
10 weeks		19.2	16.8	22.7
5 months		17.0	18.3	20.5
Reduced ascorbic acid[g]				
Initial	13.9			
1 month		8.7	11.1	16.0
10 weeks		11.9	10.3	15.7
5 months		10.1	11.1	12.2

Table 3. (concl'd)

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[a]FB = fresh-blanched asparagus, neither packaged nor stored; F = asparagus packaged in foil for frozen storage only; S = asparagus packaged in laminated film for frozen storage only; B = asparagus packaged in laminated film for frozen storage and for boil-in-bag pouch.

[b]Measured on Gardner Color-Difference Meter.

[c]Calculated from Gardner Color Difference Meter readings for greenness (a-) and yellowness (b+).

[d]Measured on Warner-Bratzler shearing apparatus using the 25 lb dynamometer.

[e]Calculated from Brabender Semi-Automatic Moisture Tester readings.

[f,g]Determined by a modification of the method of Schaffert and Kingsley.

Table 4. Statistical analyses of data in Table 3 on palatability scores and objective measurements.

Factor	Least significant differences[a,b]					
	A	B	C	D	E	F
Palatability scores						
Appearance: color	--	--	--	--	--	--
Appearance: shape	--	--	--	--	--	--
Aroma	0.68	0.53	--	0.49	--	0.83
Flavor	0.69	0.63	1.03	0.95	0.59	0.85
Texture	0.63	0.37	--	--	0.47	0.51
Objective measurements						
Color: reflectance (*Rd*)	--	2.09	2.42	2.72	2.88	--
Color: degree of greenness (*a/b*)	--	--	--	--	--	--
Shear value	--	--	2.53	2.29	--	2.74
Total solids	--	--	--	--	--	--
Ascorbic acid: total	3.94	4.17	4.98	3.97	4.01	--
Ascorbic acid: reduced	3.44	--	--	--	--	--

[a] $P = 0.05$.

[b] A = analysis to compare fresh-blanched asparagus and that packaged by each of the 3 methods at 1 month storage, B = analysis to compare fresh-blanched asparagus and that packaged by each of the 3 methods at 10 weeks' storage, C = analysis to compare fresh-blanched asparagus and that packaged by each of 3 methods at 5 months' storage, D = analysis to compare fresh-blanched asparagus and that packaged in foil at each of 3 storage times, E = analysis to compare fresh-blanched asparagus and that packaged in laminated film for use in frozen storage only at each of 3 storage times, F = analysis to compare fresh-blanched asparagus and that packaged in laminated film for use as a boil-in-bag pouch at each of 3 storage times.

Table 5. Average objective values for frozen asparagus.

Factors	Rd[a]	a/b[b]	Ascorbic acid[c]	
			Total	Reduced
Storage				
1 month	18.93			
10 weeks	16.31			
5 months	17.63			
Packaging methods[d]				
F		0.6455	19.00	10.25
S		0.6614	18.10	10.82
B		0.5799	22.47	14.65
LSD[e]	1.74	0.43	2.34	2.20

[a]Measured on Gardner Color-Difference Meter.

[b]Calculated from Gardner Color-Difference Meter readings for greenness (a-) and yellowness (b+).

[c]Determined by a modification of the Method of Schaffert and Kingsley.

[d]F = asparagus packaged in foil for frozen storage only; S = asparagus packaged in laminated film for frozen storage only; B = asparagus packaged in laminated film for frozen storage and for boil-in-bag pouch.

[e]Least significant difference, P = 0.05.

and S had Rd values significantly ($P = 0.05$) reduced. By analyzing storage data for the fresh-blanched asparagus and that frozen using each of the packaging methods, it was noted the asparagus packaged in F and in S had significantly ($P = 0.05$) lower Rd values at 10 weeks than that fresh-blanched. Asparagus in S also had significantly ($P = 0.05$) reduced Rd values at 5 months frozen storage. When cooked, asparagus in no one packaging method had consistently higher or lower Rd values than another. No consistent significant trends in change of Rd values were observed.

Values for degree of greenness (a/b) after cooking were significantly ($P = 0.05$) lower for the asparagus packaged in B than for that stored in either F or S (Table 5). The boil-in-bag pouch did not allow escape or dilution of the volatile and nonvolatile acids given off during cooking, nor was any water available except that from the asparagus itself. Perhaps with the limited moisture in the pouch the acids were not as dilute, nor could some of the volatile acids escape, as in the case of asparagus in F and S, cooked in a measured amount of water in a covered kettle. Assuming a lowering of the pH in the boil-in-bag pouch more conversion of the chlorophyll to pheophytin might have taken place, thereby giving decreased greenness (a/b) values.

Although color scores for asparagus during extended storage for 3 packaging methods did not show significant differences, some differences were noted in objective measurements. Objective analysis of color on a Color-Difference Meter might be less subject to variation and more discriminatory than human scoring over long periods of time.

Aroma and texture. Average scores for aroma and texture of frozen asparagus ranged from "acceptable" to "moderately desirable" (Table 3). Considering aroma and texture scores (Table 4) at 1 month, the asparagus frozen in packages F, S, and B each had significantly (P = 0.05) lower scores than fresh-blanched asparagus. This also was found at 10 weeks (P = 0.05) but not at 5 months. Different methods of analyses of the data (Table 4) did not present always consistently significant trends. Aroma scores for fresh-blanched asparagus and asparagus stored in F and B decreased significantly (P = 0.05) at 1 month and in F at 10 weeks. Under the same conditions of analyses, at each evaluation time texture scores for asparagus frozen in S were significantly (P = 0.05) lower than scores for the fresh-blanched. Texture scores for that frozen in B were significantly (P = 0.05) lower at 1 month and at 5 months than the scores for fresh-blanched asparagus. Since the quality decline took place with all types of packaging used, aroma and texture quality might be affected by the freezing process.

Shear value. Fibrous structures contribute to the perceived texture of many vegetables (Matz, 1962). A study of shearing force is one method for evaluating fibrousness (Kramer, 1951). Wiley et al. (1956) found a significant correlation between shear press values and fiber measurement.

In the present study shear values were measured on the Warner-Bratzler shearing apparatus, using the 25 lb dynamometer.

The average shear values after frozen storage were higher than those for the fresh-blanched asparagus (Table 3). At 5 months frozen storage (Table 4), asparagus frozen by all 3 packaging methods had significantly (P = 0.05) higher shear readings than that fresh-blanched.

Analyses of the data by another method did not show a significant difference at 5 months for the asparagus frozen in S. Apparently some change might have taken place in the tissue over the longest storage time studied to give the higher shear reading, indicating increased fibrousness. Thic change did not seem related to the factors evaluated by the palatability panel for texture: the texture scores improved rather than declined at 5 months.

Total solids. No significant changes in percentage total solids as calculated from measurement of moisture content in the C. W. Brabender Semi-Automatic Moisture Tester were noted at extended storage periods or in different packaging methods (Table 4).

Histological work. During the freezing process and in frozen storage ice crystal formation and enlargement alters the cellular structure of the plant product by mechanical rupture. A study of the pattern of tissue rupture can indicate the extent and location of damage. Van Hulle et al. (1965) found that voids in carrot tissue were caused by ice formation, and that the fixing and staining procedures did not result in any gross misrepresentation of the frozen structure. In their work frozen cut sections of tissue were placed in a fixative and were held at 22°F for 4 hr before allowing the fixative to warm to room temperature. Recrystallization can occur during the early stages of thawing, but is minimized by rapid thawing (Fennema and Powrie, 1964). In the present study, cross-sections of the frozen asparagus spears were dropped into Craf's solution which was at room temperature.

No tissue rupture was apparent in the fresh asparagus. After blanching, the cells remained intact except for a sloughing off of the epidermal layer of cells. MacArthur (1948) noted only a few small tears in fresh cooked asparagus. Blanching is a shorter process than cooking, therefore it is logical that no damage except to the outer layer of cells was noted in the blanched tissue.

At 1 month, the asparagus stored in the foil and in the laminated film both had the epidermal layer of cells broken away and damaged. Small intercellular spaces, indicating sites of ice crystal formation and damage, were located around the outer edges of the cross-section of asparagus. Crushed cells and cells with broken walls were present around these intercellular spaces. Cell walls, for the most part, were intact throughout the rest of the cross-section. In samples from one replication the vascular tissues were distorted with cells with broken walls around these areas.

At 10 weeks' storage there also was damage to the epidermal cell layer. Intercellular spaces were more numerous and somewhat larger throughout the cross-section, with crushed cells and cells with broken walls around these spaces. Areas of intact cells remained in other regions of the cross-section.

At 5 months' storage extensive cell damage was apparent. Small and large intercellular spaces were visible throughout the cross-section. Cell damage was located around these areas. Few areas of intact cells were observed; even in areas without larger spaces than normal between cells. Also, vascular tissue was damaged. In one replication, asparagus stored in the laminated film showed less extensive damage than that from other replications, with the vascular tissue intact. This was from a spear of larger than usual diameter.

Asparagus in the foil and in the laminated film had a similar kind and degree of damage at each evaluation time. Cell damage increased as the storage time increased. Fennema and Powrie (1964) stated that ice crystals generally have a tendency to enlarge during frozen storage.

In this study, at 5 months the shear readings for asparagus frozen by all 3 packaging methods were significantly higher than those for fresh-blanched (Table 4). Apparently the fibrousness as measured on the Warner-Bratzler shearing apparatus was not related to the cell damage as studied microscopically.

Flavor. Flavor scores for asparagus after frozen storage decreased from a rating of "desirable" to "moderately desirable" or "acceptable" (Table 3). At all 3 storage times a significant ($P = 0.05$) flavor score (Table 4) decrease was noted for asparagus in all types of packaging when compared with fresh-blanched asparagus. By analyzing the storage data for the fresh-blanched asparagus and that frozen using each of the packaging methods, it was noted that asparagus packaged in F had significantly (P = 0.05) lower scores at 1 month and 5 months than the scores for that fresh-blanched, whereas that in S and B had significantly (P = 0.05) lower scores at all 3 storage times.

Storage seemed to be the chief factor in the decline of flavor quality. Palatability panel members often commented on the score sheet that one sample had a bitter flavor; this usually was the sample in B. The sealed pouch did not allow escape of volatile compounds during cooking. The asparagus from F and S was cooked in a minimum amount of water in a kettle. At 10 weeks, a significant (P = 0.05) difference occurred between the flavor scores for the asparagus in F and that in B. This may have been related to the bitter flavor.

Ascorbic acid. Ascorbic acid content is recognized as an index of quality retention in frozen foods (Desrosier, 1963; Guadagni, 1960). Oxidation of reduced ascorbic acid results in an increase in dehydroascorbic acid. The appearance of diketogulonic acid follows the formation of dehydroascorbic acid. Although dehydroascorbic and diketogulonic acid are not differentiated in this study, a portion of the ascorbic acid oxidative products might be expected to be in the form of the biologically available dehydroascorbic acid. Mills *et al.* (1949), stated that unless foods have been allowed to deteriorate badly, less than 5% of the ascorbic acid present is in the form of diketogulonic acid.

In the present study, the average values for total ascorbic acid were lower for asparagus packaged in F and S than for that fresh-blanched or packaged in B (Table 3). Asparagus packaged in B had a significantly ($P = 0.05$) higher total ascorbic acid content (Table 5) than the asparagus in F and S. At all 3 storage times total ascorbic acid values for asparagus in B were not significantly different from the values for the fresh-blanched asparagus (Table 4), whereas the asparagus in F and S had significantly ($P = 0.05$) lower values than that fresh-blanched. The limited amount of air and moisture in the pouch during cooking might account for the significant differences in total ascorbic acid content between that in B and that in F and S. The asparagus in F and S was cooked in a minimum (measured) amount of water in a kettle. Possibly some ascorbic acid was solubilized in this water. The ascorbic acid content of the cooking liquid was not measured, since the liquid was not considered an edible portion of the vegetable. Also Desrosier (1965) suggested, some of the ascorbic acid might have been lost due to exposure of the tissue to air in the cooking process.

For reduced ascorbic acid the values were higher for fresh-blanched asparagus and for that packaged in B than for that packaged in F or S (Table 3). This could be expected since the total ascorbic acid content was higher for fresh-blanched asparagus and that in B than for that in F and S. Also, the reduced ascorbic acid values for asparagus in B were significantly ($P = 0.05$) higher than values for that in F and S (Table 5). At 1 month storage the reduced ascorbic acid of asparagus in B was significantly ($P = 0.05$) higher than the reduced ascorbic acid content of that in F or S (Table 4). The reduced ascorbic acid content in the fresh-blanched asparagus was significantly (P = 0.05) higher than that for the asparagus in F. No significant decreases in reduced ascorbic acid were noted as the storage time extended. Probably no conversion of the reduced acid to its oxidized forms takes place at temperatures below 0°F (Dietrich et al., 1957; Kramer, et al., 1949).

Acceptability. Average percentages for general acceptability of the asparagus declined after frozen storage (Table 3). After 100% acceptance for the fresh-blanched asparagus, acceptance dropped to between 72.1 and 88.8%, with no specific trends relating to storage time or packaging method.

SUMMARY

The effects of 3 packaging methods on the quality of frozen asparagus were investigated and compared. Heat sealed laminated film packages were used (1) for frozen storage, the asparagus being removed for cooking, and (2) for frozen storage and boil-in-bag pouches. Aluminum foil packages with confectioner's closure were used for frozen storage only.

The asparagus, with 5 replications of each method, was evaluated fresh, fresh-blanched, and at storage times of 1 month, 10 weeks, and 5 months. When a comparison was made of fresh and fresh-blanched spears, no significant differences except for shear value were noted. After frozen storage the scores for appearance did not change significantly, but the scores for aroma, flavor, and texture were significantly lower than scores for the fresh-blanched. The general acceptability

rating decreased during frozen storage.

Ascorbic acid values were significantly higher and objective greenness values significantly lower for the asparagus in the boil-in-bag pouch than those for the fresh-blanched. No other trends relating to packaging methods were noted. Cell damage increased as storage time extended but shear value after 5 months was significantly higher than for fresh-blanched. No consistently significant trends for reflectance values and no significant changes in total solids were noted at the storage times studied.

Under the conditions of this study, each of the 3 packaging methods was satisfactory for frozen storage of asparagus for as long as 5 months. Ascorbic acid retention was significantly better in the boil-in-bag pouch than with any other packaging method.

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APPENDIX

Form 1. Evaluation of fresh and frozen asparagus.

Measurements made:	Palatability	Color	Shear value	Total solids	Histological work	Ascorbic acid
Fresh, before blanching			X		X	
Fresh, after blanching			X		X	
Fresh, after cooking	X	X		X		
Fresh, after blanching and cooking	X	X		X		X
Frozen, each evaluation period before cooking			X		X	
Frozen, each evaluation period after cooking	X	X		X		X

Form 2. Score Card.

Asparagus

Factors		Sample number 1	2	3	Comments
1. Appearance:					
Color:	bright, not too pale nor bronzy green				
Shape:	stalks not broken, leaflets intact				
2. Aroma:	fresh, not haylike				
3. Flavor:	fresh; not bitter, flat, or "off"				
4. Texture:	firm, yet tender, not mushy				
Would you consider this an acceptable product to serve at a meal?					

Scale:
7 extremely or very desirable
6 desirable
5 moderately desirable
4 acceptable
3 slightly undesirable
2 undesirable
1 inedible

Table 6. Appearance: shape scores for cooked asparagus.[a]

Sample	Fresh		Frozen		
	Unblanched	Blanched	F[b]	S[c]	B[d]
Initial					
1	6.4	6.2			
2	6.0	4.8			
3	6.2	6.6			
4	6.3	6.1			
5	6.2	6.2			
Av	6.2	6.0			
1 month					
1			5.4	5.5	5.6
2			5.0	5.5	5.0
3			5.2	4.8	6.5
4			5.3	4.2	6.3
5			5.8	5.6	5.6
Av			5.3	5.1	5.8
10 weeks					
1			5.6	4.9	5.9
2			5.1	5.4	5.1
3			5.2	6.0	6.2
4			5.1	5.0	4.7
5			5.0	4.9	5.0
Av			5.2	5.5	5.4
5 months					
1			6.3	6.0	6.2
2			4.8	5.2	5.2
3			5.1	5.6	6.0
4			6.0	5.8	5.6
5			5.7	5.8	6.0
Av			5.6	5.7	5.8

[a]Range: 7 (very desirable) to 1 (inedible).
[b]Packaged in foil for frozen storage only.
[c]Packaged in laminated film for frozen storage only.
[d]Packaged in laminated film for use as boil-in-bag pouch.

Table 7. Appearance: color scores for cooked asparagus.[a]

Sample	Fresh		Frozen		
	Unblanched	Blanched	F[b]	S[c]	B[d]
Initial					
1	6.0	5.8			
2	5.8	5.2			
3	5.0	5.6			
4	5.6	5.7			
5	5.7	5.7			
Av	5.6	5.6			
1 month					
1			5.8	5.7	5.3
2			5.2	5.3	4.3
3			6.2	4.8	5.5
4			5.4	5.8	5.8
5			6.2	5.5	4.6
Av			5.8	5.5	5.1
10 weeks					
1			5.3	5.3	5.6
2			5.5	5.0	5.9
3			4.8	4.8	5.7
4			5.0	6.0	4.9
5			5.3	6.0	5.1
Av			5.2	5.4	5.4
5 months					
1			6.5	6.2	5.8
2			5.5	6.0	4.7
3			5.1	5.6	6.0
4			5.6	5.8	5.2
5			5.7	5.8	6.0
Av			5.7	5.9	5.5

[a]Range: 7 (very desirable) to 1 (inedible).
[b]Packaged in foil for frozen storage only.
[c]Packaged in laminated film for frozen storage only.
[d]Packaged in laminated film for use as boil-in-bag pouch.

Table 8. Aroma scores for cooked asparagus.[a]

Sample	Fresh		Frozen		
	Unblanched	Blanched	F[b]	S[c]	B[d]
Initial					
1	6.8	6.4			
2	6.4	5.8			
3	5.6	6.0			
4	6.3	6.0			
5	5.8	6.0			
Av	6.2	6.2			
1 month					
1			5.5	5.5	5.3
2			5.3	4.2	4.0
3			5.0	5.5	5.0
4			5.5	5.8	5.5
5			5.6	6.0	5.4
Av			5.4	5.4	5.0
10 weeks					
1			5.9	5.4	6.0
2			5.4	5.6	5.1
3			5.5	5.0	5.5
4			5.3	5.6	5.7
5			5.9	5.6	4.9
Av			5.6	5.4	5.4
5 months					
1			6.5	6.3	6.3
2			5.5	5.3	4.3
3			5.3	5.3	5.6
4			5.6	6.0	5.6
5			5.8	6.0	5.8
Av			5.7	5.8	5.5

[a]Range: 7 (very desirable to 1 (inedible).
[b]Packaged in foil for frozen storage only.
[c]Packaged in laminated film for frozen storage only.
[d]Packaged in laminated film for use as boil-in-bag pouch.

Table 9. Flavor scores for cooked asparagus.[a]

Sample	Fresh		Frozen		
	Unblanched	Blanched	F[b]	S[c]	B[d]
Initial					
1	5.8	6.4			
2	6.4	5.4			
3	4.2	6.0			
4	5.8	6.1			
5	5.6	6.0			
Av	5.6	6.0			
1 month					
1			4.8	5.0	4.5
2			5.7	5.2	4.8
3			4.3	5.5	4.8
4			3.8	4.8	5.0
5			4.8	6.0	4.8
Av			4.8	5.3	4.8
10 weeks					
1			4.8	4.8	4.5
2			5.9	5.2	4.0
3			4.8	4.5	4.7
4			4.9	5.1	4.1
5			5.6	4.3	3.9
Av			5.2	4.9	4.2
5 months					
1			6.2	5.2	4.7
2			4.2	4.2	3.0
3			5.0	5.0	4.7
4			3.8	5.0	5.8
5			4.3	4.7	4.2
Av			4.7	4.8	4.5

[a]Range: 7 (very desirable to 1 (inedible).

[b]Packaged in foil for frozen storage only.

[c]Packaged in laminated film for frozen storage only.

[d]Packaged in laminated film for use as boil-in-bag pouch.

Table 10. Texture scores for cooked asparagus.[a]

Sample	Fresh		Frozen		
	Unblanched	Blanched	F[b]	S[c]	B[d]
Initial					
1	5.8	5.4			
2	5.4	5.4			
3	4.6	5.8			
4	5.8	5.3			
5	6.0	6.0			
Av	5.5	5.6			
1 month					
1			4.8	4.5	4.7
2			5.2	4.7	4.3
3			4.2	4.5	5.2
4			5.2	4.7	5.8
5			4.4	5.2	4.6
Av			4.8	4.7	4.9
10 weeks					
1			5.1	4.6	5.0
2			5.4	4.6	5.0
3			4.8	4.8	5.3
4			5.3	5.1	5.1
5			5.6	5.1	5.1
Av			5.2	4.8	5.1
5 months					
1			5.7	5.0	4.7
2			4.7	4.3	4.5
3			4.7	5.0	5.3
4			3.8	5.2	4.8
5			5.7	5.0	5.3
Av			4.9	4.9	4.9

[a]Range: 7 (very desirable to 1 (inedible).

[b]Packaged in foil for frozen storage only.

[c]Packaged in laminated film for frozen storage only.

[d]Packaged in laminated film for use as boil-in-bag pouch.

Table 11. Acceptability (%) of cooked asparagus.[a]

Sample	Fresh		Frozen		
	Unblanched	Blanched	F[b]	S[c]	B[d]
Initial					
1	100.0	100.0			
2	100.0	100.0			
3	100.0	100.0			
4	100.0	100.0			
5	100.0	100.0			
Av	100.0	100.0			
1 month					
1			83.3	83.3	83.3
2			100.0	80.0	80.0
3			60.0	60.0	80.0
4			83.3	83.3	83.3
5			50.0	100.0	80.0
Av			75.3	81.3	81.3
10 weeks					
1			75.0	85.7	75.0
2			100.0	75.0	71.4
3			83.3	66.7	100.0
4			85.7	71.4	71.4
5			100.0	85.7	42.8
Av			88.8	76.9	72.1
5 months					
1			100.0	83.3	83.3
2			66.7	66.7	66.7
3			85.7	85.7	100.0
4			60.0	80.0	80.0
5			100.0	83.3	66.7
Av			82.5	79.8	79.3

[a]Scored as yes or no.

[b]Packaged in foil for frozen storage only.

[c]Packaged in laminated film for frozen storage only.

[d]Packaged in laminated film for use as boil-in-bag pouch.

Table 12. Color: reflectance (Rd) values for cooked asparagus.[a]

Sample	Fresh		Frozen		
	Unblanched	Blanched	F[b]	S[c]	B[d]
Initial					
1	24.3	21.2			
2	17.7	18.5			
3	18.3	23.0			
4	20.7	21.8			
5	16.6	17.0			
Av	19.5	20.3			
1 month					
1			17.4	16.4	17.2
2			19.7	22.2	24.5
3			22.3	21.1	25.5
4			16.9	16.7	19.4
5			16.3	14.4	13.9
Av			18.5	18.2	20.1
10 weeks					
1			16.1	16.7	17.2
2			18.6	15.9	16.2
3			15.5	15.0	15.7
4			16.5	16.6	16.5
5			14.8	16.3	17.1
Av			16.3	16.1	16.5
5 months					
1			16.5	16.1	16.8
2			17.6	17.9	19.0
3			20.2	17.0	----
4			17.6	17.5	20.6
5			17.4	16.3	15.9
Av			17.9	17.0	18.1

[a]Gardner Color-Difference Meter measurement.

[b]Packaged in foil for frozen storage only.

[c]Packaged in laminated film for frozen storage only.

[d]Packaged in laminated film for use as boil-in-bag pouch.

Table 13. Color: greenness (a-) values for cooked asparagus.[a]

Sample	Fresh		Frozen		
	Unblanched	Blanched	F[b]	S[c]	B[d]
Initial					
1	13.7	14.9			
2	15.0	13.8			
3	15.2	13.0			
4	14.7	13.1			
5	15.4	15.6			
Av	14.8	14.1			
1 month					
1			13.5	15.5	13.0
2			13.5	15.1	13.4
3			15.7	15.0	13.3
4			12.5	12.9	12.1
5			14.4	15.5	13.4
Av			13.9	14.8	13.0
10 weeks					
1			13.6	12.6	11.4
2			13.4	13.1	12.5
3			13.8	13.4	13.6
4			14.5	13.4	12.5
5			15.1	15.6	13.3
Av			14.1	13.6	12.7
5 months					
1			13.9	13.5	13.2
2			13.4	15.1	10.6
3			14.9	14.3	----
4			15.2	14.5	13.3
5			15.9	15.8	14.1
Av			14.7	14.6	12.8

[a]Gardner Color-Difference Meter measurement.

[b]Packaged in foil for frozen storage only.

[c]Packaged in laminated film for frozen storage only.

[d]Packaged in laminated film for use as boil-in-bag pouch.

Table 14. Color: yellowness (b+) values for cooked asparagus.[a]

Sample	Fresh		Frozen		
	Unblanched	Blanched	F[b]	S[c]	B[d]
Initial					
1	24.2	23.0			
2	21.9	21.4			
3	22.2	24.2			
4	22.4	22.8			
5	21.9	21.4			
Av	22.2	22.6			
1 month					
1			22.2	21.4	22.0
2			22.9	23.7	24.1
3			24.0	24.0	24.6
4			21.0	21.8	23.1
5			21.6	21.0	20.8
Av			22.3	22.4	22.9
10 weeks					
1			23.6	22.0	23.2
2			22.1	21.6	21.4
3			21.7	21.0	20.2
4			21.6	21.2	21.6
5			20.4	20.6	21.5
Av			21.9	21.3	21.6
5 months					
1			21.8	21.0	21.6
2			22.4	21.8	22.7
3			22.7	21.8	----
4			21.7	21.6	23.2
5			21.4	21.5	21.0
Av			22.0	21.5	22.1

[a]Gardner Color-Difference Meter measurement.

[b]Packaged in foil for frozen storage only.

[c]Packaged in laminated film for frozen storage only.

[d]Packaged in laminated film for use as boil-in-bag pouch.

Table 15. Color: degree of greenness (a/b) values for cooked asparagus.[a]

Sample	Fresh		Frozen		
	Unblanched	Blanched	F[b]	S[c]	B[d]
Initial					
1	.568	.646			
2	.684	.648			
3	.682	.538			
4	.656	.573			
5	.704	.727			
Av	.659	.626			
1 month					
1			.612	.723	.587
2			.590	.636	.558
3			.656	.626	.540
4			.596	.590	.524
5			.668	.738	.644
Av			.624	.663	.571
10 weeks					
1			.568	.599	.538
2			.616	.584	.534
3			.639	.641	.676
4			.668	.630	.575
5			.739	.756	.617
Av			.646	.642	.374
5 months					
1			.636	.719	.611
2			.596	.618	.469
3			.656	.656	----
4			.700	.671	.574
5			.743	.734	.670
Av			.666	.680	.581

[a]Calculated from Gardner Color-Difference Meter measurements.
[b]Packaged in foil for frozen storage only.
[c]Packaged in laminated film for frozen storage only.
[d]Packaged in laminated film for use as boil-in-bag pouch.

Table 16. Shear values.[a]

Sample	Fresh		Frozen		
	Unblanched	Blanched	F[b]	S[c]	B[d]
Initial					
1	11.6	3.8			
2	8.7	3.3			
3	8.7	2.3			
4	9.8	4.0			
5	6.9	2.7			
Av	9.1	3.2			
1 month					
1			5.7	5.8	6.5
2			2.3	5.2	5.8
3			4.9	3.9	4.2
4			4.1	8.2	6.5
5			3.1	5.8	3.6
Av			4.0	5.2	5.3
10 weeks					
1			3.7	5.7	3.7
2			4.0	5.8	9.9
3			9.8	3.4	4.2
4			6.9	8.9	6.5
5			3.1	2.7	3.7
Av			5.5	5.3	5.6
5 months					
1			6.0	3.9	6.6
2			7.2	8.5	10.2
3			7.2	8.1	4.0
4			6.4	8.7	9.3
5			4.7	4.4	6.4
Av			6.3	6.7	7.3

[a]Measured on Warner-Bratzler shear apparatus, 25 lb dynamometer.

[b]Packaged in foil for frozen storage only.

[c]Packaged in laminated film for frozen storage only.

[d]Packaged in laminated film for use as boil-in-bag pouch.

Table 17. Percentage total solids for cooked asparagus.[a]

Sample	Fresh		Frozen		
	Unblanched	Blanched	F[b]	S[c]	B[d]
Initial					
1	7.2	7.0			
2	6.6	6.6			
3	6.9	7.2			
4	7.3	7.8			
5	6.7	6.7			
Av	6.9	7.1			
1 month					
1			7.9	7.2	7.8
2			6.3	8.7	7.6
3			8.1	9.4	7.8
4			7.2	8.1	7.0
5			7.2	7.5	7.6
Av			7.3	8.2	7.6
10 weeks					
1			7.3	6.7	6.9
2			8.8	12.9	8.1
3			7.5	7.5	7.9
4			7.9	7.6	8.1
5			7.2	6.6	7.0
Av			7.7	8.3	7.6
5 months					
1			7.2	6.4	7.6
2			7.8	6.9	8.2
3			7.3	7.6	---
4			7.5	8.4	8.1
5			6.9	6.4	7.6
Av			7.3	7.1	7.9

[a]Calculated from Brabender Moisture Tester readings.

[b]Packaged in foil for frozen storage only.

[c]Packaged in laminated film for frozen storage only.

[d]Packaged in laminated film for use as boil-in-bag pouch.

Table 18. Total (T), dehydro + diketo (D), and reduced (R)[a] ascorbic acid values for cooked asparagus (mg/100 g).

Sample	Fresh, unblanched			Frozen								
				Foil			Seal-in-bag			Boil-in-bag		
	T	D	R	T	D	R	T	D	R	T	D	R
Initial												
1	25.4	8.2	17.2									
2	27.8	12.2	15.6									
3	23.0	11.2	11.8									
4	18.6	8.7	9.9									
5	26.6	11.5	15.1									
Av	24.2	10.4	13.9									
1 month												
1				19.6	9.0	10.6	20.6	9.0	11.6	25.6	8.0	17.6
2				16.8	7.2	9.6	19.3	6.6	12.7	26.5	8.0	18.5
3				19.8	10.9	8.9	14.8	8.4	6.4	18.3	6.3	12.0
4				17.3	11.9	5.4	19.5	6.8	12.7	25.0	9.5	15.5
5				15.7	6.5	9.2	21.8	9.7	12.1	25.7	9.2	16.5
Av				17.8	9.1	8.7	19.2	8.1	11.1	24.2	-8.2	16.0
10 weeks												
1				25.6	7.4	18.2	19.2	7.6	11.6	21.1	5.7	19.1
2				19.6	5.9	13.7	17.5	7.6	9.9	22.5	7.1	15.4
3				14.8	8.6	6.2	16.2	5.2	11.9	19.8	5.6	14.2
4				----	----	----	----	---	----	25.5	7.5	18.0
5				16.7	7.1	9.6	14.5	5.8	8.7	24.8	5.7	19.1
Av				19.2	7.3	11.9	16.8	6.6	10.3	22.7	7.0	15.7
5 months												
1				15.3	5.8	9.5	14.6	6.8	7.8	16.8	6.8	10.0
2				16.0	7.2	8.8	22.6	8.2	13.9	28.0	9.8	18.2
3				18.0	8.2	9.8	19.2	7.5	11.7	20.6	9.3	11.3
4				----	----	----	20.9	7.8	13.1	22.4	6.8	15.6
5				18.7	6.4	12.3	14.5	5.7	8.8	14.5	8.6	5.9
Av				17.0	6.7	10.0	18.3	7.2	11.1	20.5	8.3	12.2

[a]Obtained by subtracting measured values: total - (dehydro + diketo).

Table 19. Analyses of variance for fresh and fresh-blanched asparagus.

Source	D/F	MS	F-value	Sig.[a]
Palatability scores				
Appearance: color				
Treatments	1	0.0010	0.01	ns
Error	8	0.0985		
Appearance: shape				
Treatments	1	0.1440	0.58	ns
Error	8	0.2470		
Aroma				
Treatments	1	0.0010	0.006	ns
Error	8	0.1700		
Flavor				
Treatments	1	0.4410	1.10	ns
Error	8	0.4000		
Texture				
Treatments	1	0.0090	0.04	ns
Error	8	0.2020		
Objective values				
Color: reflectance (Rd)				
Treatments	1	1.5210	0.20	ns
Error	8	7.7560		
Color: degree of greenness (a/b)				
Treatments	1	0.002624	0.63	ns
Error	8	0.004138		
Shear value				
Treatments	1	87.6160	50.21	***
Error	8	1.7450		
Total solids				
Treatments	1	0.0360	0.22	ns
Error	8	0.1605		

[a]ns = not significant; ***, P = 0.001.

Table 20. Analyses of variance for comparing the effects of storage times and the effects of packaging methods.

Source	D/F	MS	F-value	Sig.[a]
Palatability scores				
Appearance: color				
Storage time (T)	2	0.4976	2.2401	ns
Packaging method (P)	2	0.2242	1.0095	ns
T x P	4	0.2876	1.2946	ns
Error	36	0.2221		
Appearance: shape				
Storage time (T)	2	0.2696	1.0890	ns
Packaging method (P)	2	0.2749	1.1114	ns
T x P	4	0.2142	.8661	ns
Error	36	0.2473		
Aroma				
Storage time (T)	2	0.6216	2.4996	ns
Packaging method (P)	2	0.2536	1.0197	ns
T x P	4	0.0459	0.1845	ns
Error	36	0.2487		
Flavor				
Storage time (T)	2	0.3327	0.8734	ns
Packaging method (P)	2	0.9447	2.4802	ns
T x P	4	0.4063	1.0668	ns
Error	36	0.3809		
Texture				
Storage time (T)	2	0.2549	1.3478	ns
Packaging method (P)	2	0.1229	0.6498	ns
T x P	4	0.0699	0.3696	ns
Error	36	0.1891		
Objective values				
Color: reflectance (<u>Rd</u>)				
Storage time (T)	2	25.6116	4.6095	*
Packaging method (P)	2	5.1509	0.9270	ns
T x P	4	1.0886	0.1959	ns
Error	36	5.5562		
Color: degree of greenness (<u>a/b</u>)				
Storage time (T)	2	0.0021	0.6285	ns
Packaging method (P)	2	0.0280	8.2274	*
T x P	4	0.0011	0.3228	ns
Error	36	0.0034		

Table 20. (concl.)

Source	D/F	MS	F-value	Sig.[a]
Total ascorbic acid				
Storage time (T)	2	12.8287	1.2996	ns
Packaging method (P)	2	97.7147	9.8992	**
T x P	4	9.1063	0.9225	ns
Error	36	9.8710		
Reduced ascorbic acid				
Storage time (T)	2	8.7647	0.9958	ns
Packaging method (P)	2	85.6647	9.7331	*
T x P	4	13.7703	1.5646	ns
Error	36	8.8013		
Shear value				
Storage time (T)	2	14.4249	3.1349	ns
Packaging method (P)	2	2.4269	0.5274	ns
T x P	4	0.7836	0.1703	ns
Error	36	4.6014		
Total solids				
Storage time (T)	2	0.6462	0.5786	ns
Packaging method (P)	2	0.5616	0.5028	ns
T x P	4	0.8622	0.7720	ns
Error	36	1.1169		

[a]ns = not significant; *, P = 0.05; **, P = 0.01.

Table 21. Analyses of variance for palatability scores for fresh-blanched and packaged asparagus.

Factor	D/F	Storage time								
		1 month			10 weeks			5 months		
		MS	F-value	Sig.[a]	MS	F-value	Sig.	MS	F-value	Sig.
Appearance: color										
Treatment	3	0.3952	1.8706	ns	0.1500	0.9646	ns	0.1098	0.6303	ns
Error	16	0.2112			0.1555			0.1742		
Total	19									
Appearance: shape										
Treatment	3	0.7933	2.4561	ns	0.5605	1.8498	ns	0.1827	0.6421	ns
Error	16	0.3230			0.3030			0.2845		
Total	19									
Aroma										
Treatment	3	1.1192	4.3336	*	0.5840	5.1454	*	0.3533	1.3147	ns
Error	16	0.2582			0.1135			0.2688		
Total	19									
Flavor										
Treatment	3	1.6180	6.7346	**	2.6940	16.2779	**	2.2552	4.0984	*
Error	16	0.2402			0.1655			0.5502		
Total	19									
Texture										
Treatment	3	0.7978	4.3777	*	0.4753	7.2294	**	0.5560	2.2556	ns
Error	16	0.1822			0.0658			0.2465		
Total	19									

[a]*, P = 0.05; **, P = 0.01; ns, not significant.

Table 22. Analyses of variance for values of objective measurements for fresh-blanched and packaged asparagus.

Factor	D/F	1 month MS	1 month F-value	1 month Sig.[a]	10 weeks MS	10 weeks F-value	10 weeks Sig.	5 months MS	5 months F-value	5 months Sig.
Color: reflectance (Rd)										
Treatment	3	5.9073	0.4997	ns	20.0287	8.8495	**	10.0627	3.3478	*
Error	16	11.8225			2.2632			3.0058		
Total	19									
Color: degree of greenness (a/b)										
Treatment	3	0.0072	2.2002	ns	0.0035	0.7961	ns	0.0098	2.4252	ns
Error	16	0.0033			0.0044			0.0041		
Total	19									
Shear value										
Treatment	3	5.0792	2.4934	ns	6.3872	1.1885	ns	16.6232	4.9923	*
Error	16	2.0370			5.3742			3.3298		
Total	19									
Percentage total solids										
Treatment	3	1.1338	2.7722	ns	1.2165	0.6125	ns	0.6818	2.3593	ns
Error	16	0.4090			1.9860			0.2890		
Total	19									
Ascorbic acid: total										
Treatment	3	56.2658	6.4791	**	56.9560	5.8869	**	50.9293	3.6974	*
Error	16	8.6842			9.6750			13.7745		
Total	19									
Ascorbic acid: reduced										
Treatment	3	50.8205	7.7450	**	27.8272	2.8750	ns	13.4840	1.3165	ns
Error	16	6.5618			9.6790			10.2425		
Total	19									

[a]*, P = 0.05; **, P = 0.01; ns, not significant.

Table 23. Analyses of variance for palatability scores for fresh-blanched and stored asparagus.

Factor	D/F	Packaging[a] F MS	F F-value	F Sig.[b]	S MS	S F-value	S Sig.	B MS	B F-value	B Sig.
Appearance: color										
Treatment	3	0.3338	2.2182	ns	0.2085	1.3762	ns	0.2493	1.0432	ns
Error	16	0.1505			0.1515			0.2390		
Total	19									
Appearance: shape										
Treatment	3	0.5800	2.3722	ns	0.6333	2.0563	ns	0.3205	0.8952	ns
Error	16	0.2445			0.3080			0.3580		
Total	19									
Aroma										
Treatment	3	0.5400	4.7162	*	0.6258	2.8512	ns	1.0747	3.5062	*
Error	16	0.1145			0.2195			0.3065		
Total	19									
Flavor										
Treatment	3	1.7165	3.6835	*	1.5627	9.6016	**	2.9820	9.1123	**
Error	16	0.4660			0.1628			0.3272		
Total	19									
Texture										
Treatment	3	0.6592	2.5475	ns	0.7500	8.4034	**	0.4860	3.3174	*
Error	16	0.2588			0.0892			0.1465		
Total	19									

[a]F = asparagus packaged in foil for frozen storage only; S = asparagus packaged in laminated film for frozen storage only; B = asparagus packaged in laminated film for frozen storage as well as for boil-in-bag pouch.

[b]*, P = 0.06; **, P = 0.01; ns, not significant.

Table 24. Analyses of variance for values of objective measurements for fresh-blanched stored asparagus.

Factor	D/F	Packaging[a] F MS	F-value	Sig.[b]	S MS	F-value	Sig.	B MS	F-value	Sig.
Color reflectance (Rd)										
Treatment	3	13.7165	3.3816	*	16.5827	3.6314	*	15.9298	1.8810	ns
Error	16	4.0562			4.5665			8.4688		
Total	19									
Color: degree of greenness (a/b)										
Treatment	3	0.0019	0.5486	ns	0.0027	0.6619	ns	0.0030	0.7165	ns
Error	16	0.0035			0.0041			0.0041		
Total	19									
Shear value										
Treatment	3	9.7307	3.4251	*	10.3538	2.5875	ns	14.0040	3.5922	*
Error	16	2.8410			4.0015			3.8985		
Total	19									
Percentage total solids										
Treatment	3	0.3913	1.2355	ns	2.1013	0.9666	ns	0.5818	3.0108	ns
Error	16	0.3168			2.1740			0.1932		
Total										
Ascorbic acid: total										
Treatment	3	53.2232	6.0684	**	52.4458	5.8626	**	16.0392	1.1125	ns
Error	16	8.7705			8.9458			14.4175		
Total	19									
Ascorbic acid: reduced										
Treatment	3	25.2913	2.9132	ns	12.6898	2.0854	ns	15.7005	1.3400	ns
Error	16	8.6818			6.0850			11.7165		
Total	19									

[a]F = asparagus packaged in foil for frozen storage only; S = asparagus packaged in laminated film for frozen storage only; B = asparagus packaged in laminated film for frozen storage as well as for boil-in-bag pouch.

[b]*, P = 0.05; **, P = 0.01; ns, not significant.

THE EFFECTS OF CERTAIN PACKAGING METHODS ON THE QUALITY OF FROZEN ASPARAGUS

by

CELINE MARCELLA SIMON

B. S. HEc, Alverno College, 1965

AN ABSTRACT OF A THESIS

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The effects of 3 packaging methods on the quality of frozen asparagus were investigated and compared. Heat sealed laminated film packages were used (1) for frozen storage, the asparagus being removed for cooking, and (2) for frozen storage and boil-in-bag pouches. Aluminum foil packages with confectioner's closure were used for frozen storage only.

The asparagus, with 5 replications of each method, was evaluated fresh, fresh-blanched, and at storage times of 1 month, 10 weeks, and 5 months. When a comparison was made of fresh and fresh-blanched spears, no significant differences except for shear value were noted. After frozen storage the scores for appearance did not change significantly, but the scores for aroma, flavor, and texture were significantly lower than scores for the fresh-blanched. The general acceptability rating decreased during frozen storage.

Ascorbic acid values were significantly higher and objective greenness values significantly lower for the asparagus in the boil-in-bag pouch than those for the fresh-blanched. No other trends relating to packaging methods were noted. Cell damage increased as storage time extended but shear value after 5 months was significantly higher than for fresh-blanched. No consistently significant trends for reflectance values and no significant changes in total solids were noted at the storage times studied.

Under the conditions of this study, each of the 3 packaging methods was satisfactory for frozen storage of asparagus for as long as 5 months. Ascorbic acid retention was significantly better in the boil-in-bag pouch than with any other packaging method.