STORAGE OF LOW-MOISTURE FOODS: EFFECT OF STORAGE TEMPERATURE, TIME AND OXYGEN LEVEL ON CONSUMER ACCEPTABILITY AND NUTRIENT CONTENT

A Thesis

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INTRODUCTION AND LITERATURE REVIEW

Food quality deteriorates during storage. Reduced moisture and other stabilizing treatments during processing decrease but do not prevent quality losses in dehydrated foods. Undesirable changes which do occur include development of off-flavors, browning, fading of pigments, decreases in water reabsorption and losses of nutrients. Villota et al. (1980a) conducted an extensive survey of literature with respect to storage stability of dehydrated foods. Organoleptic properties were most often listed as a product's cause of failure.

Organoleptic Properties

Salunkhe et al. (1979) studied the effects of long-term storage on the quality of freeze-dehydrated ration items in vacuum-packed flexible pouches. Items studied included beef hash, beef stew, chicken stew, spaghetti with meat sauce, chili con carne with beans, chicken and rice, pork with escalloped potato, and beef and rice. The products were stored at 40, 70, and 100°F and evaluated by a 20 judge taste panel using a 9-point Hedonic scale at 0, 4, 10, 16, 20, 26, 32, and 44 months storage. Color, flavor, odor, texture, and overall acceptability of all products stored at 100°F and of chicken with rice, pork with escalloped potato, chili con carne with beans, beef stew, and spaghetti with meat sauce, stored at 70°F were significantly reduced at 44 months. There were no significant reductions in quality of products stored at 40°F. All products stored at all temperatures were acceptable quality, recieving an average score of 5 or greater on a nine-point hedonic scale, after

44 months. Beef stew, for an example received an original color score of about 6.8. After 44 months storage the color scores were 6.5, 6.0, and 5.1 for 40, 70, and 100°F storage respectfully. Flavor scores decreased in 44 months from an original 7.0 to 6.6 at 40°F, 6.1 at 70°F and 5.4 at 100°F.

Bishov et al. (1971) studied the quality and stability of freeze-dried carrots, spinach, sweet potatoes, green peas, green beans, white potatoes, apricots, peaches, pork loin, beef, chicken dark meat, chicken white meat and shrimp in "zero" oxygen headspace. "Zero" oxygen headspace was achieved using an atmosphere of 5% hydrogen in nitrogen with a palladium catalyst to reduce any residual oxygen. These foods were compared with identical products stored in 0.5% oxygen, 1% oxygen and 2% oxygen. All samples were stored at 100°F for 12 months. A 6-judge flavor profile panel reported overall aroma and flavor amplitudes and defined specific flavor notes and their intensities. Significant flavor deterioration of carrots stored in 2% oxygen occurred in 1 week while flavor deterioration of white potatoes stored in 2% oxygen was not detected until 8 months. "Zero" oxygen samples were still described as "fresh like" after 12 months. Color, odor and flavor of the freeze-dried carrots were evaluated using a nine-point hedonic scale by a 12-member trained taste panel. No significant changes in color, flavor or odor were detected in the "zero" or 0.5% oxygen samples during the 12-month storage period. Under 1% and 2% oxygen, fading of color was observed at 2 months. Color of these samples was rated significantly lower than both the "zero" and 0.5% oxygen samples at 3 months. Oxidized carotene odors were detected in the 1% and 2% oxygen samples and were rated significantly poorer than odors from the "zero" oxygen sample after 2 months and 2 weeks respectively. Differences in flavor from the "zero" oxygen pack were significant after 2 months under 1% and after 2 weeks under 2% oxygen. In addition consumer panels consisting of 30 randomly selected judges consistently preferred carrots, beef chunks and chicken stew packaged in "zero" oxygen to the same products packaged in 1% or 2% oxygen. Oxygen uptake of the products was monitored throughout the study. Meat items which contain natural heme pigments had the most rapid uptake of oxygen. Highly pigmented vegetables (sweet potatoes, carrots and spinach) consumed oxygen more rapidly than lesser pigmented vegetables (white potatoes and green beans). The two fruit items, apricots and peaches had a very slow uptake of oxygen.

Tuomy and Walker (1970) studied the effect of storage time, moisture level and headspace oxygen on the quality of dehydrated egg mix. Moisture was adjusted to 2.0, 2.5, 3.0, 3.5, or 4.0%. Samples were sealed in metal cans with 1, 7 or 21% residual oxygen, and stored at 100°F for 0, 3, 6, 12, and 24 weeks. Color, odor, flavor, and texture were evaluated by a ten member trained taste panel using a 9-point hedonic scale. Storage time, available oxygen and moisture level contributed significantly to the deterioration of the color and flavor of the dehydrated mix. Storage time and moisture had a significant effect on texture, however, oxygen did not. Color deteriorated most rapidly under all conditions.

Browning was evident in the product containing 2.0 and 2.5% moisture after 24 weeks and the 3.0% moisture sample after only 12 weeks. The authors recommended a maximum moisture content of 2.0% for dehydrated egg mix.

Wong et al. (1956) studied the storage stability of vacuum-dried tomato juice powder. Samples were packed in air, air-sulfited, nitrogen (< 0.5% oxygen), vacuum (30 in. Hg), carbon dioxide and air-albumen; with and without desiccants and stored at 70, 90, and 100°F for 6 weeks 3, 6, 9, and 12 months. As early as 6 weeks taste panels detected grassy and oxidative off-flavors in all air-packed samples. Off-flavor intensity varied directly with increasing temperature and length of storage. A bleaching of color was observed in all air-packed samples regardless of temperature. Colors of all other samples were rated similar to or darker red than the controls (nitrogen-packed and stored at -10°F). In-package desiccant with an inert atmosphere appeared to be the best packaging procedure.

Tomato products sometimes improve in color shortly after processing due to cis-trans isomerization of lycopene, (Boskovic, 1979, Lovric et al., 1970). Exposure to heat during drying converts some all-trans lycopene to cis-forms which are less colored. The cis-isomers are also more easily oxidized. Re-isomerizaton to the more stable all-trans form is favored by increased storage temperature, but so is oxidation. Better color retention was achieved at 68°F than at 36°F or 14°F in foam-mat dried tomato powder samples stored in air. An increase in tomato odor also occurred at 68°F. Color loss due to oxidation was reduced by nitrogen packing. As autoxidation advanced the lycopene molecule was split into smaller molecular fragments. Typical hay- or grass-like odors evolved. At 98.6°F nonenzymatic browning occurred causing rapid darkening but no significant loss of carotenoid pigments.

Nonenzymatic browning leads to loss of acceptable color in many dehydrated fruits and vegetables. Resnik and Chirife (1979) studied nonenzymatic browning in dehydrated apples. Organic acids in the apple catalyze degradation of fructose and glucose to furfurals which condense with nitrogenous compounds to form brown pigments. There was an accumulation of 5-hydroxy-methyl-furfural (5-HMF) during heat induced browning. The apparent activation energy for formation of 5-HMF increased with decreased moisture content. This decreased reaction rate was due to reduced mobility of sugars and organic acids which catalyze the reaction.

Draudt and Huang (1966) studied the effect of moisture on browning of freeze-dried peaches and bananas. Samples were stored at 82°F. Little browning occurred during 6 months storage at moisture contents below 5%. Above 5% moisture browning increased rapidly with increasing moisture content up to 12%. This browning was believed to be nonenzymatic. Several carbonylamine browning intermediates were identified.

Browning of dehydrated sulfited white potatoes, carrots and cabbage was studied by Legault et al. (1951). The rate of browning was affected by both moisture and temperature. It was found that the rate of browning in these vegetables increased approximately 6 to 8 fold per 18°F rise in temperature. The effect of temperature became progressively greater with decreasing moisture content. Rate of browning decreased between 1.2 to 4.6 fold per 2% decrease in moisture. This effect of moisture increased as the product approached complete dryness. Package atmosphere showed little effect on the rate of browning in these three vegetables.

Mizrahi et al. (1970) studied the rates of browning in dehydrated unsulfited cabbage at four different temperatures (86, 98, 112, and 126°F) and at seven different moisture contents (1.4, 2.1, 3.2, 5.6, 8.9, 11.7, and 17.9%) at each temperature. Browning increased linearly with time, except in the low-moisture samples stored at 86°F. Rates of browning correlated with moisture and temperature. Equations were devised by which storage at high moisture and temperature can be used to predict ambient nonenzymatic browning of dehydrated vegetables.

Earlier Gooding and Duckworth (1957) studied the feasibility of accelerated storage test to predict the shelf life of dehydrated vegetables in tropical climates. The rate of browning in dehydrated potatoes stored at 131°F was closely correlated to the rate of browning at 98°F, only approximately 28 times faster.

The storage stability of freeze-dried, drum-dried and air-dried bananas was compared by Brekke and Allen (1967). Moisture content was 17.5% for the air-dried sample, 3.6% for the freeze-dried and 2.7% for the drum-dried bananas. Air-dried samples stored at 100°F were black after 4 months storage. After 12 months, air-dried bananas stored at 75°F were brown but those stored at 55°F were only slightly different than the freshly dried material. Drum-dried and freeze-dried samples were acceptable after one year storage at 75°F. Differences were probably more related to moisture level than drying procedure. A bitter flavor was detected in the browned samples.

Dehydrated carrots stored in oxygen develop an off-flavor, characterized by a violet odor. Falconer et al. (1964) established a direct relationship (correlation coefficient 0.94) between the loss of carotene and off-flavor development detected by taste panels in dehydrated carrots. The off-flavor was thought due to the formation of beta-ionone and other oxidation products of the carotene. Walter et al. (1970) also attributed off-odors and off-flavors in dehydrated sweet potatoes to oxidation products of carotene.

Dehydrated whole egg powders rapidly develop a characteristic off-flavor during storage. To determine the origin of this off-flavor, Fevold et al. (1946) fractionated whole eggs into egg white, egg yolk, lipovitellin, livetin, acetone-soluble lipids and crude acetone-insoluble phospholipids. Fractions were stored at 36.5°F and later combined with unstored fractions to form whole egg powder for palatability evaluation. The major off-flavor arose from oxidation of the phospholipid fraction of the egg yolk. Storage of the egg powder in carbon dioxide or nitrogen prolonged its storage life.

Rancid flavor was detected by taste panels in air-packed dehydrated potatoes stored at 73°F within three months (Sullivan et al. 1974). Samples stored under nitrogen did not exhibit a flavor change. Potatoes with higher sugar content developed more browning and a "toasted" or "burnt" flavor during storage.

Wuhrmann et al. (1959) studied the effects of storage temperature and atmosphere on the stability of dehydrated soup mixes. Samples were stored at 32 or 100^{o}F in air or nitrogen. After one month's storage there were significant flavor differences among the samples due to both temperature and atmosphere. Samples stored at 32^{o}F were more stable than samples stored at 100^{o}F. Samples stored under nitrogen developed less off-flavor than those stored under air. The protective effect of nitrogen lessened as storage time increased. At 3 months the nitrogen-packed 100^{o}F samples had more off-flavor than its oxygen-packed counterpart. The effect of temperature was enhanced with time while that of atmosphere became insignificant.

Villota et al. (1980b) after conducting an extensive literature survey established a model correlating shelf life of dehydrated vegetable products with storage conditions. The model postulated was:

$$\ln t_f = a_o + a_1 (1/T) + a_2 (m - BET)$$

where t_f = time of failure, days; T = temperature, ^{o}Kelvin; m = moisture, gH_2O/g sample; BET = monolayer moisture content, gH_2O/g sample; a_o, a_1, a_2 = constants. They theorized that only water in excess of the monolayer value increased the mechanisms of food deterioration. The temperature function is based on the Arrhenius equation. Statistical fit was excellent in all cases where flavor was the cause of failure. The correlation was less perfect in some cases where color was the cause of failure. Products packed in nitrogen exhibited higher activation energies than their air-packed counterparts. Activation energies for air-packed products were in the range of lipid oxidation whereas those of nitrogen-packed products were higher since failure was mostly due to nonenzymatic browning. Differences between powdered foods which were air- and nitrogen-packed were less, possibly due to oxygen entrapment.

Nutrient Stability

The same conditions that determine sensory acceptability (oxygen concentration, moisture content, temperature and time of storage), also affect overall nutrient retention in dehydrated foods.

Tressler et al. (1943) conducted an early study on vitamin loss during storage in dehydrated vegetables. Dehydrated rutabagas, beets, cabbage and potatoes were packaged three ways: 1) in tightly closed glass jars, 2) under carbon dioxide in tightly closed glass jars and 3) in either moisture-proof cellophane or pliofilm bags and stored at -40, 33, 58 and 75^{o}F. Thiamin was stable for three to four months under all conditions studied. Carotene and ascorbic acid were stable at -40^{o}F but had considerable loss at higher temperatures. Rutabagas stored at either 58 or 75^{o}F lost over 50% ascorbic acid in 4 months and 70% carotene in 12 months. Storage under carbon dioxide reduced the rate of carotene loss but had little effect on ascorbic acid loss. Moisture content of the vegetables studied was 5-9%.

Morgan et al. (1945) studied the nutrient loss in vegetables during dehydration and storage. Carrots, spinach, broccoli, green peas, and snap beans were dehydrated, stored in tightly closed glass jars at 32, 68, and 86°F and evaluated for nutrient content after 3 to 4 months storage. Insignificant amounts of ascorbic acid were lost from spinach and carrots stored at 68°F for 4 months. Broccoli stored at 68°F for 3 months lost 40% thiamin, but spinach had negligible thiamin loss. No further storage data was reported.

Mallette and Dawson (1946) studied vitamin loss in dehydrated cabbage, Irish potatoes and sweet potatoes stored under controlled conditions of temperature, moisture, and atmosphere. In carbon dioxide-packed cabbage stored for one year, there was no significant loss of thiamin, even at 95-100°F. Ascorbic acid content remained relatively constant at 40-50°F. Fifteen percent ascorbic acid was lost at 70-80°F storage, and over 80% in just 6 months at 95-100°F storage. Potatoes lost considerable ascorbic acid during dehydration. The remaining ascorbic acid deteriorated rapidly especially at high storage temperatures. Sweet potatoes lost 60% ascorbic acid but only 20% carotene in 4 months at 95-100°F.

Heberlein and Clifcorn (1944) studied the effect of packaging and storage on the vitamin content of eleven dehydrated fruits and vegetables. Samples were packed in air, carbon dioxide or nitrogen in sealed metal cans or packaged in paper cartons and stored at room temperature (75-80°F), 98°F or 130°F. They were evaluated at 2 weeks, 1, 2, 3, 6, 9, and 12 months. Ascorbic acid and carotene were better retained in inert atmospheres. Carbon dioxide protected as well as nitrogen. Storage atmosphere had no significant effect on thiamin. Increased storage temperature adversely affected the retention of all three vitamins. Vitamin content in most products declined rapidly at first and then leveled off between 3-6 months.

Beta-carotene

Walter et al. (1970) studied the autoxidation of carotenoids in dehydrated sweet potato flakes (DSF) using ^{14}C-beta-carotene to identify the end products. Approximately 75% of the beta-carotene was stable, however that beta-carotene which was not stable was rapidly oxidized to lower molecular weight products, some of which were volatile. These volatile oxidation products were responsible for the off-odor and possibly the off-flavor associated with stored DSF. They postulated that most of the carotene was protected by being embedded in an oxygen impermeable mass.

Beta-carotene decoloration was studied in low moisture microcrystalline cellulose with 5% beta-carotene systems by Chou and Breene (1972). Beta-carotene oxidation which decolorizes the pigment was detected by changes ir spectral reflectance. Samples were dried (held over solid $CaCl_2$) or adjusted to 0.44 water activity (a_w) and stored at 31, 68, and 95^oF. Increased moisture in the system reduced the rate of oxidation, whereas higher temperatures increased the rate of oxidation.

Ayra et al. studied the effects of a_w on beta-carotene degradation in a model system (1979a) and in dehydrated carrots (1979b). Beta-carotene impregnated cellulose powders were adjusted to 0.00, 0.22, 0.33, 0.43, and 0.73 a_w and stored in dark desiccators at room temperature. Oxygen was replenished every other day by opening the desiccators for two minutes. Beta-carotene degradation significantly decreased with increased a_w even at levels above the monolayer of moisture. With dehydrated carrots treated similarly the maximum stability for beta-carotene was at 0.43 a_w (8.8-10.0% moisture), above or below which carotene destruction increased significantly. Increased mobility of catalysts and exposure of new sites due to swelling were thought to account for the increased destruction at higher a_w.

Haralampu and Karel (1983) studied the effect of a_w on beta-carotene degradation in dehydrated sweet potatoes. A_w ranged from 0.02 to 0.75. Beta-carotene degradation was inversely proportional to a_w throughout the entire range. Contrary to the results of Ayra et al. (1979b) in this food system there was no increased degradation at high a_w's.

Goldman et al. (1983) studied the decoloration of 0.4% beta-carotene on microcrystalline cellulose stored at 95°F. Headspace oxygen ranged from 0 to 20.9% and a_w ranged from 0 to 0.84. The presence of oxygen in the headspace was a critical factor in beta-carotene degradation in the dry system, even at low oxygen concentrations (1.0-2.0%). Forty percent beta-carotene was lost in 40 days at 1.0% oxygen and 70% at 2.0% oxygen; however, degradation was only 12% in 60 days at 0 headspace oxygen. The effect of oxygen was also evident at high concentrations (10.0-20.9%). The limiting factor was the absorbed oxygen, a function of partial pressure and the nature of the absorbant. Increased a_w reduced the rate of oxidation throughout the entire range tested.

Beta-carotene decoloration at low oxygen was studied by Teixeira Neto et al. (1981). The model system used was a mixture of 10% microcrystalline cellulose with nonfat dry milk, coated with a 3% beta-carotene in chloroform solution and stored at 98°F. In the 1.0-2.0% oxygen range, rate constants were a function of the headspace oxygen concentration; however there was little change in the rate constant from 2-21% headspace oxygen. In this system the protective effect of lower oxygen was substantial only at concentrations below 2.0%.

Kinetic equations for beta-carotene degradation accounting for both the effect of oxygen and moisture were formulated by Saguy et al. (1985), using microcrystalline cellulose model systems. The predicted retention correlated well with observed retention. Degradation occurred faster under conditions of depleting oxygen than at static conditions where oxygen was constantly repleted. Oxygen content of dehydrated foodstuffs in sealed containers is depleted during storage due to oxidation.

Stephens and McLemore (1969) stored dehydrated carrot flakes for two years at 68°F. Beta-carotene in carrot flakes packed in nitrogen (less than 2% oxygen) decreased from 1200 to 1050 ppm in two months whereas carrot flakes packed in air decreased to 400 ppm in the same amount of time. Beta-carotene content thereafter remained constant in both samples.

Ramakrishnan and Francis (1979) studied carotenoid stability in model systems of cellulose or starch equilibrated under different relative humidities and stored at 77^{o}F in dark glass bottles. Air was added periodically to ensure sufficient oxygen. Water exerted a protective effect in both systems. Starch also had a protective effect against carotenoid oxidation.

Ascorbic Acid

The effects of moisture and oxygen on ascorbic acid retention in dehydrated orange juice were studied by Karel and Nickerson (1964). Samples were adjusted to various a_w's, packed in air or thoroughly deaerated under vacuum (absolute pressure less than 100 microns) and stored at 98^{o}C. Ascorbic acid destruction increased with increased moisture. Increased moisture decreased "sample viscosity" which increased mobility of the reactants, thus increasing the rate of ascorbic acid destruction. The effect of oxygen was insignificant.

Destruction of ascorbic acid in dehydrated tomato juice (DTJ) was studied by Riemer and Karel (1978a). DTJ samples were stored at 68, 98 and 124^{o}F at a_w's of 0.11, 0.32, 0.57, and 0.75 and oxygen concentrations of 0, 0.2, 3.5, 7.2 and 21%. Ascorbic acid retention was a function of a_w and temperature but not oxygen concentration. These researchers later showed that the destruction of ascorbic acid in DTJ is largely anaerobic, (Riemer and Karel 1978b). Again there was no significant difference in ascorbic acid degradation between air and O_2-free storage. Under O_2-free conditions entrapped oxygen was not sufficient for aerobic degradation.

Kirk et al., (1977) studied ascorbic acid degradation in a model system similar to a dry breakfast cereal fortified with ascorbic acid. Samples were packed in thermal death time (TDT) 208 X 006 cans (no headspace oxygen) or 303 X 406 enamel cans and stored at 40, 68, 86 or 98^{O}F. Ascorbic acid stability decreased with increasing a_w's and temperatures. Under similar a_w's and temperatures, rate constants for ascorbic acid destruction were greater in 303 cans than in TDT cans, indicating an oxygen effect in the destruction of ascorbic acid. A similar study by Dennison and Kirk (1978) supports the oxygen effect on ascorbic acid degradation in model food systems stored at room temperature or below. At 98^{O}F and above the solubility of oxygen decreases and there is no longer a significant effect. Perhaps the absence of an oxygen effect in dehydrated orange juice reported by Karel and Nickerson (1964) and DTJ reported by Riemer and Karel (1978a&b) reflects a stabilizing influence of low pH. Labuza and Tannenbaum (1972) suggest the difference might be moisture related. At low moisture ascorbic acid would be destroyed mainly by oxidation, but at higher a_w's nonenzymatic browning, which is independent of oxygen, would be the predominating mechanism of ascorbic acid destruction.

Ascorbic acid degradation was dependent on the dissolved oxygen concentration in a liquid model system at pH 6.1 (Eison-Perchonok and Downes, 1982). The reaction rate was also temperature dependent, occurring significantly faster at higher temperatures.

Thiamin

Dwivedi and Arnold (1973) reviewed thiamin degradation in food products and model systems. Temperature, pH and time of storage are the most important factors affecting the loss of thiamin. Thiamin in solution is destroyed via two pathways; 1) breaking of the CH_2 "bridge" yielding the pyrimidine and thiazole moieties and 2) breakdown of the thiazole ring with the production of hydrogen sulfide. Breakage at the methylene "bridge" is the major pathway in aqueous solutions at pH 6.0 or below. At pH 7.0 and above, hydrogen sulfide appeared to be a major product. In foods systems thiamin may also be destroyed by reactions with carbohydrates in a Maillard type reaction. This results in browning and the production of off flavors. Proteins and soluble starch may protect thiamin in food.

Dennison et al. (1977) studied thiamin stability in three commercially prepared dry cereals and a model system simulating a breakfast cereal. These were stored in TDT cans at various a_w's and temperatures. Thiamin retention was approximately 100% after eight months storage at temperatures at or below 98°F and a_w's at or below 0.65. At 113°F and a_w's greater than 0.24 thiamin was destroyed via Maillard-type reactions, and browning was very pronounced. Samples were also stored in paperboard boxes which allowed oxygen transmission. After eight months less than 2% of the thiamin was destroyed, which suggested thiamin destruction in dehydrated foods at 98°F is independent of oxygen.

Thiamin stability in pasta products was studied by Kamman et al. (1981). Thiamin loss increased with increasing a_w and storage temperature. At a_w 0.65 and 77°F approximately 10% thiamin loss occurred during one year storage; at 95°F 40% was lost, and at 113°F over 80%. The authors concluded that at normal storage conditions, with a_w's 0.44-0.50 and temperatures below 86°F thiamin losses should be insignificant during 18-21 months storage.

Salunke et al. (1979) found thiamin loss to be significant in freeze-dehydrated military rations stored for 44 months at 40, 70 and 100°F. Stored items included beef hash, beef stew, chicken stew, spaghetti with meat sauce, chili con carne with beans, chicken and rice, pork with escalloped potato, and beef and rice. Thiamin losses were 2-9% at 70°F and 10-20% at 100°F. There was no significant loss of thiamin in items stored at 40°F.

The stability of thiamin in various dehydrated foods was compared by Rice et al. (1944). When stored for 21 days at 120°F, thiamin was retained 100% in dehydrated skim milk, 94% in meat-cereal mixtures, 85% in ground whole wheat, 35% in dehydrated egg and 18% in dehydrated pork. Thiamin in dehydrated pork was readily destroyed at temperatures of 98°F and above. Thiamin appeared to be more stable in carbohydrate rich foods. Atmosphere had little effect on thiamin stability. Increasing moisture increased thiamin loss in dehydrated pork up to a maximum at 6% moisture.

Dehydrated foods are complex systems. In addition to storage conditions, quality retention is dependent upon the initial quality of the product, methods of processing, and component interactions specific to each product. The purpose of this study was to monitor the quality of several dehydrated foods over an extended (three year) storage period. The effects of storage temperature, time and reduced oxygen on nutrient content and consumer acceptability were investigated.

Materials and Methods

Food system

Twenty commercially prepared low moisture products: apple slices, banana slices, green beans, small white (navy) beans, butter product, carrots, egg mix, nonfat-dry milk, rolled oats, peach slices, peanut butter powder, potato granules, salad blend, elbow spaghetti (macaroni), stroganoff-style casserole, tomato crystals, vegetable noodle soup, texturized vegetable protein (TVP), whole wheat and baker's yeast, packaged in No. 2 1/2 or No. 10 sealed metal cans were obtained from the Vacu-dry Company, Emeryville, CA., (currently located in Sebastopol, CA.). Half of the cans for each product were nitrogen-pack (less than 2% residual oxygen); the other half were air-pack (17-21% oxygen). Table 1 lists product description at time of pack. Samples were shipped to Brigham Young University, Provo, UT, where they were stored at 40, 70 and 100^{o}F, and evaluated at 6, 12, 18, 24, 30, and 36 months. At least 20 ounces (one to four cans depending on net weight) of each product per treatment, per time period were stored.

TABLE 1 - PRODUCT DESCRIPTION AT TIME OF PACK

PRODUCT	RESIDUAL NITROGEN	OXYGEN ATMOS.	SO_2	MOISTURE	COMMENTS
Carrots, diced, variable cut, Red Core Cantenay variety.	0.8%	18.4%	10 ppm	4.5%	Product sprayed with starch solution as antioxidant.
Potato granules, instant.	1.3%	16.3%	310 ppm	5.8%	Contains sodium - acid pyrophosphate, and BHA
Green beans, cross-cut.	1.0%	18.2%	690 ppm	4.4%	
Salad blend,	0.6%	19.6%	810 ppm	3.5%	Sodium sulfite, sodium bisulfite, and starch as preservatives.
Rolled oats, "quick cooking"	1.2%	20.0%	---	7.7%	Protein not less than 16%. Ovenized 12 hours at mill.
Banana slices.	0.8%	19.3%	---	1.6%	
Texturized vegetable protein (TVP) Beef flav.	0.8%	17.5%	---	6.3%	Not fortified.
Milk, non-fat dry.	0.7%	18.2%	---	1.8%	Grade A, low heat-spray process, pasteurized.
Butter.	1.3%	18.0%	---	0.8%	BHA added.
Egg product, dried.	1.5%	18.0%	---	2.4%	Contains artificial color.

TABLE 1 - CONTINUED

PRODUCT	RESIDUAL OXYGEN NITROGEN	RESIDUAL OXYGEN ATMOS.	SO_2	MOISTURE	COMMENTS
Tomato crystals.	0.8%	18.5%	530 ppm	3.7%	
Vegetable noodle soup.	0.9%	18.0%	50 ppm	5.9%	Utilizes medium egg noodle (enriched).
Stroganoff-style casserole.	0.8%	18.0%	---	6.4%	Utilizes wide egg noodle (enriched).
Apple slices, perforated, Rome Beauty variety.	1.2%	19.0%	580 ppm	1.7%	
Peach slices, Freestone, Elberta variety.	0.9%	18.0%	2140 ppm	5.2%	Washed and dried by Valley View Packing Co.
Whole wheat, hard red winter variety.	0.7%	17.0%	---	8.7%	Double cleaned.
Small white beans (navy).	0.2%	19.0%	---	7.8%	Double cleaned.
Elbow spaghetti.	2.4%	19.0%	---	9.3%	Enriched.
Peanut butter powder.	1.1%	16.3%	---	1.2%	Dry, roasted peanuts-milled to flour.
Yeast, Active	0.9%	17.4%	---	6.1%	

Residual oxygen measurement

The percent oxygen contained within each can was measured using an Altex Model #0260 Oxygen Analyzer. The electrode was enclosed in a 10 ml disposable syringe with a can-lid piercing needle on the end. The altitude change from Emeryville to Provo, (4000 foot difference) caused pressure in most cans which flushed and filled the syringe with the interior can atmosphere. Difficulties arose when pressures were not adequate. Values recorded are the average for each treatment.

Odor determination

The presence of off-odors was determined subjectively by two or more experienced analysts immediately upon opening the cans.

Clumping determination

Degree of clumping was determined subjectively using the following scale:

Light clumping - falls apart as poured from container.

Medium clumping - requires some moderate pressure to break apart.

Heavy clumping - will not unclump until pried apart or immersed in water.

Sample preparation

At the completion of each storage period, samples to be tested were transferred to 40°F storage. One product was opened per day for the next 20 working days. All product from each treatment (stroganoff and vegetable soup samples excluded), was mixed thoroughly in a large bowl. Taste panel samples were placed back in the metal cans, sealed with a plastic lid and stored at 40°F until evaluated, (usually a couple of days). An adequate-sized sample for the analytical work was dry-homogenized in a Waring Blendor and stored at -4°F in vapor proof polyethylene bags until time of analysis, (up to 6 months).

Moisture content measurement

Moisture content was determined by drying the freshly homogenized samples for a minimum of 12 hours in a vacuum oven at 176°F under 25 inches of mercury, vacuum. Sample size was that which would nearly fill a 57 mm aluminum weighing dish and ranged from 5-30 grams.

Beta-carotene determination

Beta-carotene content was calculated from the pigment absorption at 450 nm after extraction and purification in acetone-hexane (AOAC, 1980, modified; appendix A).

Vitamin A in butter was determined by the Carr/Price method (AOAC, 1980, modified; appendix B).

Thiamin determination

Thiamin was determined by the fluorometric thiochrome assay (AOAC, 1980) with modifications in column exchange resin (Rettenmaier et al., 1979) and phosphatase enzyme and extraction solvent (MacBride and Wyatt, 1983) as detailed in appendix C.

Ascorbic acid determination

Total ascorbic acid was determined spectrophotometrically using the 2-4 dinitrophenylhydrazone procedure of Roe and Kuether (1943, modified; appendix D).

Taste panel

Approximately 25-30 panelists participated during each test period. Of these panelists, 8-10 were faculty/staff in the Food Science and Nutrition Department, who changed slightly during the 3-year study. The remaining panelists were university students who participated throughout one testing period but changed from semester to semester. Attendance of panelists was not always consistent. Extras participated to insure at least 20 panelists. Only 10-12 panelists were used at the 18 month evaluation. Panelists were instructed to rate the product quality as a dehydrated food but received no other formal training. One product was evaluated per sitting with one or two sittings per day. Samples were prepared as specified in appendix E. Panelists were presented with all six treatments, identified only by three-digit code number, in a randomized order and instructed to drink water between samples. Products were evaluated for flavor, color, texture and overall acceptability. Preference was indicated on a line scale with very poor at the left and very good at the right (appendix F). Marks were later translated into a numeric percentage (0 very poor - 100 very good). Samples were considered unfit for consumption and eliminated from testing if they received an average flavor score of less than 40 on the previous period's evaluation.

Data analysis

The data were analyzed using Rummage II (Scott et al., 1984) for multiple analysis of variance and covariance. Fisher's LSD was used to determine significant differences between treatments. Taste panel data were transformed using the arcsine(square root(x/100)) prior to analysis.

RESULTS AND DISCUSSION

Residual Oxygen

The mean residual oxygen of the air-packed samples is listed in Table 2. Figures 1 - 4 show the effect of storage time on the interior can oxygen of air-packed products. Initial values, taken upon arrival of the products at BYU, are not included in the figures but are listed in Table 2. Oxygen was depleted during storage due to oxidation reactions. Products with original moisture content below 2% (apple, 1.7%: banana, 1.6%; butter, 0.8%; milk, 1.8%; peanut butter, 1.2% H_2O) showed slow oxygen uptake (average value of 15% oxygen or more at 36 months) whereas many products with original moisture content above 5% (macaroni, 9.3%; potato, 5.8%; stroganoff, 6.4%; TVP, 6.3%; vegetable soup, 5.9%; wheat, 8.7%; yeast, 6.1% H_2O) absorbed oxygen more rapidly (average value less than 10% oxygen at 36 months). Carrots and eggs also absorbed oxygen rapidly. This seems contrary to some literature (Haralampu and Karel, 1983 and Ayra et al., 1979a & b) where oxidation was

TABLE 2 - RESIDUAL OXYGEN IN AIR PACKED LOW-MOISTURE FOODS.

		% OXYGEN		
	TIME	40 DEGREE N2 NO	70 DEGREE N2 NO	100 DEGREE N2 NO
APPLE	6 MONTH	19.92	19.98	19.32
	12 MONTH	19.75	19.90	20.67
	18 MONTH	20.58	20.52	19.72
	24 MONTH	19.67	19.60	16.65
	30 MONTH	19.42	19.40	18.35
	36 MONTH	20.50	20.57	18.05
BANANA	6 MONTH	18.10	19.60	17.45
	12 MONTH	21.57	18.10	17.47
	18 MONTH	18.90	17.63	12.83
	24 MONTH	18.90	16.20	16.17
	30 MONTH	19.20	16.60	7.97
	36 MONTH	19.63	16.37	8.70
BUTTER	6 MONTH	18.30	19.10	17.65
	12 MONTH	18.95	18.45	14.80
	18 MONTH	20.40	18.30	17.55
	24 MONTH	18.70	15.40	14.80
	30 MONTH	16.05	11.95	5.90
	36 MONTH	18.05	13.00	13.70
CARROT	6 MONTH	18.17	17.57	11.27
	12 MONTH	18.30	15.33	7.00
	18 MONTH	15.87	13.60	4.77
	24 MONTH	15.73	11.05	1.37
	30 MONTH	17.13	13.50	2.40
	36 MONTH	13.50	11.73	2.20
EGG	6 MONTH	18.70	17.40	18.85
	12 MONTH	18.80	14.65	15.95
	18 MONTH	19.05	19.95	20.10
	24 MONTH	17.45	10.80	2.15
	30 MONTH	17.10	12.70	3.35
	36 MONTH	15.00	8.60	1.75

TABLE 2 - CONTINUED

	TIME	% OXYGEN 40 DEGREE N2 NO	70 DEGREE N2 NO	100 DEGREE N2 NO
GR BEAN	6 MONTH	19.90	19.93	15.77
	12 MONTH	19.88	19.25	15.90
	18 MONTH	19.28	18.08	10.90
	24 MONTH	18.60	17.65	2.48
	30 MONTH	17.25	16.12	2.80
	36 MONTH	18.50	16.13	4.62
MACARONI	6 MONTH	19.70	20.20	14.10
	12 MONTH	21.10	18.20	19.20
	18 MONTH	20.10	16.30	3.20
	24 MONTH	19.50	13.40	3.50
	30 MONTH	20.60	15.40	19.30
	36 MONTH	20.30	8.10	2.30
MILK	6 MONTH	18.85	16.20	15.90
	12 MONTH	21.10	19.20	16.60
	18 MONTH	19.75	18.70	18.15
	24 MONTH	19.85	18.95	13.30
	30 MONTH	20.75	19.95	15.20
	36 MONTH	19.90	19.00	14.10
N BEAN	6 MONTH	19.10	19.40	15.90
	12 MONTH	18.50	19.70	15.50
	18 MONTH	19.60	17.50	9.80
	24 MONTH	20.30	16.30	10.40
	30 MONTH	19.80	18.60	5.80
	36 MONTH	18.90	8.40	5.40
OATMEAL	6 MONTH	21.55	19.30	17.20
	12 MONTH	20.50	18.40	19.05
	18 MONTH	15.70	16.45	12.05
	24 MONTH	17.80	14.80	9.35
	30 MONTH	17.55	17.45	14.05
	36 MONTH	17.25	12.90	6.80

TABLE 2 - CONTINUED

		% OXYGEN		
	TIME	40 DEGREE N2 NO	70 DEGREE N2 NO	100 DEGREE N2 NO
P BUTTER	6 MONTH	14.20	18.60	18.70
	12 MONTH	18.70	22.00	17.80
	18 MONTH	23.30	20.40	19.95
	24 MONTH	5.60	6.80	7.70
	30 MONTH	16.00	20.40	18.00
	36 MONTH	19.10	19.00	6.95
PEACH	6 MONTH	20.05	21.50	16.50
	12 MONTH	19.05	21.05	16.95
	18 MONTH	22.60	20.35	16.45
	24 MONTH	19.85	18.40	2.20
	30 MONTH	20.80	20.65	4.90
	36 MONTH	20.50	18.50	5.75
POTATO	6 MONTH	20.20	20.20	17.40
	12 MONTH	15.60	19.80	16.40
	18 MONTH	19.50	19.70	10.80
	24 MONTH	8.50	6.90	3.50
	30 MONTH	17.40	17.40	1.70
	36 MONTH	6.10	3.80	2.10
S BLEND	6 MONTH	20.07	19.40	9.97
	12 MONTH	21.02	18.20	3.27
	18 MONTH	20.72	20.58	6.70
	24 MONTH	17.50	14.32	1.62
	30 MONTH	18.92	16.02	6.05
	36 MONTH	17.02	13.20	2.18
STROG	6 MONTH	20.80	19.40	6.65
	12 MONTH	18.75	9.50	1.45
	18 MONTH	20.10	12.35	0.90
	24 MONTH	18.70	9.00	1.90
	30 MONTH	19.85	10.85	1.00
	36 MONTH	18.85	5.05	0.95

TABLE 2 - CONTINUED

	TIME	% OXYGEN 40 DEGREE N2 NO	% OXYGEN 70 DEGREE N2 NO	% OXYGEN 100 DEGREE N2 NO
TOMATO	6 MONTH	19.50	19.25	8.60
	12 MONTH	19.15	20.65	7.80
	18 MONTH	18.95	16.95	4.00
	24 MONTH	19.35	16.43	3.00
	30 MONTH	20.05	17.85	4.25
	36 MONTH	19.05	15.85	1.20
TVP	6 MONTH	17.75	14.10	21.65
	12 MONTH	19.75	21.45	20.85
	18 MONTH	13.20	20.00	19.55
	24 MONTH	13.15	11.90	7.30
	30 MONTH	14.65	12.00	1.70
	36 MONTH	7.30	5.80	0.45
VEG SOUP	6 MONTH	19.47	18.53	0.83
	12 MONTH	20.50	13.60	12.03
	18 MONTH	18.93	13.87	1.03
	24 MONTH	18.67	7.80	4.03
	30 MONTH	18.70	9.83	0.73
	36 MONTH	17.33	5.17	1.40
WHEAT	6 MONTH	18.80	17.90	14.10
	12 MONTH	20.00	22.70	20.10
	18 MONTH	18.50	20.70	8.00
	24 MONTH	19.00	12.50	2.30
	30 MONTH	18.60	19.60	17.20
	36 MONTH	16.00	8.60	5.60
YEAST	6 MONTH	17.20	15.25	7.35
	12 MONTH	16.60	19.95	3.00
	18 MONTH	12.70	19.65	0.90
	24 MONTH	16.85	18.55	2.15
	30 MONTH	15.80	16.95	1.95
	36 MONTH	9.35	2.50	0.45

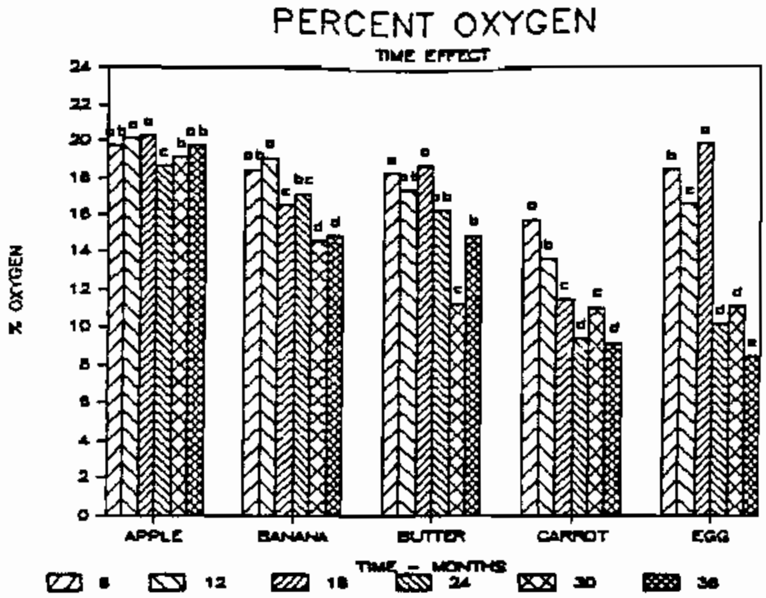

Figure 1 - Effect of storage time on the interior can oxygen of air-packed products: apple, banana, butter, carrot, egg. Significant differences, p = .05 indicated by different letters above treatment.

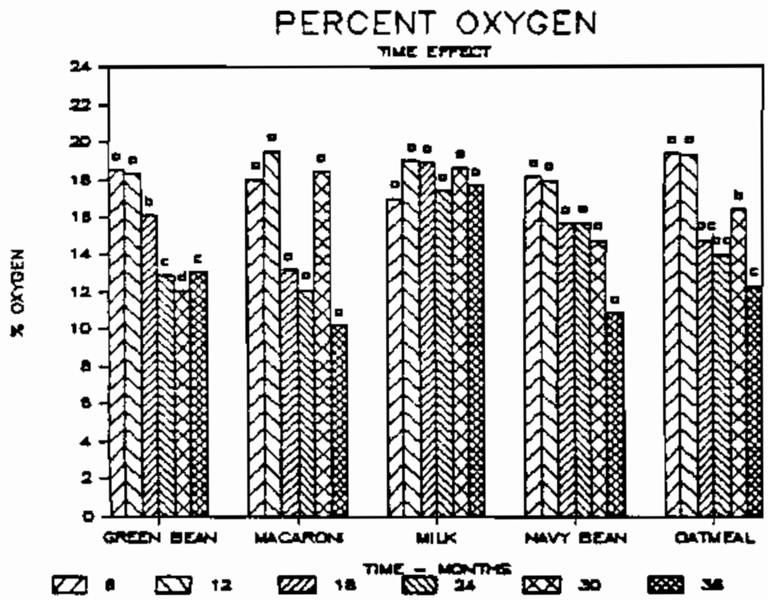

Figure 2 - Effect of storage time on the interior can oxygen of air-packed products: green bean, macaroni, milk, navy bean, oatmeal. Significant differences, p = .05 indicated by different letters above treatment.

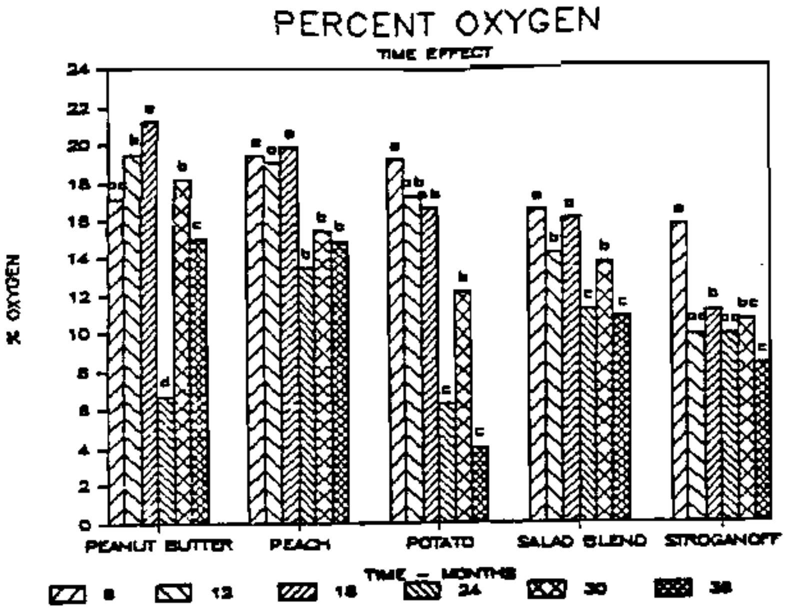

Figure 3 - **Effect of storage time on the interior can oxygen of air-packed products: peanut butter, peach, potato, salad blend, stroganoff.** Significant differences, p = .05 indicated by different letters above treatment.

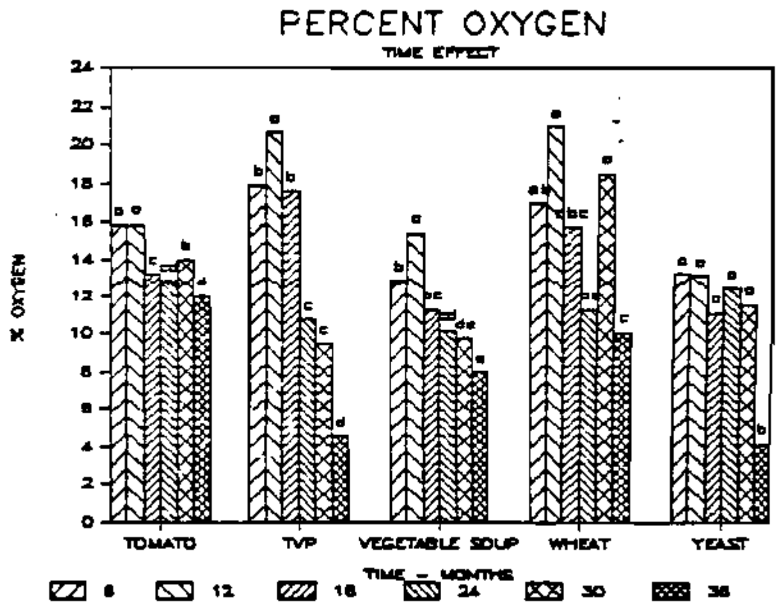

Figure 4 - **Effect of storage time on the interior can oxygen of air-packed products: tomato, TVP, vegetable soup, wheat, yeast.** Significant differences, p = .05 indicated by different letters above treatment.

reported to be inversely proportional to a_w in low-moisture products. Maximum stability of beta-carotene in dehydrated carrots was at 8.8-10.0% moisture a ccording to Ayra et al. (1979a). There are many other factors, however, including pigments, lipids, and pro-oxidants in food systems which affect oxygen uptake. Bishov et al. (1971) reported rapid oxygen uptake by dried meat and highly pigmented vegetables. Fruits and lesser pigmented vegetables showed slower oxygen uptake. The fruits (bananas, peaches and apples) in this study had slow oxygen uptake whereas carrots and tomatoes, both highly pigmented vegetables had more rapid oxygen uptake. Eggs contain iron compounds which probably catalyze the fat oxidation thus explaining their high rate of oxygen uptake.

Figures 5 - 8 show the effect of storage temperature on the residual oxygen. In all cases oxygen uptake was much faster at 100°F. This is consistent with Arrhenius kinetics, (Labuza and Riboh, 1982). After three years storage many air-packed products stored at 100°F (carrots, eggs, potatoes, salad blend, stroganoff, tomatoes, TVP, vegetable soup, and yeast) had residual oxygen below 2% (Table 2).

Nitrogen-packed products contained less than 2% oxygen initially. Changes in oxygen level were minimal. These values are not reported or discussed.

Odor Development

Table 3 lists the time when off-odors were first detected for each sample. Off-odors developed rapidly in products stored at

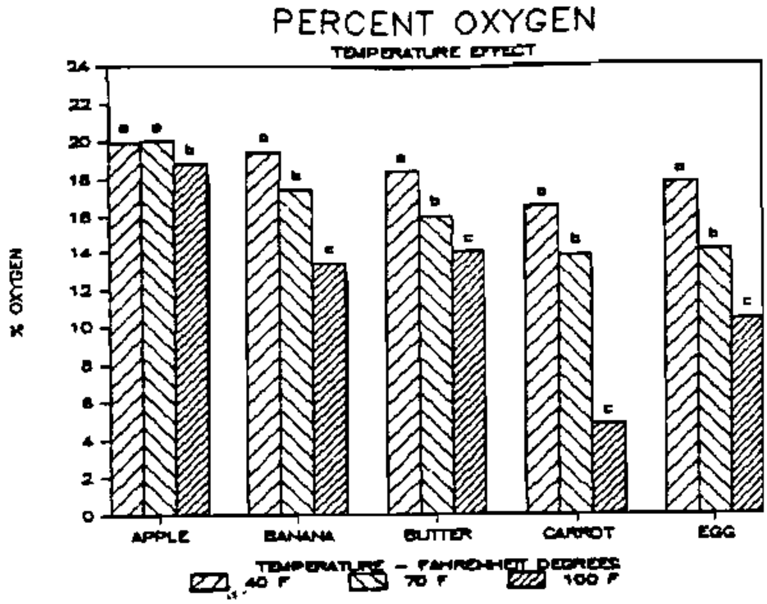

Figure 5 - Effect of storage temperature on the interior can oxygen of air-packed products: apple, banana, butter, carrot, egg. Significant differences, p = .05 indicated by different letters above treatment.

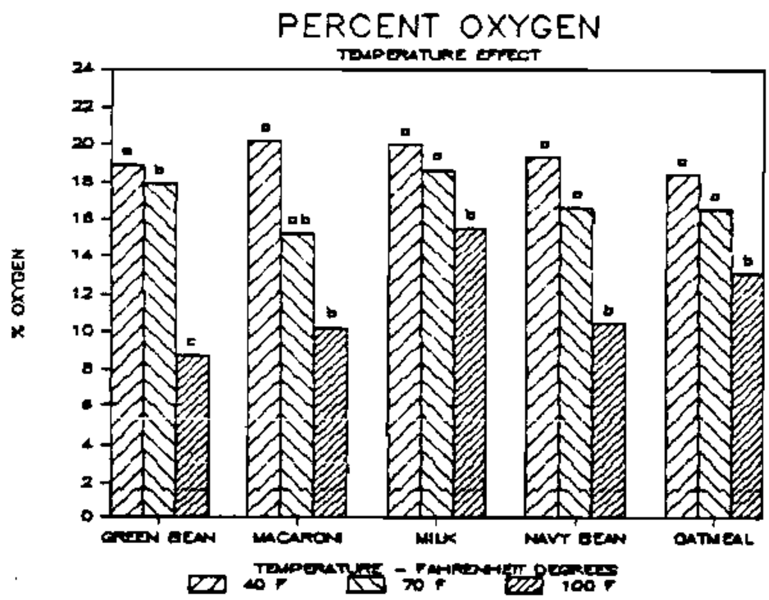

Figure 6 - Effect of storage temperature on the interior can oxygen of air-packed products: green bean, macaroni, milk, navy bean, oatmeal. Significant differences, p = .05 indicated by different letters above treatment.

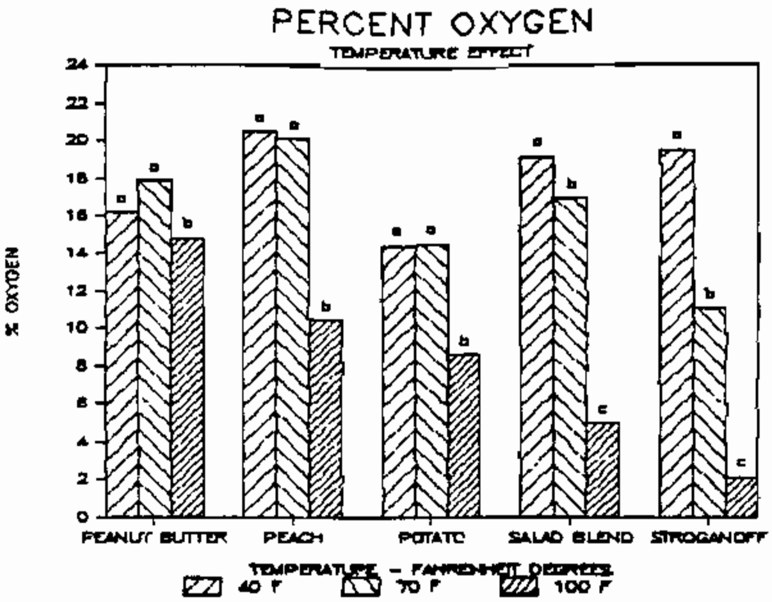

Figure 7 - Effect of storage temperature on the interior can oxygen of air-packed products: peanut butter, peach, potato, salad blend, stroganoff. Significant differences, p = .05 indicated by different letters above treatment.

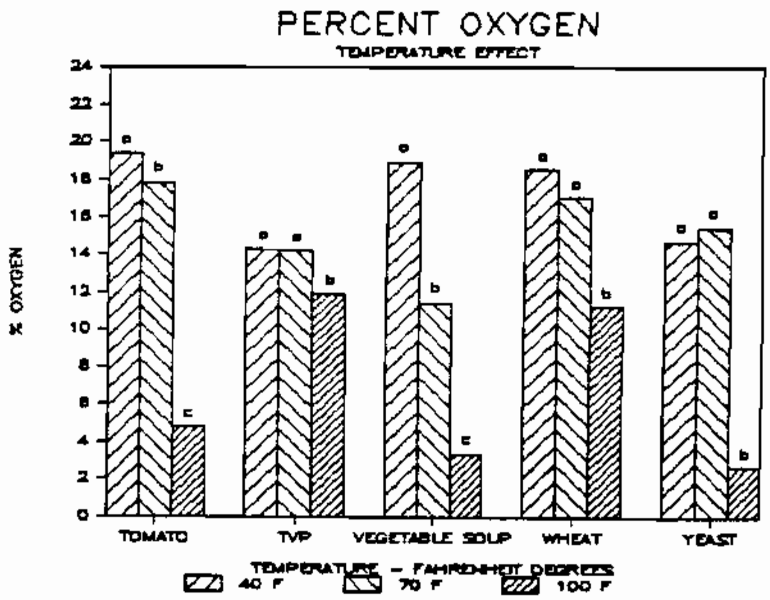

Figure 8 - Effect of storage temperature on the interior can oxygen of air-packed products: tomato, TVP, vegetable soup, wheat, yeast. Significant differences, p = .05 indicated by different letters above treatment.

TABLE 3 - OFF-ODORS, TIME OF FIRST DETECTION

PRODUCT	40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
APPLE			30 MONTHS		6 MONTHS	6 MONTHS
BANANA					6 MONTHS	6 MONTHS
BUTTER				30 MONTHS	6 MONTHS	6 MONTHS
CARROT			18 MONTHS	18 MONTHS	6 MONTHS	6 MONTHS
EGG			6 MONTHS	6 MONTHS	6 MONTHS	6 MONTHS
GREEN BEAN		36 MONTHS	30 MONTHS	36 MONTHS	6 MONTHS	6 MONTHS
MACARONI					30 MONTHS	30 MONTHS
MILK					18 MONTHS	18 MONTHS
NAVY BEAN			36 MONTHS		30 MONTHS	24 MONTHS
OATMEAL					6 MONTHS	18 MONTHS
PEACHES					18 MONTHS	18 MONTHS
PEANUT BUTTER			36 MONTHS		36 MONTHS	6 MONTHS
POTATO		36 MONTHS	36 MONTHS	36 MONTHS	24 MONTHS	24 MONTHS
SALAD BLEND	18 MONTHS	18 MONTHS	18 MONTHS	18 MONTHS	6 MONTHS	6 MONTHS
STROGANOFF			24 MONTHS	24 MONTHS	6 MONTHS	6 MONTHS
TOMATO				30 MONTHS	24 MONTHS	24 MONTHS
TVP		36 MONTHS		36 MONTHS	6 MONTHS	6 MONTHS
VEGETABLE SOUP			36 MONTHS		6 MONTHS	6 MONTHS
WHEAT					36 MONTHS	36 MONTHS
YEAST			6 MONTHS	6 MONTHS	6 MONTHS	6 MONTHS

Odors were not recorded for the 12 month storage period.

$100^{\circ}F$. By 36 months off-odors were detected in all the products stored at $100^{\circ}F$, and in many products stored at room temperature ($70^{\circ}F$). Nitrogen packing did not significantly retard the onset of off-odors, however the off-odors present were different indicating different pathways of degradation. Salad blend was especially susceptible to off-odor development, probably due to the cabbage sulfur compounds present.

Clumping

The degree of clumping found in the products is listed in Table 4. Five products were particularly prone to clumping: butter, eggs, stroganoff, vegetable soup and tomatoes. Clumping was more extensive at $100^{\circ}F$. Interior can atmosphere did not significantly affect the degree of clumping.

Moisture

Figures 9 - 12 show the effect of storage time on the moisture content of the samples. The percent moisture was somewhat erratic, however it did show a significant upward trend with time in all products. Water is produced in the nonenzymic browning reaction. Moisture increases were most dramatic in many of the products which experienced the greatest browning: apples, carrots, green beans, peaches, potatoes, salad blend and tomatoes (Tables 11 - 29).

The effect of storage temperature on moisture content is shown in Figures 13 - 16. The moisture significantly increased with increasing temperature in most but not all products. This would be expected in compliance with the Arrhenius equation.

TABLE 4 - CLUMPING DETECTED IN LOW-MOISTURE PRODUCTS.

	TIME	DEGREE OF CLUMPING					
		40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
APPLE	6 MONTH						
	18 MONTH						
	24 MONTH						
	30 MONTH			MC			MC
	36 MONTH					MC	MC
BANANA	6 MONTH						
	18 MONTH						
	24 MONTH						
	30 MONTH		LC				LC
	36 MONTH						
BUTTER	6 MONTH	LC	LC	LC	LC	MC	MC
	18 MONTH	LC	LC	LC	LC	MC	MC
	24 MONTH					HC	HC
	30 MONTH	LC	LC	MC	MC	HC	HC
	36 MONTH	LC	LC	MC	LC	HC	MC
CARROT	6 MONTH						
	18 MONTH						
	24 MONTH						
	30 MONTH						
	36 MONTH						

Clumping was not recorded for the 12 month storage period.
LC = light clumping MC = medium clumping HC = heavy clumping

TABLE 4 - CONTINUED

	TIME	DEGREE OF CLUMPING 40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
EGG	6 MONTH	LC	LC	LC	LC	MC	MC
	18 MONTH	LC	LC	LC	MC	MC	MC
	24 MONTH			LC	LC	MC	MC
	30 MONTH				LC	HC	HC
	36 MONTH			LC	LC	HC	HC
BR BEAN	6 MONTH						
	18 MONTH						
	24 MONTH						
	30 MONTH						
	36 MONTH						
MAC	6 MONTH						
	18 MONTH						
	24 MONTH						
	30 MONTH						
	36 MONTH						
MILK	6 MONTH						
	18 MONTH	LC	LC	LC		LC	LC
	24 MONTH	LC	LC	LC		LC	LC
	30 MONTH						
	36 MONTH						

TABLE 4 - CONTINUED

	TIME	DEGREE OF CLUMPING 40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
N BEAN	6 MONTH						
	18 MONTH						
	24 MONTH						
	30 MONTH						
	36 MONTH						
OATMEAL	6 MONTH						
	18 MONTH						
	24 MONTH						
	30 MONTH						
	36 MONTH						
P BUT	6 MONTH						
	18 MONTH	LC	LC	LC	LC	LC	LC
	24 MONTH	LC	LC	LC	LC	LC	LC
	30 MONTH						
	36 MONTH	LC	LC	LC	LC	LC	LC
PEACH	6 MONTH						
	18 MONTH						
	24 MONTH						
	30 MONTH					LC	
	36 MONTH					HC	LC

TABLE 4 - CONTINUED

		DEGREE OF CLUMPING					
	TIME	40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
POTATO	6 MONTH						
	18 MONTH						
	24 MONTH						
	30 MONTH						
	36 MONTH					LC	LC
S BLEND	6 MONTH						
	18 MONTH						
	24 MONTH						
	30 MONTH						
	36 MONTH						
STROB	6 MONTH	LC	LC	LC	MC	HC	HC
	18 MONTH		LC		MC	HC	HC
	24 MONTH			LC	LC	HC	HC
	30 MONTH			MC	MC	HC	HC
	36 MONTH			MC	MC	HC	HC
TOMATO	6 MONTH	LC				HC	HC
	18 MONTH	MC	MC	MC	MC	HC	HC
	24 MONTH	LC	LC	LC	LC	HC	HC
	30 MONTH			MC	MC	HC	HC
	36 MONTH			MC	MC	HC	HC

TABLE 4 - CONTINUED

	TIME	DEGREE OF CLUMPING					
		40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
TVP	6 MONTH						
	18 MONTH						
	24 MONTH						
	30 MONTH						
	36 MONTH						
VEGS	6 MONTH					HC	HC
	18 MONTH					HC	HC
	24 MONTH					HC	HC
	30 MONTH			MC	MC	HC	HC
	36 MONTH	LC	LC	HC	MC	HC	HC
WHEAT	6 MONTH						
	18 MONTH						
	24 MONTH						
	30 MONTH						
	36 MONTH						
YEAST	6 MONTH						
	18 MONTH						
	24 MONTH						
	30 MONTH						
	36 MONTH						

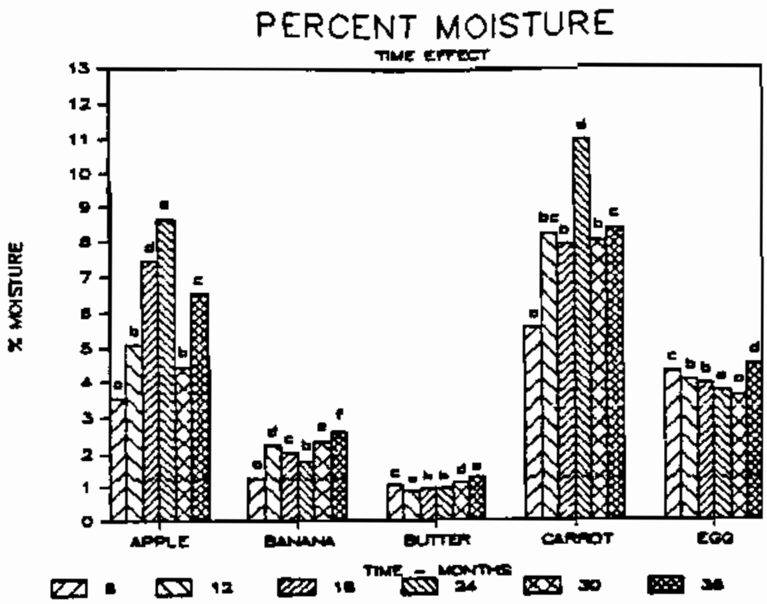

Figure 9 - Effect of storage time on moisture content of low-moisture products: apple, banana, butter, carrot, egg. Significant differences, p = .05 indicated by different letters above treatment.

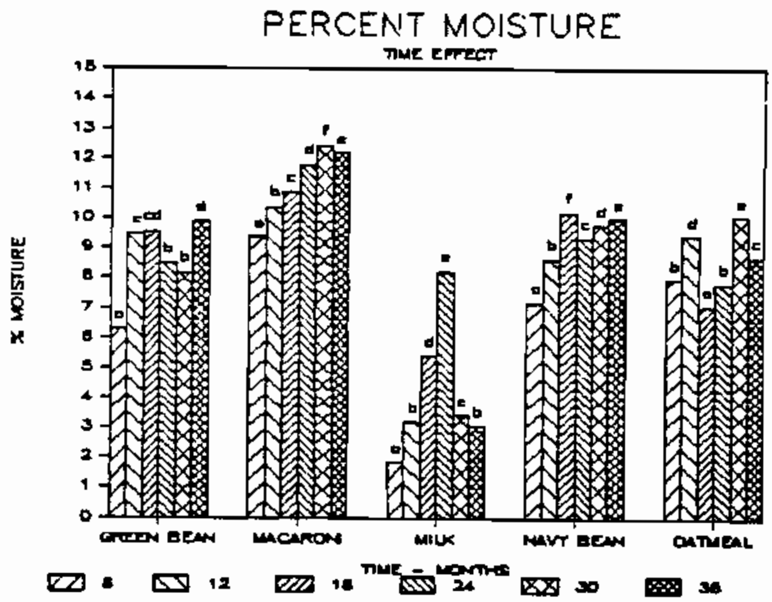

Figure 10 - Effect of storage time on moisture content of low-moisture products: green bean, macaroni, milk, navy bean, oatmeal. Significant differences, p = .05 indicated by different letters above treatment.

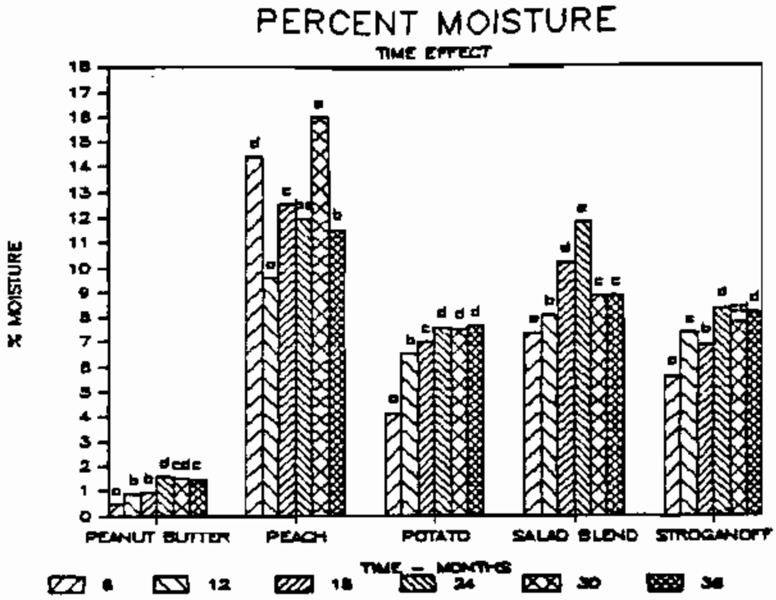

Figure 11 - **Effect of storage time on moisture content of low-moisture products: peanut butter, peach, potato, salad blend, stroganoff.** Significant differences, p = .05 indicated by different letters above treatment.

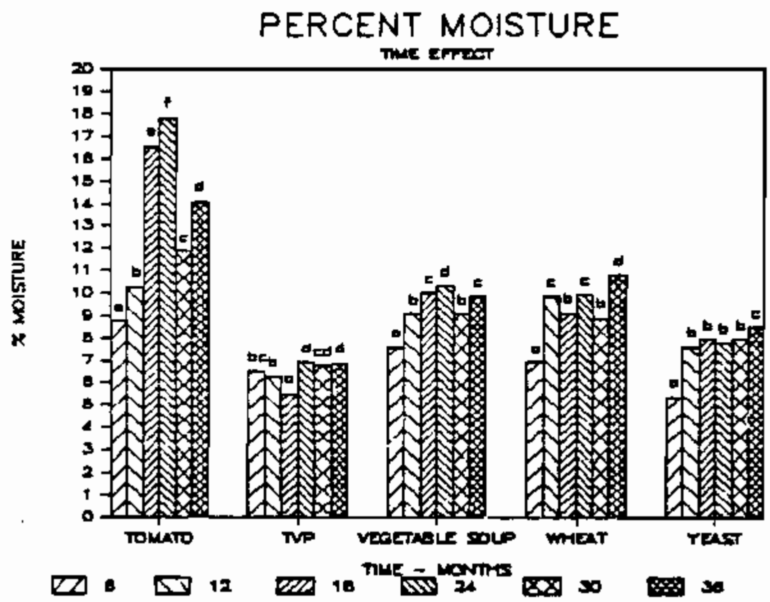

Figure 12 - **Effect of storage time on moisture content of low-moisture products: tomato, TVP, vegetable soup, wheat, yeast.** Significant differences, p = .05 indicated by different letters above treatment.

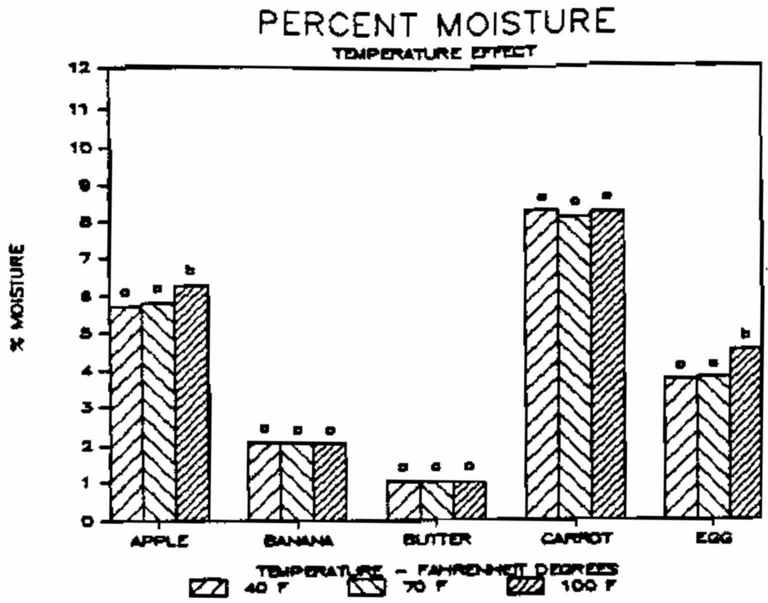

Figure 13 - Effect of storage temperature on moisture content of low-moisture products: apple, banana, butter, carrot, egg. Significant differences, p = .05 indicated by different letters above treatment.

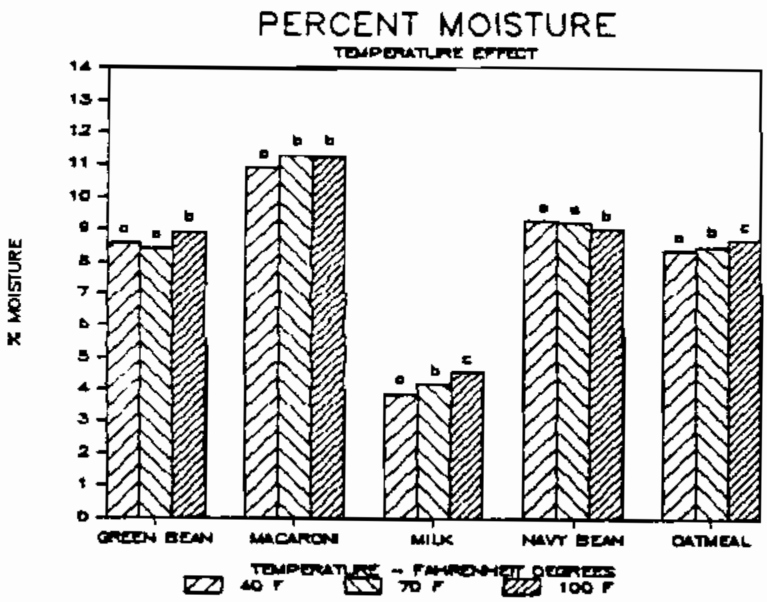

Figure 14 - Effect of storage temperature on moisture content of low-moisture products: green bean, macaroni, milk, navy bean, oatmeal. Significant differences, p = .05 indicated by different letters above treatment.

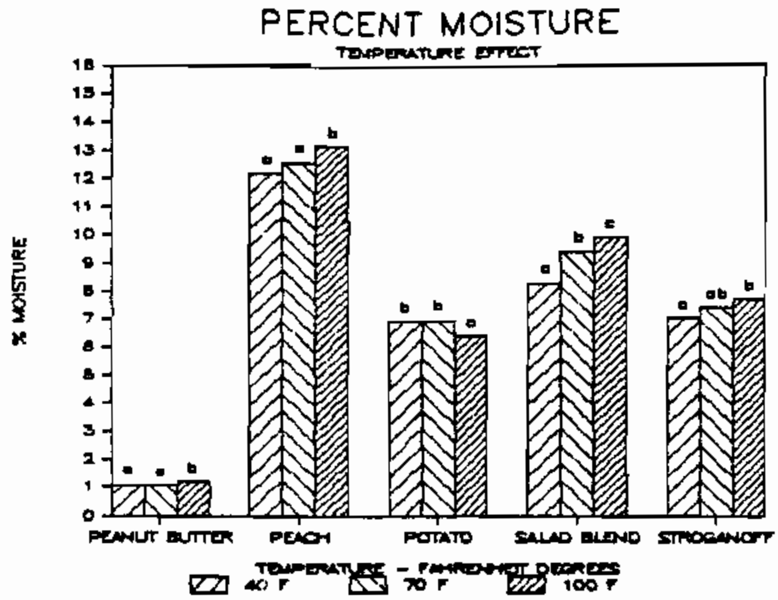

Figure 15 - Effect of storage temperature on moisture content of low-moisture products: peanut butter, peach, potato, salad blend, stroganoff. Significant differences, p = .05 indicated by different letters above treatment.

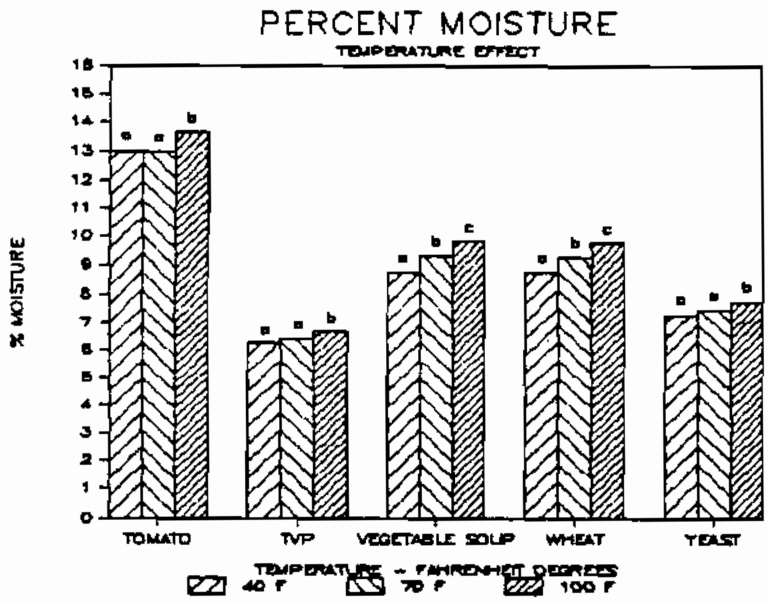

Figure 16 - Effect of storage temperature on moisture content of low-moisture products: tomato, TVP, vegetable soup, wheat, yeast. Significant differences, p = .05 indicated by different letters above treatment.

Figures 17 - 20 show the effect of nitrogen packing on the moisture content of the dehydrated products. This factor for most products was not significant. In only two products, apples and green beans was the difference enough to be of practical importance. In both cases moisture was higher in the nitrogen-packed samples.

The percent moisture for each treatment is listed in Table 5. Initial values are listed however not included in the graphs.

Beta-carotene

Table 6 lists the mean beta-carotene content, per treatment of the samples tested. Six low-moisture products, carrots, green beans, peaches, salad blend, tomatoes, and vegetable soup were significant sources of beta-carotene. Other products tested for beta-carotene but having only trace amounts were butter, macaroni, stroganoff, and TVP. Vitamin A was tested in butter and the results are listed in Table 7.

Initial beta-carotene values are low and assumed incorrect. Subsequent values for all products except peaches are consistently higher. Aluminum oxide was used initially as the absorbant for pigment separation. A magnesium oxide-filter aid mixture was used as the absorbant during subsequent testing periods. Much better yield and separation of pigments was achieved using magnesium oxide. Initial beta-carotene values are not shown in any of the graphs but are listed in Table 6.

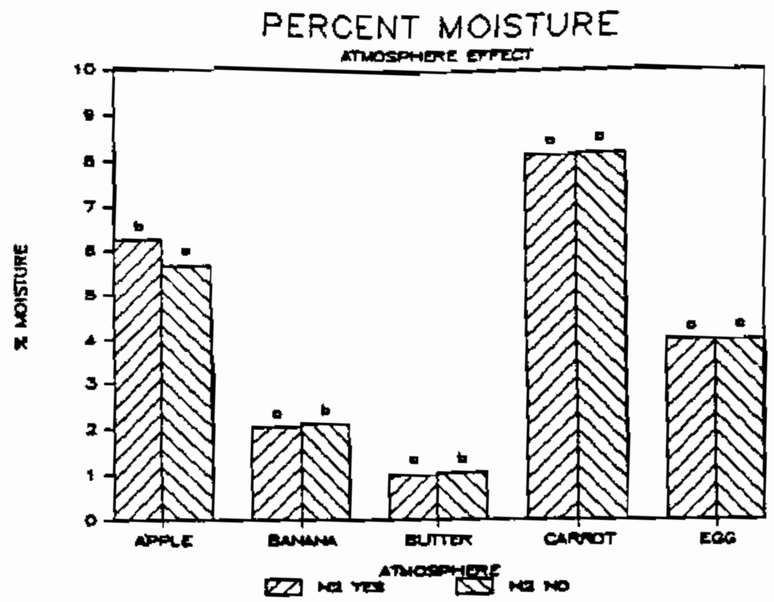

Figure 17 - Effect of interior can oxygen on moisture content of low-moisture products: apple, banana, butter, carrot, egg. Significant differences, p = .05 indicated by different letters above treatment.

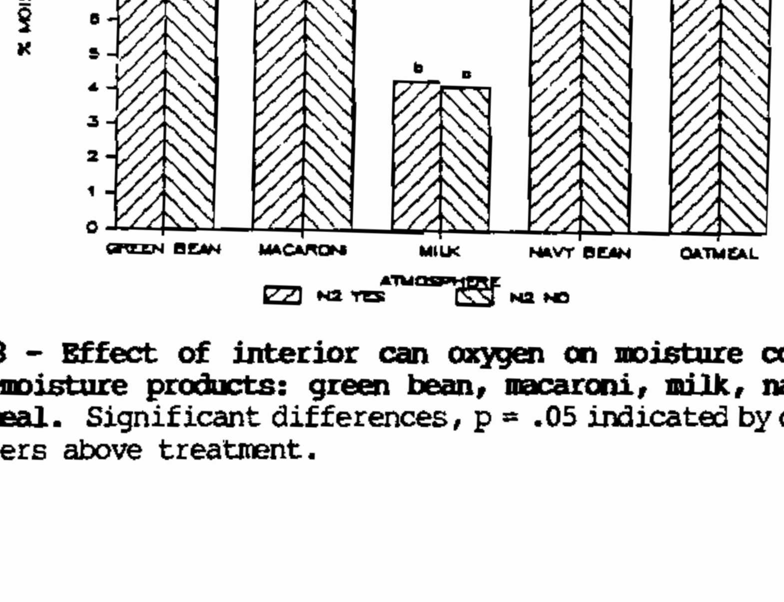

Figure 18 - Effect of interior can oxygen on moisture content of low-moisture products: green bean, macaroni, milk, navy bean, oatmeal. Significant differences, p = .05 indicated by different letters above treatment.

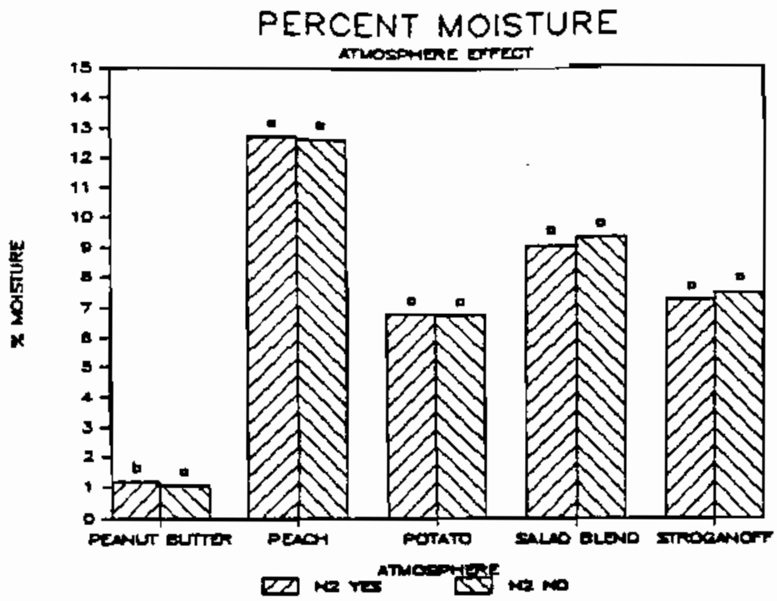

Figure 19 - Effect of interior can oxygen on moisture content of low-moisture products: peanut butter, peach, potato, salad blend, stroganoff. Significant differences, p = .05 indicated by different letters above treatment.

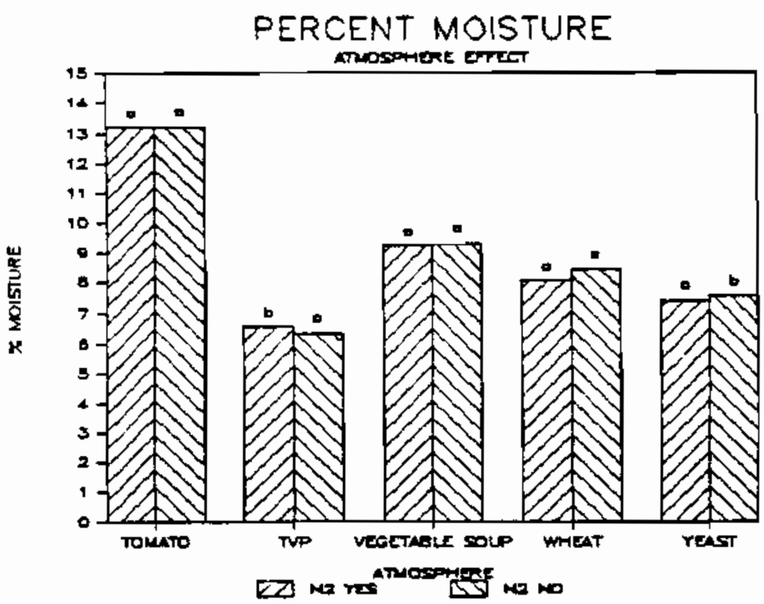

Figure 20 - Effect of interior can oxygen on moisture content of low-moisture products: tomato, TVP, vegetable soup, wheat, yeast. Significant differences, p = .05 indicated by different letters above treatment.

TABLE 5 - PERCENT MOISTURE OF LOW-MOISTURE PRODUCTS, TREATMENT MEANS.

	TIME	% MOISTURE					
		40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
APPLE	INITIAL	3.36					
	6 MONTH	3.37	3.88	3.78	3.23	3.37	3.59
	12 MONTH	2.82	2.58	5.87	6.48	6.46	6.15
	18 MONTH	9.38	8.16	7.80	5.82	6.64	6.98
	24 MONTH	10.45	6.48	8.48	6.72	10.22	9.77
	30 MONTH	3.76	4.24	4.55	4.25	5.10	4.80
	36 MONTH	6.96	6.80	7.38	5.50	5.87	6.71
BANANA	INITIAL	2.41					
	6 MONTH	1.33	1.29	1.29	1.58	1.14	1.24
	12 MONTH	2.36	2.27	2.18	2.13	2.26	2.35
	18 MONTH	1.94	2.06	2.00	2.06	2.00	2.19
	24 MONTH	1.90	1.86	1.77	1.82	1.89	1.62
	30 MONTH	2.34	2.40	2.26	2.38	2.34	2.52
	36 MONTH	2.65	2.70	2.63	2.78	2.64	2.70
BUTTER	INITIAL	1.00					
	6 MONTH	1.07	1.04	1.07	1.12	1.02	1.07
	12 MONTH	0.74	0.76	0.78	0.93	0.86	0.86
	18 MONTH	0.85	0.90	0.94	1.02	0.94	0.96
	24 MONTH	1.04	1.00	0.86	0.83	0.94	0.94
	30 MONTH	1.06	1.13	1.12	1.10	1.14	1.17
	36 MONTH	1.25	1.36	1.28	1.21	1.14	1.24
CARROT	INITIAL	5.17					
	6 MONTH	5.06	5.36	5.56	5.59	5.67	5.94
	12 MONTH	8.96	8.68	8.63	8.58	7.20	7.40
	18 MONTH	8.32	8.12	7.28	7.78	7.86	8.12
	24 MONTH	10.7	10.4	11.14	10.61	10.85	11.90
	30 MONTH	8.50	7.72	7.65	8.00	8.05	8.25
	36 MONTH	8.16	8.85	8.38	7.66	8.61	8.65

TABLE 5 - CONTINUED

	TIME	% MOISTURE 40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
EGG	INITIAL	4.20					
	6 MONTH	4.12	4.29	4.07	4.15	4.32	4.61
	12 MONTH	3.48	3.68	4.31	3.96	4.42	4.18
	18 MONTH	3.84	3.86	3.87	3.96	3.68	4.32
	24 MONTH	3.51	3.36	3.13	3.08	4.63	4.66
	30 MONTH	3.09	3.11	3.25	3.20	4.50	4.40
	36 MONTH	3.93	4.24	4.34	3.86	5.16	5.22
BR BEAN	INITIAL	5.83					
	6 MONTH	6.54	5.56	6.50	6.38	6.42	6.22
	12 MONTH	11.27	9.60	9.92	7.34	9.56	9.26
	18 MONTH	10.10	7.45	10.69	8.84	10.20	10.06
	24 MONTH	9.02	8.80	8.22	7.71	8.66	8.42
	30 MONTH	7.18	7.55	8.14	7.96	9.33	8.78
	36 MONTH	10.44	9.47	9.34	9.78	10.58	9.64
MACARONI	INITIAL	11.95					
	6 MONTH	9.76	9.12	9.43	9.46	9.15	9.33
	12 MONTH	9.72	9.34	10.56	11.17	10.79	10.70
	18 MONTH	10.87	10.80	10.90	10.84	10.84	10.94
	24 MONTH	10.98	11.53	11.86	11.91	12.08	12.30
	30 MONTH	12.53	12.28	12.40	12.48	12.44	12.33
	36 MONTH	12.28	11.92	12.26	12.23	12.28	11.98
MILK	INITIAL	2.78					
	6 MONTH	1.76	1.71	1.91	1.82	1.95	1.96
	12 MONTH	2.94	2.75	3.46	3.12	3.43	3.42
	18 MONTH	4.74	5.08	5.74	4.92	5.77	6.18
	24 MONTH	8.14	6.54	8.42	7.60	9.36	9.22
	30 MONTH	3.38	3.38	3.33	3.28	3.36	3.74
	36 MONTH	3.03	2.92	3.10	3.20	3.02	3.12

TABLE 5 - CONTINUED

	TIME	% MOISTURE 40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
NAVY BEAN	INITIAL	9.53					
	6 MONTH	7.16	7.70	7.24	6.98	6.86	7.11
	12 MONTH	7.99	7.35	9.52	8.62	8.90	9.34
	18 MONTH	11.36	9.82	11.86	9.54	9.26	9.41
	24 MONTH	9.11	9.48	9.28	9.35	9.12	9.56
	30 MONTH	11.46	9.12	9.05	10.02	9.55	9.29
	36 MONTH	10.66	10.24	9.47	9.70	10.16	9.72
OATMEAL	INITIAL	9.69					
	6 MONTH	7.86	7.98	8.01	8.02	7.91	8.07
	12 MONTH	9.58	9.54	9.08	9.07	9.54	9.71
	18 MONTH	7.08	7.02	7.08	7.10	7.10	7.00
	24 MONTH	7.06	7.06	8.10	7.50	8.70	8.52
	30 MONTH	9.93	9.88	10.16	10.18	10.14	9.98
	36 MONTH	8.46	8.56	8.67	8.84	8.72	8.84
P BUTTER	INITIAL	1.40					
	6 MONTH	0.38	0.42	0.56	0.56	0.42	0.54
	12 MONTH	0.90	0.84	1.11	0.62	0.87	0.92
	18 MONTH	0.96	0.76	1.04	0.74	1.19	1.00
	24 MONTH	1.44	1.58	1.58	1.42	1.72	1.70
	30 MONTH	1.62	1.72	1.46	1.37	1.47	1.44
	36 MONTH	1.55	1.27	1.44	1.36	1.66	1.50
PEACH	INITIAL	5.96					
	6 MONTH	15.40	14.34	14.61	14.10	13.57	14.24
	12 MONTH	5.42	5.16	12.88	12.66	10.30	10.72
	18 MONTH	12.79	13.50	11.51	10.51	13.18	13.40
	24 MONTH	11.14	12.07	11.15	11.61	13.22	12.29
	30 MONTH	18.04	14.34	14.60	15.30	16.40	17.12
	36 MONTH	11.90	11.90	10.60	11.20	11.44	12.18

TABLE 5 - CONTINUED

	TIME	% MOISTURE 40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
P	INITIAL	7.33					
O	6 MONTH	4.14	4.14	4.32	4.03	4.14	4.32
T	12 MONTH	7.70	7.67	7.50	7.53	4.48	4.36
A	18 MONTH	7.16	7.20	6.97	7.17	6.86	6.94
T	24 MONTH	7.66	7.58	7.70	7.64	7.60	7.52
O	30 MONTH	7.64	7.64	7.64	7.35	7.62	7.48
	36 MONTH	7.56	7.34	7.75	7.89	7.64	7.74
B	INITIAL	6.98					
	6 MONTH	6.44	6.04	7.98	8.42	7.02	8.14
B	12 MONTH	5.36	3.70	9.25	9.42	10.24	10.45
L	18 MONTH	11.28	9.84	9.62	9.50	10.22	10.57
E	24 MONTH	11.42	12.17	11.76	11.13	11.30	12.89
N	30 MONTH	7.90	8.46	8.63	9.26	9.14	9.58
D	36 MONTH	7.00	9.78	8.77	8.56	9.34	9.50
	INITIAL	6.60					
S	6 MONTH	5.38	6.25	5.12	5.71	5.92	5.23
T	12 MONTH	5.78	5.85	8.26	7.57	8.11	8.44
R	18 MONTH	6.86	7.06	6.70	7.18	6.46	6.87
O	24 MONTH	8.19	8.30	7.70	8.65	8.45	8.56
G	30 MONTH	6.94	7.83	7.56	7.74	8.12	8.30
	36 MONTH	7.70	7.66	7.96	8.34	8.59	8.80
T	INITIAL	8.23					
O	6 MONTH	8.82	8.22	8.34	9.10	9.06	8.91
M	12 MONTH	9.05	8.84	7.22	7.69	14.92	13.76
A	18 MONTH	16.30	16.00	17.18	16.94	16.65	16.28
T	24 MONTH	18.64	18.37	19.08	18.82	15.83	16.12
O	30 MONTH	12.26	12.18	11.39	12.18	11.36	11.60
	36 MONTH	13.30	14.09	13.35	14.48	14.57	14.70

TABLE 5 – CONTINUED

	TIME	% MOISTURE 40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
TVP	INITIAL	5.70					
	6 MONTH	5.59	6.52	6.74	6.76	6.93	6.46
	12 MONTH	5.33	5.18	6.79	6.41	7.18	6.53
	18 MONTH	5.47	5.08	5.19	5.27	5.60	6.40
	24 MONTH	7.27	6.72	7.02	6.54	7.01	6.86
	30 MONTH	6.76	6.58	6.73	6.62	6.86	6.60
	36 MONTH	7.73	6.74	6.58	6.18	6.98	6.83
VEG SOUP	INITIAL	7.93					
	6 MONTH	7.13	7.58	7.91	6.52	7.98	8.12
	12 MONTH	8.15	7.38	9.18	9.74	9.96	9.76
	18 MONTH	9.86	9.38	9.66	9.62	10.60	10.68
	24 MONTH	9.84	9.44	8.48	12.92	10.33	10.70
	30 MONTH	8.30	8.54	9.18	8.69	9.88	9.67
	36 MONTH	9.86	9.52	9.90	9.54	10.02	9.99
WHEAT	INITIAL	9.72					
	6 MONTH	7.24	6.61	6.65	6.95	6.94	7.03
	12 MONTH	7.44	7.11	–	9.74	–	–
	18 MONTH	9.26	8.62	9.38	9.01	9.26	9.04
	24 MONTH	9.64	10.04	10.18	10.11	9.98	9.48
	30 MONTH	8.86	8.77	8.84	8.44	9.06	9.14
	36 MONTH	10.84	10.18	10.66	10.88	10.82	11.21
YEAST	INITIAL	7.36					
	6 MONTH	4.96	5.02	4.98	5.14	5.92	6.18
	12 MONTH	6.84	6.90	7.73	7.86	7.92	7.91
	18 MONTH	7.84	7.94	7.62	7.98	7.73	8.16
	24 MONTH	7.69	7.82	7.57	8.24	7.45	7.57
	30 MONTH	7.65	7.58	7.44	7.62	8.86	8.09
	36 MONTH	8.47	8.53	8.36	8.62	8.30	8.40

TABLE 6 - BETA-CAROTENE CONTENT OF LOW-MOISTURE PRODUCTS, TREATMENT MEANS.

		BETA-CAROTENE, mg/100g					
	TIME	40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
C	INITIAL	36.60					
A	6 MONTH	62.55	59.80	54.00	52.05	64.05	47.35
R	12 MONTH	61.85	58.65	55.05	44.85	57.00	44.65
R	18 MONTH	61.95	58.00	54.25	43.35	53.95	38.95
O	24 MONTH	60.45	53.55	53.65	40.40	53.10	38.65
T	30 MONTH	56.20	48.00	64.60	26.40	59.90	36.00
	36 MONTH	63.80	45.30	54.30	33.10	56.00	35.40
G	INITIAL	1.98					
R	6 MONTH	3.18	1.05	3.10	2.66	2.56	1.02
	12 MONTH	2.89	1.92	2.86	0.73	2.38	0.97
B	18 MONTH	2.92	1.87	2.79	1.02	2.44	0.86
E	24 MONTH	2.73	1.80	2.73	0.87	2.38	0.77
A	30 MONTH	2.93	1.34	2.53	0.83	2.53	0.90
N	36 MONTH	2.83	1.34	2.61	1.32	2.43	0.98
	INITIAL	1.73					
P	6 MONTH	1.02	0.56	1.32	0.94	1.10	0.53
E	12 MONTH	0.95	0.75	0.62	0.42	0.58	0.39
A	18 MONTH	0.90	0.68	0.64	0.44	0.58	0.41
C	24 MONTH	0.87	0.63	0.80	0.60	0.77	0.57
H	30 MONTH	0.84	0.60	0.58	0.49	0.70	0.55
	36 MONTH	0.84	0.71	0.58	0.40	0.49	0.42
S	INITIAL	6.65					
	6 MONTH	10.47	4.67	10.60	9.10	8.45	4.95
B	12 MONTH	11.80	10.45	10.86	8.46	7.75	5.89
L	18 MONTH	11.65	10.73	10.76	8.44	7.69	5.83
E	24 MONTH	11.41	9.80	10.21	8.28	7.54	5.72
N	30 MONTH	9.81	8.81	10.42	8.26	5.90	5.19
D	36 MONTH	9.31	9.03	8.71	7.99	9.49	8.58

TABLE 6 - CONTINUED

	TIME	BETA-CAROTENE, mg/100g 40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
TOMATO	INITIAL	3.38					
	6 MONTH	3.24	3.26	3.62	3.17	3.41	2.90
	12 MONTH	3.02	3.00	3.64	3.12	3.16	2.38
	18 MONTH	3.55	3.27	3.28	2.65	3.07	2.40
	24 MONTH	3.46	3.26	3.17	2.61	2.99	2.37
	30 MONTH	3.31	3.14	3.28	2.99	3.33	2.56
	36 MONTH	3.23	3.17	3.29	3.00	3.28	2.45
VEG SOUP	INITIAL	2.06					
	6 MONTH	9.40	6.13	3.42	6.05	4.11	5.79
	12 MONTH	5.98	5.25	5.04	3.20	2.71	3.20
	18 MONTH	6.60	3.16	2.99	2.41	3.62	2.02
	24 MONTH	6.44	3.18	4.07	3.12	3.47	2.18
	30 MONTH	4.15	3.70	3.29	2.61	2.66	2.25
	36 MONTH	3.70	2.82	3.82	1.80	1.99	1.74

TABLE 7 - VITAMIN A CONTENT OF DEHYDRATED BUTTER, TREATMENT MEANS.

	TIME	VITAMIN A, IU/g					
		40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
B	INITIAL	*					
U	6 MONTH	15.50	16.90	12.00	12.50	13.00	11.60
T	12 MONTH	19.48	16.13	16.83	14.56	19.00	14.62
T	18 MONTH	18.15	15.00	16.10	12.75	15.50	11.70
E	24 MONTH	17.92	15.16	14.24	10.72	15.48	11.10
R	30 MONTH	16.24	14.29	15.32	11.59	17.10	14.40
	36 MONTH	19.43	15.37	16.62	12.62	12.66	9.70

* not tested.

Figures 21 and 22 show the effect of time on *beta*-carotene content of the low-moisture products. With the exception of salad blend there was a significant decrease in vitamin content with time. Most dramatic changes were within the first year of storage. In green beans, peaches, tomatoes and vegetable soup there was very little change after 1 year. Carotene content of carrots also began to level off after one year.

It is believed that some *beta*-carotene in the products was rapidly oxidized, and that most of the vitamin remaining after 6 months was in a relatively stable form. Walter et al. (1970) reported that most of the *beta*-carotene in dehydrated sweet potatoes was not susceptible to oxidative attack. During the first 20 days of storage at 72^{O}F, 20.2% of the *beta*-carotene was lost, while only 6.8% was lost during the next 69 days. They postulated that most of the carotene was protected by being embedded in an oxygen impermeable mass. Stephens and McLemore (1969) found a rapid drop in dehydrated carrot *beta*-carotene during the first 2 months of storage at 68^{O}F but no furter loss thereafter during a two year study. Heberlein and Clifcorn (1944) found the *beta*-carotene content of dehydrated carrots leveled off between 3 and 6 months storage.

The effect of storage temperature on *beta*-carotene content of the dehydrated products is shown in Figures 23 and 24. *Beta*-carotene was destroyed more rapidly at higher temperatures. Similar results were obtained with dehydrated carrots and tomato juice powder (Heberlein and Clifcorn, 1944) and model systems

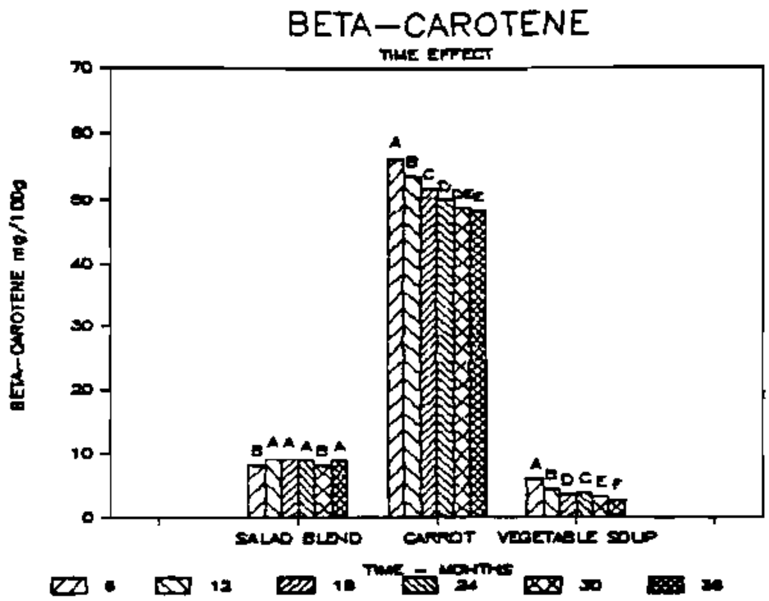

Figure 21 - Effect of storage time on beta-carotene content of low-moisture products: salad blend, carrot, vegetable soup. Significant differences, p = .05 indicated by different letters above treatment.

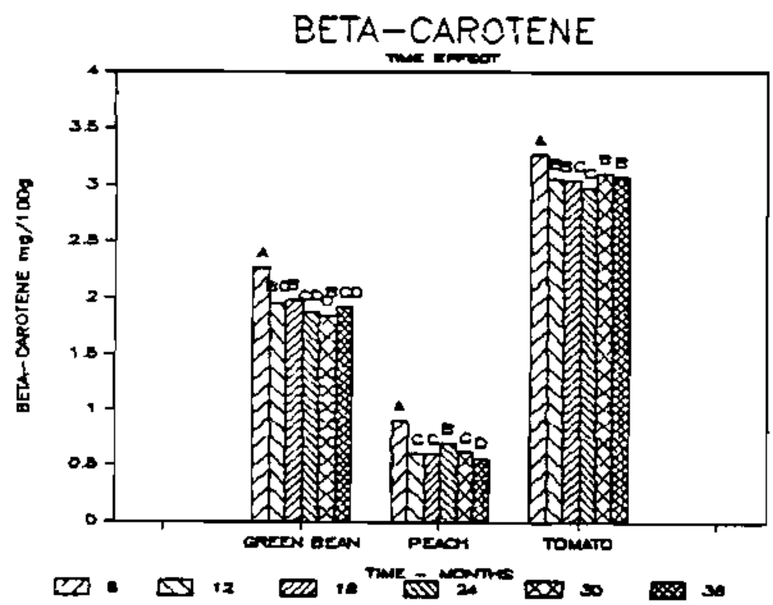

Figure 22 - Effect of storage time on beta-carotene content of low-moisture products: green bean, peach, tomato. Significant differences, p = .05 indicated by different letters above treatment.

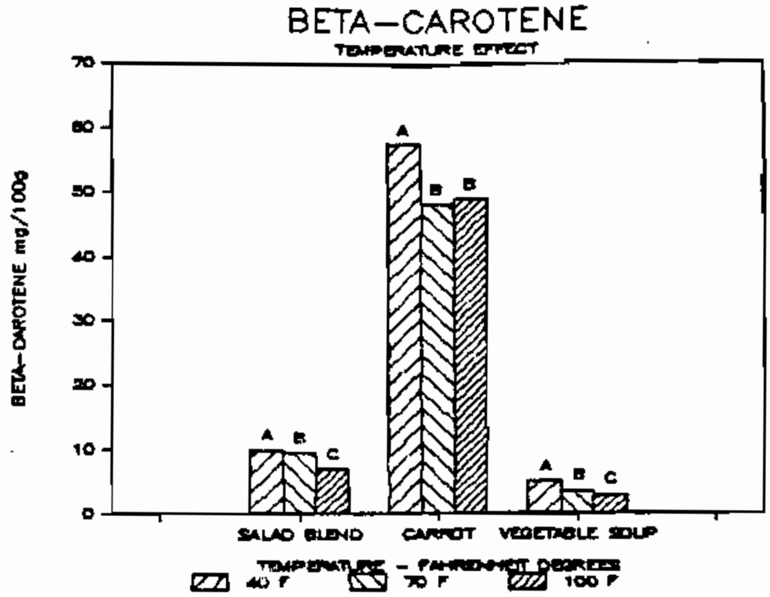

Figure 23 - Effect of storage temperature on beta-carotene content of low-moisture products: salad blend, carrot, vegetable soup. Significant differences, p = .05 indicated by different letters above treatment.

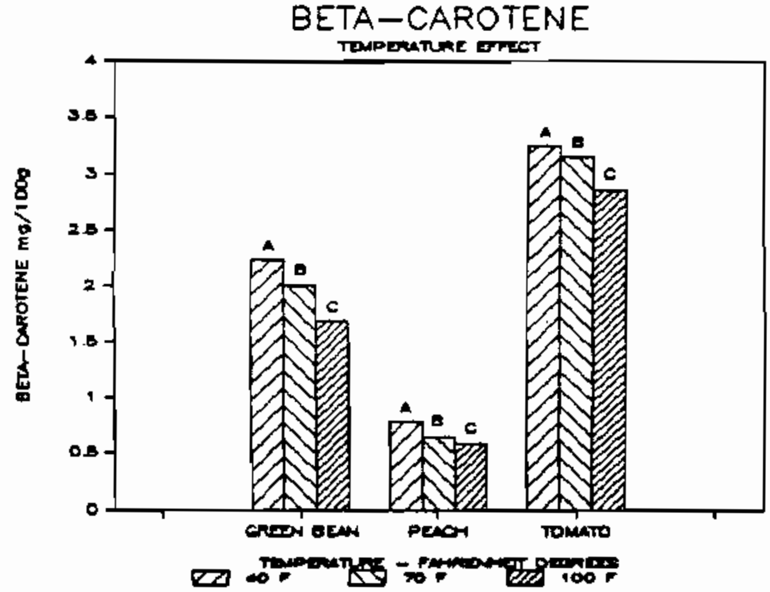

Figure 24 - Effect of storage temperature on beta-carotene content of low-moisture products: green bean, peach, tomato. Significant differences, p = .05 indicated by different letters above treatment.

(Chou and Breene, 1972). Stephens and McLemore (1969) found very little difference in the rate of beta-carotene destruction of dehydrated carrots stored at 68°F or 0°F for 2 years.

The effect of interior can atmosphere on beta-carotene content is shown in Figures 25 and 26. Beta-carotene was retained significantly better in nitrogen packed products. Oxidation is the chief pathway of beta-carotene destruction. Many researchers have shown the benefits of reduced oxygen on beta-carotene retention (Goldman et al., 1983; Teixeira Neto et al., 1981; Stephens and McLemore, 1969; Heberlein and Clifcorn, 1944).

Oxygen content of the nitrogen packed products was ca. 1% (Table 1). Significant oxidation of carotene does occur at this oxygen concentration (Goldman et al., 1983) but not as rapidly as under the 21% oxygen in air.

Vitamin A, like beta-carotene is easily oxidized. Figures 27 - 29 show the effect of storage time, temperature and atmosphere, respectfully, on vitamin A content of low-moisture butter powder. From Table 27 it appears that the vitamin A retained at 6 months was stable thereafter. Significantly more vitamin A was destroyed at 70 and 100°F than at 40°F. Vitamin A was also destroyed more rapidly in the air-packed product.

Figures 30 - 50 show the time-temperature, time-atmosphere, and atmosphere-temperature interactions for the individual products. Interactions that are not significant are designated "NS" at the end of the graph title.

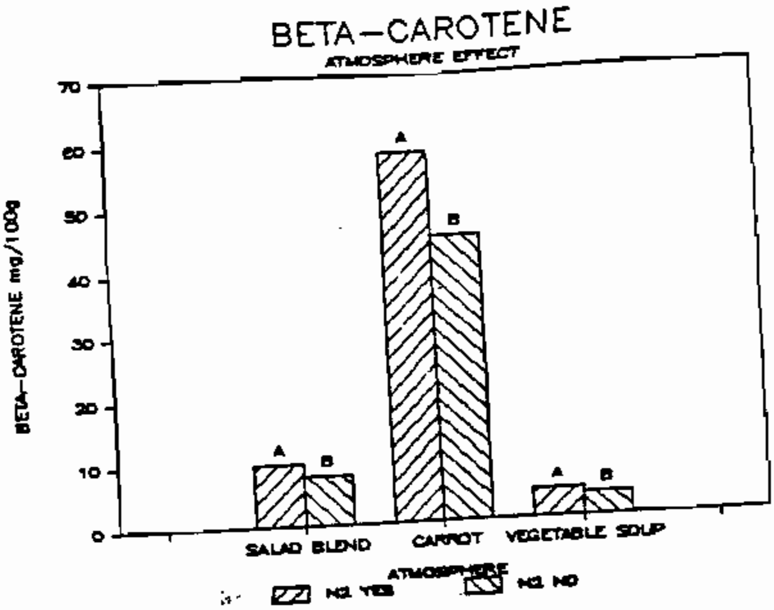

Figure 25 - Effect of interior can oxygen on beta-carotene content of low-moisture products: salad blend, carrot, vegetable soup. Significant differences, p = .05 indicated by different letters above treatment.

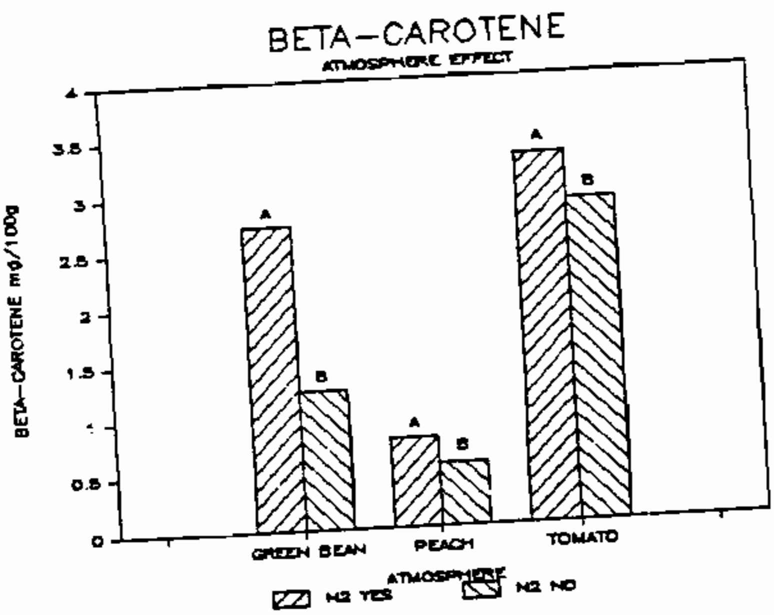

Figure 26 - Effect of interior can oxygen on beta-carotene content of low-moisture products: green bean, peach, tomato. Significant differences, p = .05 indicated by different letters above treatment.

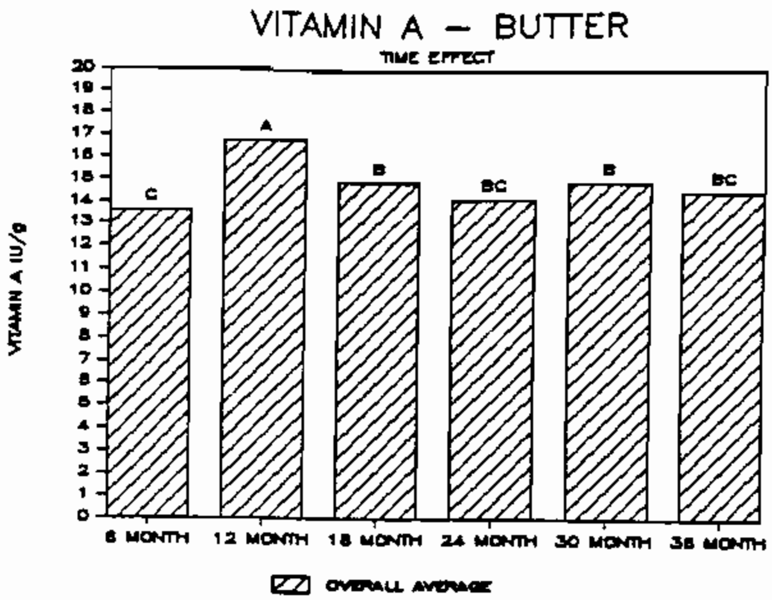

Figure 27 - Effect of storage time on vitamin A content of low-moisture butter. Significant differences, p = .05 indicated by different letters above treatment.

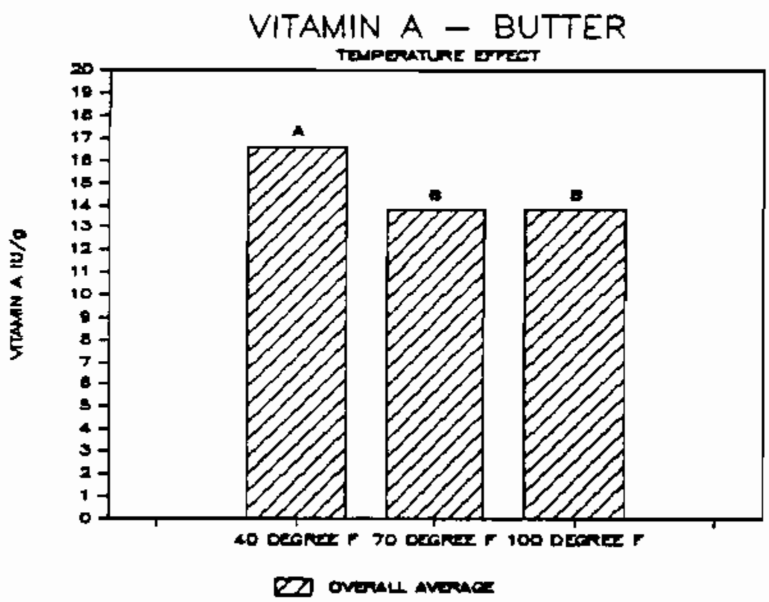

Figure 28 - Effect of storage temperature on vitamin A content of low-moisture butter. Significant differences, p = .05 indicated by different letters above treatment.

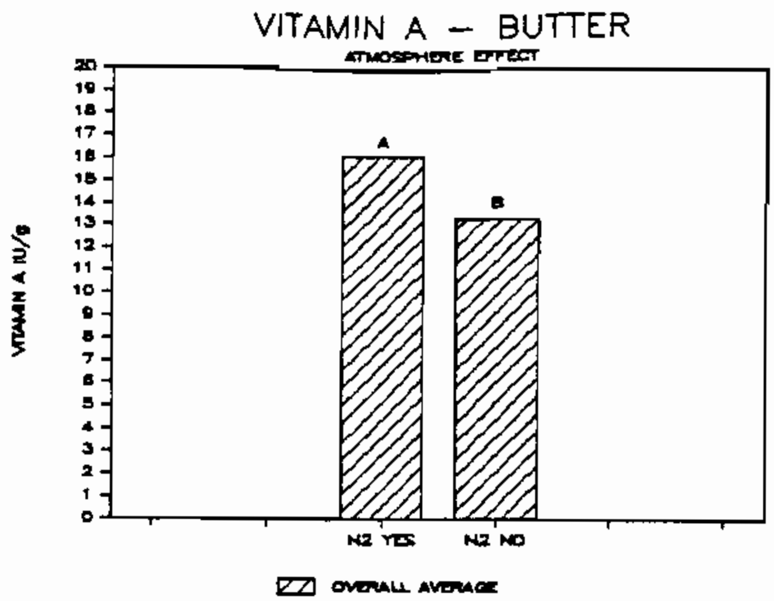

Figure 29 - Effect of interior can oxygen on vitamin A content of low-moisture butter. Significant differences, p = .05 indicated by different letters above treatment.

From the individual product time-temperature interactions it will be noticed that beta-carotene in 4 out of the 6 products was significantly lower at 6 months in samples stored at 40°F than in samples at 70°F. Lovric et al. (1970) and Boskovic (1979) reported a cis-trans isomerization of lycopene in dehydrated tomato products. Reversion back to the all-trans lycopene occurred faster at higher temperatures. Dehydrated tomatoes stored at 68°F had better color and higher lycopene retention than dehydrated tomatoes stored at 36 or 14°F, even after 385 days storage. Perhaps in the present study an isomerization of the carotene took place during dehydration that was evident in samples stored for 6 months. This could account for the lower 6 month 40°F values of beta-carotene in green beans, peaches, salad blend and tomatoes.

Carrots: At all storage times (Figure 30) carrots stored at 40°F retained significantly more carotene than those at 70 or 100°F. Carrots stored at 70 and 100°F showed very little difference from each other. Beta-carotene of carrots packed in nitrogen (Figure 31) remained relatively constant throughout the storage period whereas carotene of carrots packed in air continued to decrease. Differences in beta-carotene content between nitrogen- and air-packed carrots increased with time. Differences between nitrogen- and air-pack were also greater at 70 and 100 than at 40°F (Figure 32).

Heberlein and Clifcorn (1944) stored dehydrated carrots for 1 year at room temperature (70°F) and 98°F packed in nitrogen or air. Air-packed carrots stored at 70°F dropped from ca. 75 mg/100g to ca. 60 mg/100g in 2 months, then remained constant. Air-packed carrots at 98°F dropped to ca. 50 mg/100g in 2 months, then remained constant. Beta-carotene remained constant in nitrogen-packed carrots at 70°F. Carotene of nitrogen-packed carrots at 98°F declined steadily to ca. 50 mg/100g after 1 year. Length of time and frequency of evaluation were different between the two studies, however carotene values are similar.

Green beans: At 6 months the beta-carotene in dehydrated green beans at 40°F was significantly lower than those at 70°F (Figure 33). At the other time periods more beta-carotene was retained at 40 than either 70 or 100°F. Green beans packed under nitrogen (Figure 34) retained twice as much beta-carotene as their air-packed counterpart. After 6 months there was little change in either group with time. At all three temperatures (Figure 35) green beans

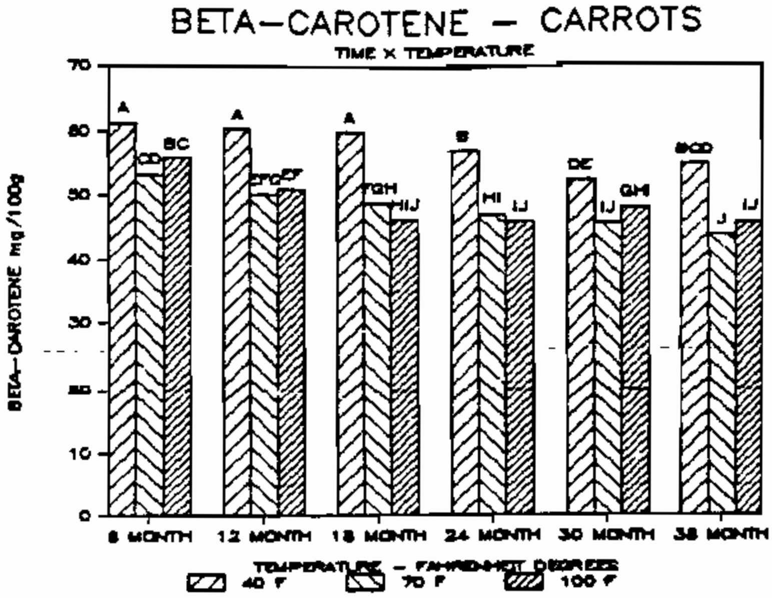

Figure 30 - **Effect of storage time and temperature on <u>beta</u>-carotene content of dehydrated carrots.** Significant differences, p = .05 indicated by different letters above treatment.

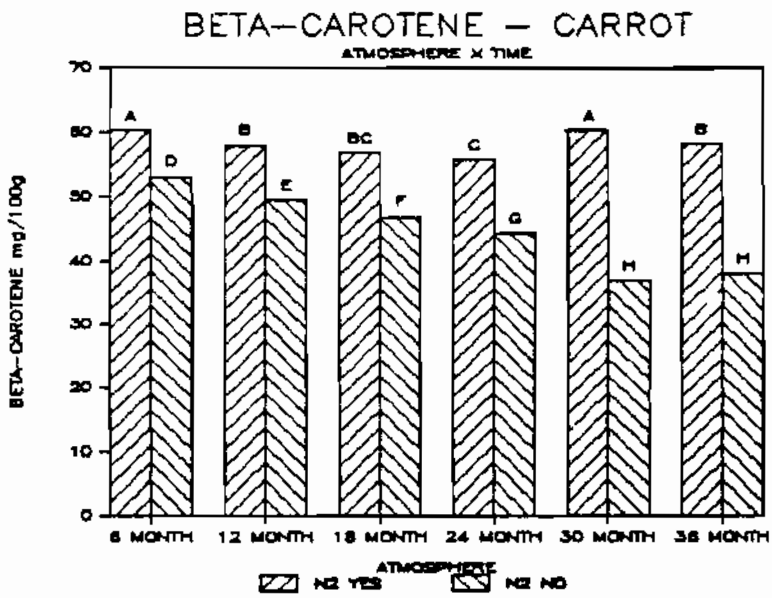

Figure 31 - Effect of interior can oxygen and storage time on <u>beta</u>-carotene content of dehydrated carrots. Significant differences, p = .05 indicated by different letters above treatment.

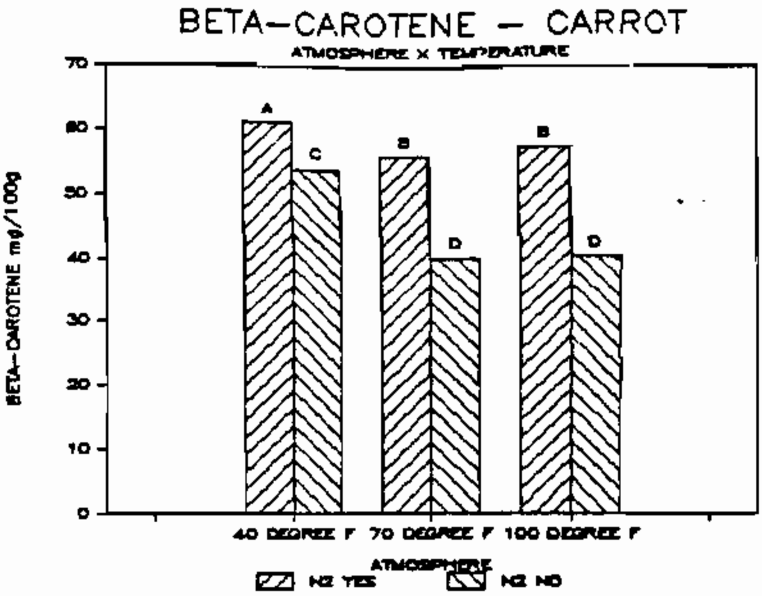

Figure 32 - Effect of interior can oxygen and storage temperature on beta-carotene content of dehydrated carrots. Significant differences, p = .05 indicated by different letters above treatment.

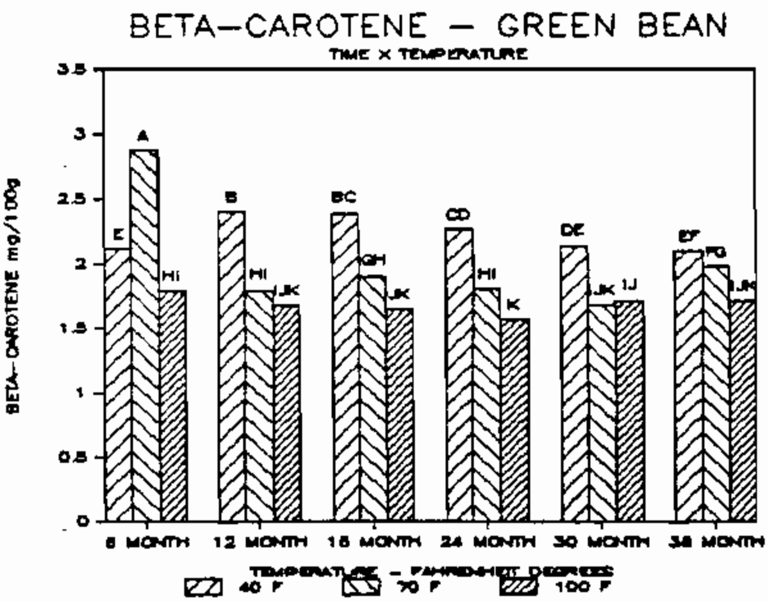

Figure 33 - Effect of storage time and temperature on beta-carotene content of dehydrated green beans. Significant differences, p = .05 indicated by different letters above treatment.

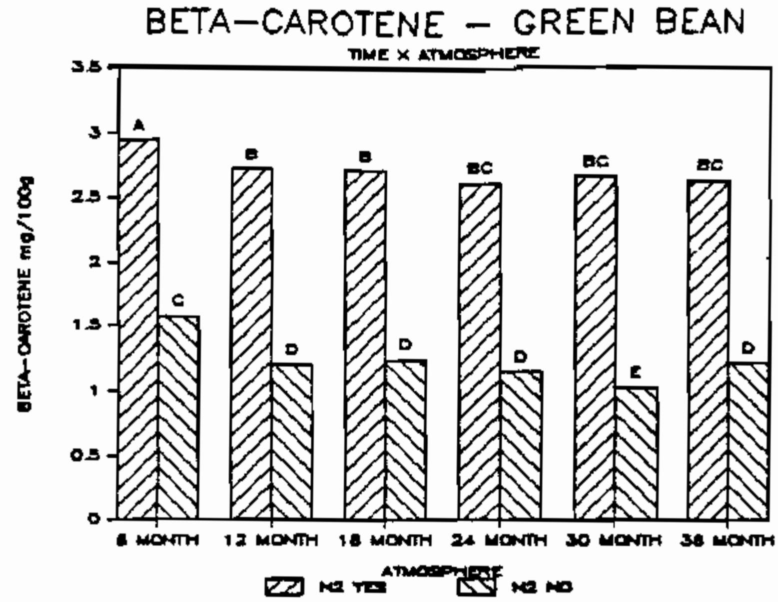

Figure 34 - Effect of interior can oxygen and storage time on beta-carotene content of dehydrated green beans. Significant differences, p = .05 indicated by different letters above treatment.

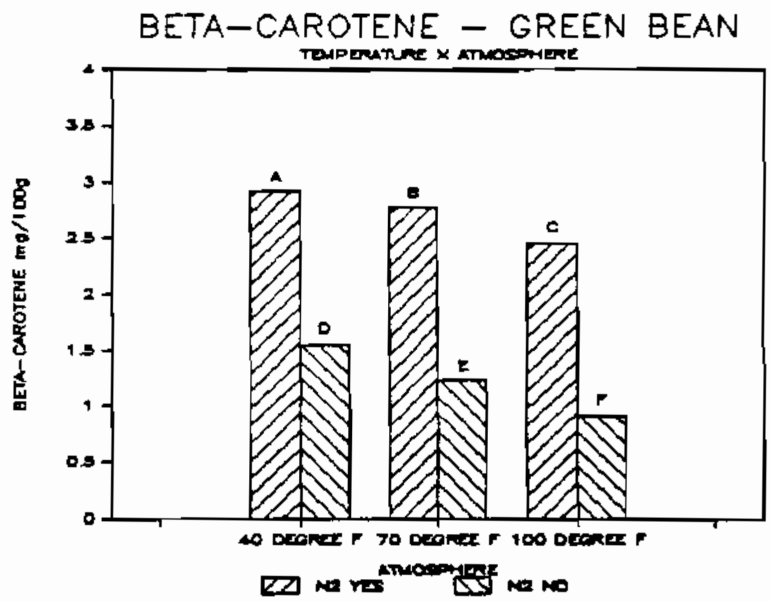

Figure 35 - Effect of interior can oxygen and storage temperature on beta-carotene content of dehydrated green beans. Significant differences, p = .05 indicated by different letters above treatment.

stored in nitrogen retained significantly more (ca. 2 times) beta-carotene than the air-packed samples.

Peaches: At 6 months dehydrated peaches (Figure 36) stored at 70°F appeared to retain more beta-carotene than those at 40 or 100°F. At all other time periods the beta-carotene content was significantly higher at 40°F, and there was little difference between the values from the 70 and 100°F samples. Atmospheric effects (Figure 37) were greatest at 6 months but the difference narrowed with time. The temperature-atmosphere interaction was not significant (Figure 38), because nitrogen-packed peaches compared to air-packed were different by almost the same amount of carotene at all three temperatures.

Salad blend: Beta-carotene content of dehydrated salad blend (Figure 39) stored at 40°F was significantly less after 6 months than the product stored at 70°F, but at later time periods it was equal to or significantly higher at 40°F. Beta-carotene of salad blend stored at 100°F was much lower than that stored at 40 or 70°F except for the anomalous 36 month period. The atmospheric effect (Figure 40) was largest at 6 months but the difference narrowed with storage time. The temperature-atmosphere interaction (Figure 41) was not significant, because nearly parallel differences existed between atmosphere values at the three storage temperatures.

Tomatoes: The beta-carotene content of dehydrated tomato flakes stored at 40°F after 6 and 12 months (Figure 42) was significantly lower than that at 70°F. There was little change in

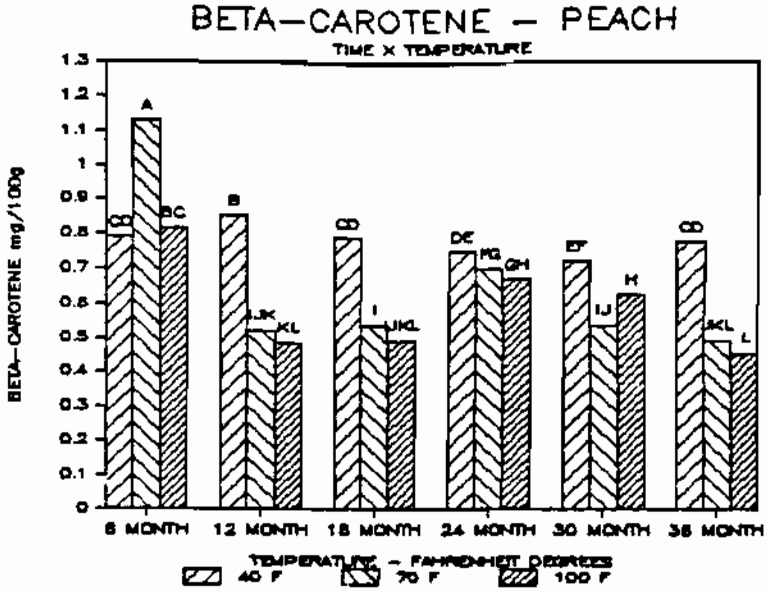

Figure 36 - Effect of storage time and temperature on beta-carotene content of dehydrated peaches. Significant differences, p = .05 indicated by different letters above treatment.

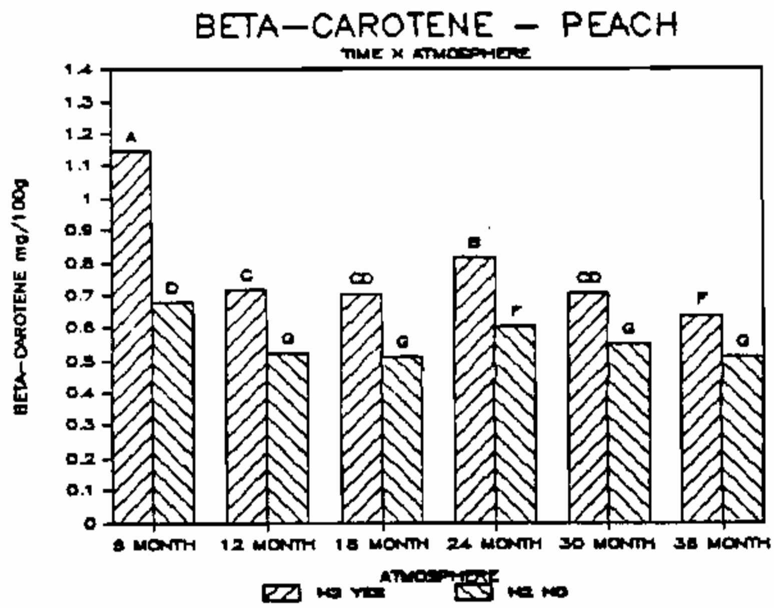

Figure 37 - Effect of interior can oxygen and storage time on beta-carotene content of dehydrated peaches. Significant differences, p = .05 indicated by different letters above treatment.

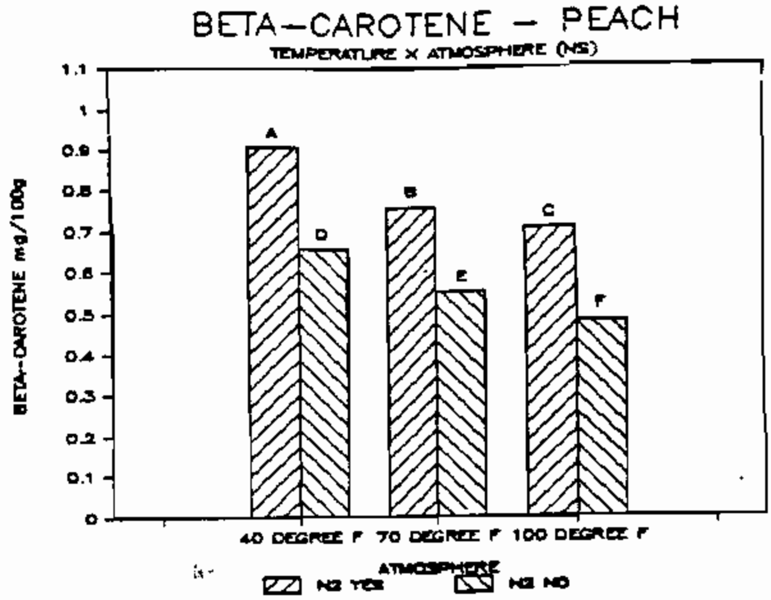

Figure 38 - Effect of interior can oxygen and storage temperature on beta-carotene content of dehydrated peaches. Significant differences, p = .05 indicated by different letters above treatment. Interaction not significant.

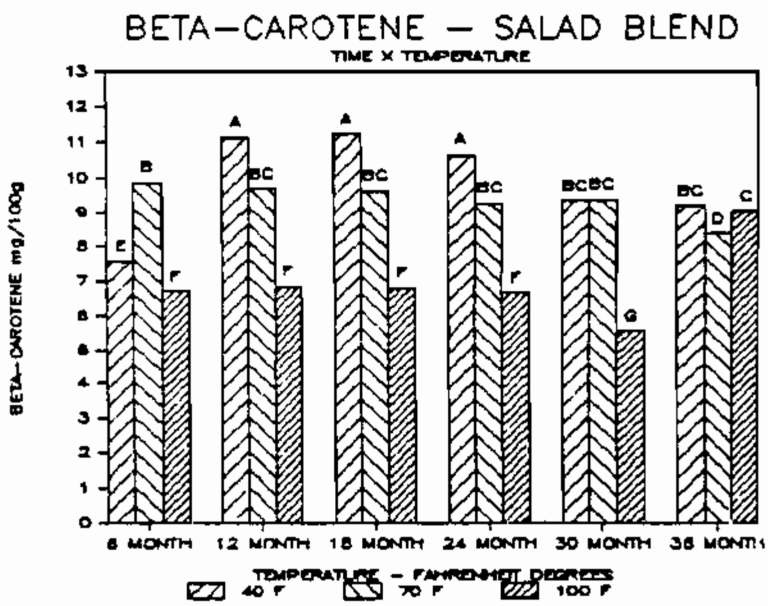

Figure 39 - Effect of storage time and temperature on beta-carotene content of dehydrated salad blend. Significant differences, p = .05 indicated by different letters above treatment.

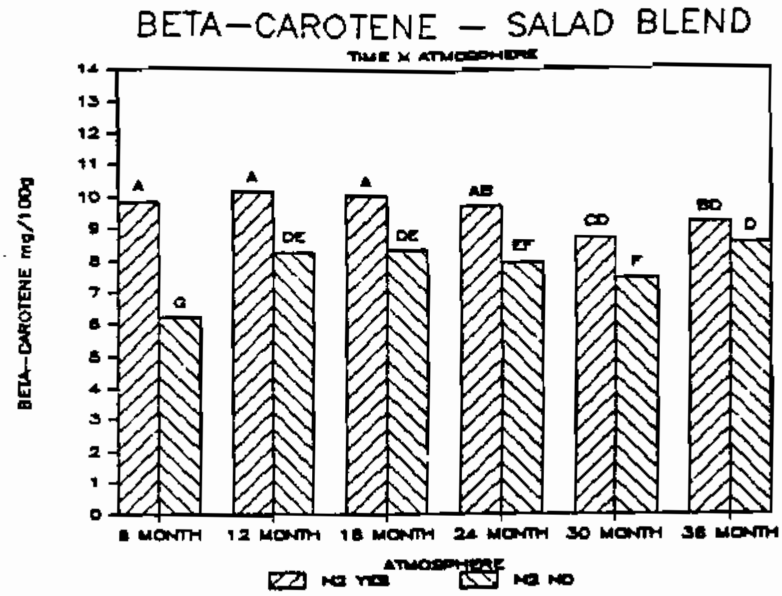

Figure 40 - **Effect of interior can oxygen and storage time on <u>beta</u>-carotene content of dehydrated salad blend.** Significant differences, p = .05 indicated by different letters above treatment.

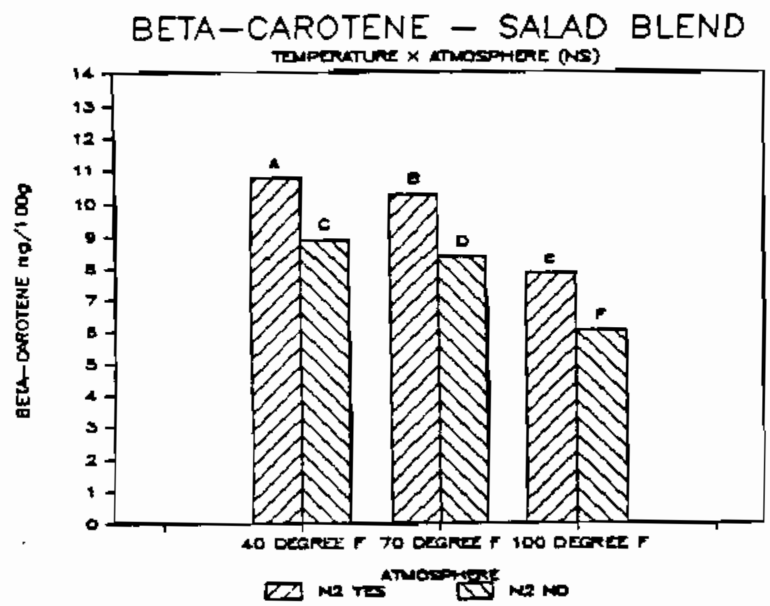

Figure 41 - **Effect of interior can oxygen and storage temperature on <u>beta</u>-carotene content of dehydrated salad blend.** Significant differences, p = .05 indicated by different letters above treatment. Interaction not significant.

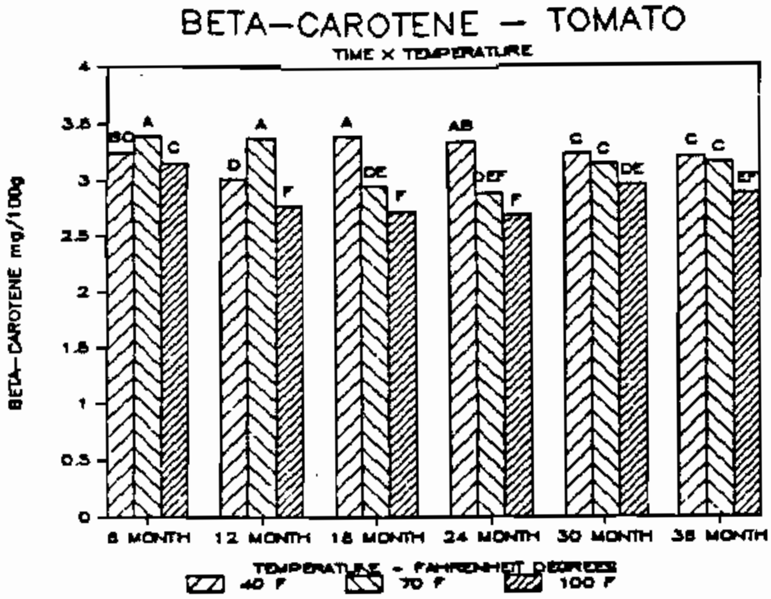

Figure 42 - Effect of storage time and temperature on <u>beta</u>-carotene content of dehydrated tomatoes. Significant differences, p = .05 indicated by different letters above treatment.

carotene content with time at any temperature. The time-atmosphere interaction (Figure 43) was not significant since the differences due to atmosphere were fairly constant at all storage times. Nitrogen-packed product retained significantly more <u>beta</u>-carotene at all time periods. The carotene difference between nitrogen-packed tomatoes and air-packed tomatoes (Figure 44) increased at higher temperatures. <u>Beta</u>-carotene of dehydrated tomato juice (Heberlein and Clifcorn, 1944) declined from <u>ca</u>. 8 mg/100g to 2-5 mg/100g by 1 year regardless of treatment. Their values are in the same range as those in this study.

<u>Vegetable soup</u>: <u>Beta</u>-carotene of dehydrated vegetable soup was significantly higher when stored at 40°F than at 70 or 100°F at all time periods (Figure 45). The greatest difference was

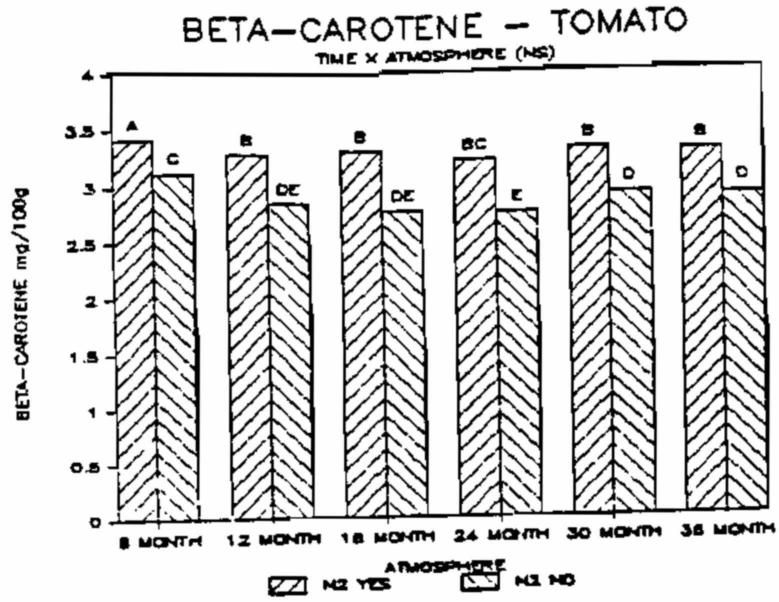

Figure 43 - Effect of interior can oxygen and storage time on beta-carotene content of dehydrated tomatoes. Significant differences, p = .05 indicated by different letters above treatment. Interaction not significant.

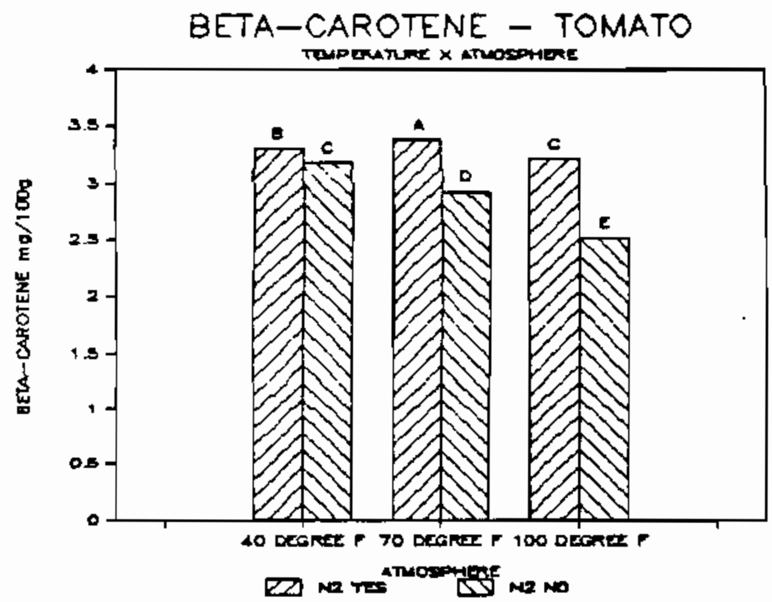

Figure 44 - Effect of interior can oxygen and storage temperature on beta-carotene content of dehydrated tomatoes. Significant differences, p = .05 indicated by different letters above treatment.

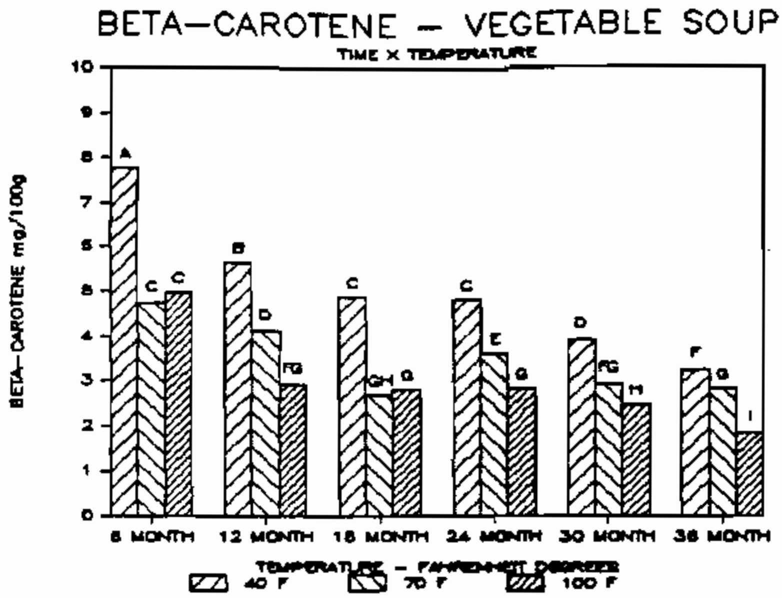

Figure 45 - Effect of storage time and temperature on <u>beta</u>-carotene content of dehydrated vegetable soup. Significant differences, p = .05 indicated by different letters above treatment.

at 6 months but it narrowed with time. The nitrogen-packed soup had a significantly higher carotene content at all time periods except 6 months (Figure 46). The protective effect of nitrogen was greatest at 40°F and just barely significant at 100°F (Figure 47).

<u>Butter</u>: General trends in vitamin A content are not evident in the time-temperature interaction for butter (Figure 48), however averaging all the time periods together (Figure 28) vitamin A retention was significantly greater at 40 than at 70 or 100°F. Only at 6 months was there no significant difference due to atmosphere (Figure 49). At all other time periods, nitrogen-packed butter contained significantly more vitamin A than the air-packed product. The temperature-atmosphere interaction (Figure 50) was not significant since the differences were parallel at all temperatures.

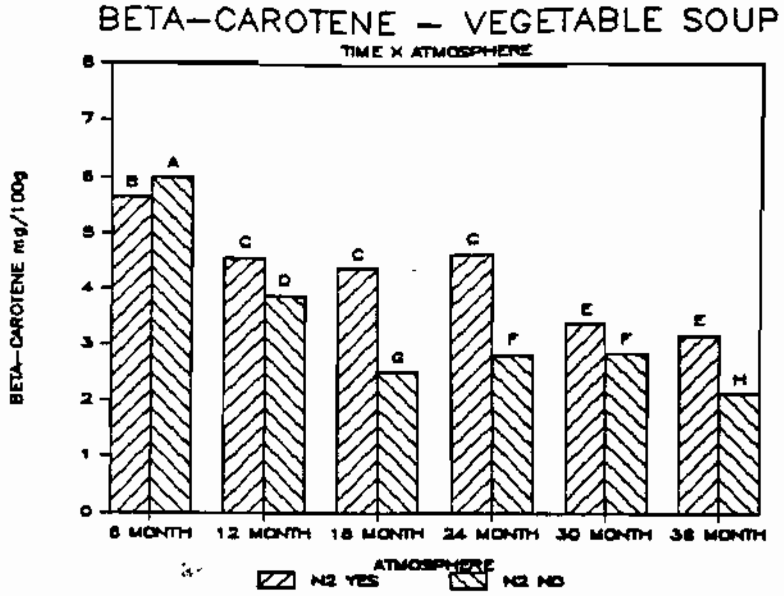

Figure 46 - Effect of interior can oxygen and storage time on beta-carotene content of dehydrated vegetable soup. Significant differences, p = .05 indicated by different letters above treatment.

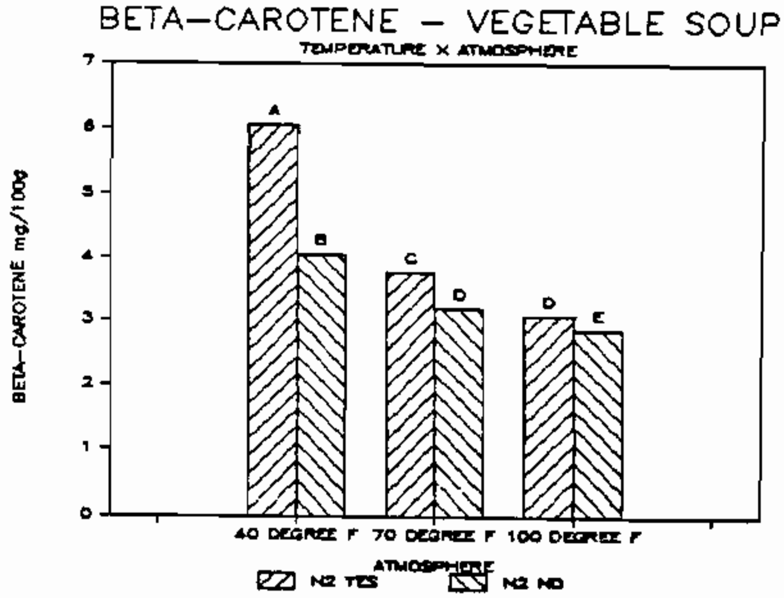

Figure 47 - Effect of interior can oxygen and storage temperature on beta-carotene content of dehydrated vegetable soup. Significant differences, p = .05 indicated by different letters above treatment.

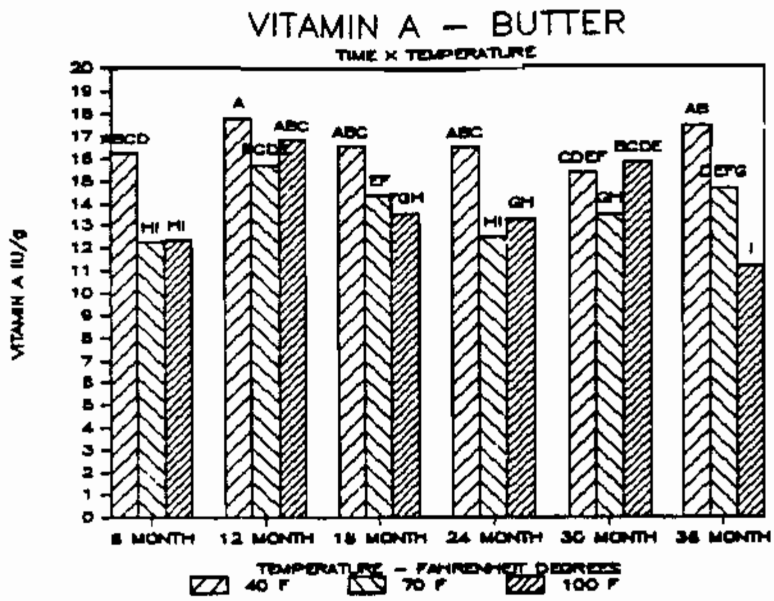

Figure 48 - **Effect of storage time and temperature on vitamin A content of dehydrated butter.** Significant differences, p = .05 indicated by different letters above treatment.

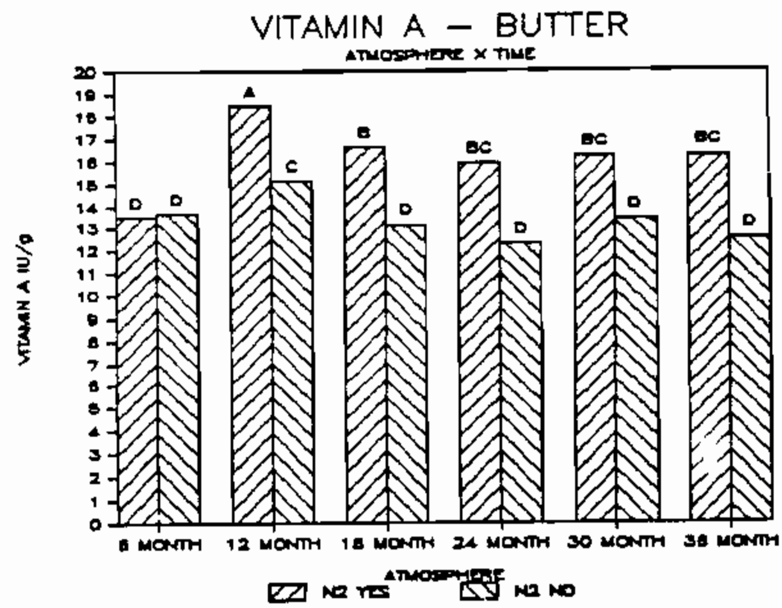

Figure 49 - **Effect of interior can oxygen and storage time on vitamin A content of dehydrated butter.** Significant differences, p = .05 indicated by different letters above treatment.

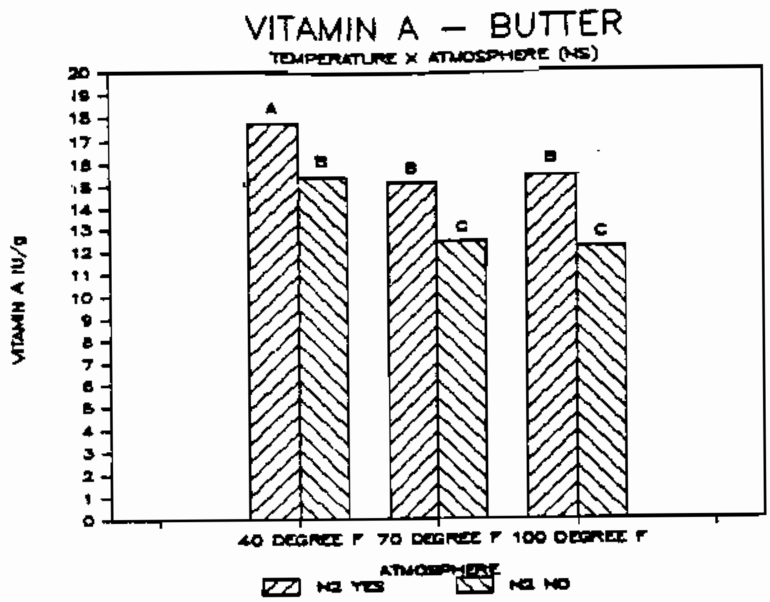

Figure 50 - Effect of interior can oxygen and storage temperature on vitamin A content of dehydrated butter. Significant differences, p = .05 indicated by different letters above treatment. Interaction not significant.

Thiamin

Mean sample thiamin content by product is listed in Table 8. Thiamin content was tested in the following low-moisture products; bananas, eggs, green beans, macaroni, milk, oatmeal, navy beans, peanut butter, salad blend, stroganoff, tomatoes, TVP, vegetable soup, wheat and yeast. There was not sufficient stroganoff saved at the 6 month time period to analyze for thiamin. Bananas, green beans and tomatoes had only trace amounts (less than .1 mg/100g) of thiamin at the initial and 6 month tests and were not tested thereafter. Green beans and tomatoes had both been treated with SO_2 which rapidly destroys thiamin. Peanut butter had significant thiamin content at 6 months but only trace amounts at 12, 18 and 24

TABLE 8 – THIAMIN CONTENT OF LOW-MOISTURE PRODUCTS, TREATMENT MEANS.

	TIME	THIAMIN, mg/100g 40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
EGG	INITIAL	trace					
	6 MONTH	0.13	trace	0.16	0.14	trace	trace
	12 MONTH	0.18	0.16	0.21	0.14	0.16	0.15
	18 MONTH	0.14	0.14	0.12	0.12	0.10	trace
	24 MONTH	0.12	0.10	0.10	trace	trace	trace
	30 MONTH	trace	trace	0.10	trace	*	*
	36 MONTH	0.13	0.12	0.12	0.11	*	*
MACARONI	INITIAL	0.68					
	6 MONTH	0.72	0.48	0.68	–	0.41	0.42
	12 MONTH	0.78	0.70	0.59	0.64	0.38	0.48
	18 MONTH	0.61	0.48	0.52	0.42	0.34	0.30
	24 MONTH	0.59	0.44	0.42	0.33	0.28	0.22
	30 MONTH	0.52	0.39	0.38	0.31	0.19	0.18
	36 MONTH	0.60	0.50	0.43	0.34	0.13	0.13
MILK	INITIAL	0.24					
	6 MONTH	trace	trace	trace	trace	trace	trace
	12 MONTH	0.12	0.15	0.13	0.13	0.16	0.14
	18 MONTH	0.12	0.10	0.11	0.10	0.11	0.10
	24 MONTH	0.11	0.10	0.10	trace	0.12	trace
	30 MONTH	0.10	0.10	0.10	0.10	0.10	trace
	36 MONTH	0.12	0.11	0.12	0.11	0.12	0.10
NAVY BEAN	INITIAL	0.38					
	6 MONTH	0.41	0.34	0.30	0.34	0.31	0.31
	12 MONTH	0.58	0.44	0.52	0.54	0.38	0.37
	18 MONTH	0.43	0.45	0.35	0.26	0.26	0.24
	24 MONTH	0.41	0.38	0.34	0.36	0.22	0.20
	30 MONTH	0.40	0.28	0.36	0.24	trace	0.12
	36 MONTH	0.36	0.32	0.31	0.30	trace	trace

trace = < 0.1 mg/100g.
* not tested due to trace amounts on previous tests.
– not tested due to sample unavailability.

TABLE 8 – CONTINUED

	TIME	THIAMIN, mg/100g					
		40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
OATMEAL	INITIAL	0.49					
	6 MONTH	0.37	0.55	0.48	0.28	0.44	0.36
	12 MONTH	0.64	0.56	0.65	0.44	0.50	0.40
	18 MONTH	0.54	0.48	0.52	0.46	0.43	0.40
	24 MONTH	0.47	0.43	0.44	0.37	0.34	0.32
	30 MONTH	0.42	0.46	0.40	0.38	0.38	0.39
	36 MONTH	0.41	0.45	0.46	0.44	0.43	0.36
B BLEND	INITIAL	trace					
	6 MONTH	0.38	0.31	0.20	0.14	0.12	0.10
	12 MONTH	0.14	0.15	0.12	0.12	0.11	trace
	18 MONTH	trace	trace	trace	0.10	trace	trace
	24 MONTH	trace	trace	trace	trace	trace	trace
	30 MONTH	*	*	*	*	*	*
	36 MONTH	*	*	*	*	*	*
BTROB	INITIAL	0.34					
	6 MONTH	–	–	–	–	–	–
	12 MONTH	0.37	0.38	0.42	0.39	0.35	0.21
	18 MONTH	0.35	0.32	0.26	0.24	0.22	0.20
	24 MONTH	0.30	0.25	0.26	0.20	0.14	0.10
	30 MONTH	0.34	0.28	0.28	0.19	0.10	trace
	36 MONTH	0.40	0.35	0.34	0.28	0.17	0.15
TVP	INITIAL	3.18					
	6 MONTH	2.00	2.60	2.16	3.55	2.10	2.55
	12 MONTH	4.12	3.44	3.84	2.87	2.76	3.55
	18 MONTH	3.50	2.78	3.54	3.49	2.30	2.05
	24 MONTH	3.25	2.66	2.98	2.80	2.02	1.59
	30 MONTH	3.30	3.14	2.94	2.76	1.86	1.34
	36 MONTH	3.58	3.22	3.05	2.42	2.51	1.79

TABLE 8 – CONTINUED

	TIME	THIAMIN, mg/100g					
		40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
VEG SOUP	INITIAL	0.19					
	6 MONTH	0.20	0.16	0.22	0.16	0.13	0.50
	12 MONTH	0.26	0.22	0.26	0.30	0.24	0.20
	18 MONTH	0.29	0.27	0.28	0.26	0.16	0.18
	24 MONTH	0.26	0.20	0.21	0.20	0.16	trace
	30 MONTH	0.28	0.24	0.20	0.18	0.12	trace
	36 MONTH	0.25	0.18	0.17	0.14	0.14	trace
WHEAT	INITIAL	0.28					
	6 MONTH	0.19	0.14	0.23	0.19	0.20	0.21
	12 MONTH	0.35	0.36	0.36	0.38	0.40	0.35
	18 MONTH	0.36	0.29	0.25	0.24	0.22	0.21
	24 MONTH	0.32	0.25	0.23	0.22	0.16	0.12
	30 MONTH	0.25	0.22	0.20	0.20	0.14	0.16
	36 MONTH	0.26	0.21	0.27	0.24	0.20	0.17
YEAST	INITIAL	6.00					
	6 MONTH	2.05	2.15	2.20	2.30	1.20	0.45
	12 MONTH	3.75	3.00	3.57	3.33	1.62	1.91
	18 MONTH	2.59	2.10	2.27	1.84	1.82	1.34
	24 MONTH	2.25	1.85	2.08	1.66	1.62	1.22
	30 MONTH	2.08	2.39	2.02	1.31	0.78	0.54
	36 MONTH	2.08	1.57	1.93	1.54	1.58	1.08

months. It was not tested at 30 and 36 months. No analysis of variance was done for these last four products. They are excluded from the Table 8 and the successive graphs. Thiamin content of peanut butter at six months was:

40°F nitrogen-pack	-	.19 mg/100g
40°F air-pack	-	.21 mg/100g
70°F nitrogen-pack	-	.22 mg/100g
70°F air-pack	-	.18 mg/100g
100°F nitrogen-pack	-	.13 mg/100g
100°F air-pack	-	.16 mg/100g

Time and atmosphere effects were not significant.

Several changes in analytical procedure were made between the initial and 6 month testing period. The ion exchange resin "thiochrome decalso," no longer available, was replaced with CG-50 resin (Rettenmaier et al., 1979). The enzyme for hydrolyzing thiamin to a free state was changed from amylase to Mylase, (MacBride and Wyatt, 1983). Centrifugation was used to assist and speed filtration. The solvent used in the fluorometric determination was changed from isobutanol to isopropanol since isobutanol is listed as carcinogenic and both solvents had very similar extraction properties (MacBride and Wyatt, 1983). Initial and 6 month values are both lower than subsequent values and their accuracy is questionable. During the 6 month analysis samples were frozen for up to 2 months prior to the fluorometric analysis while at later testing periods samples were tested within a week of extraction. Thiamin may have been lost from the extract during frozen storage.

The effect of storage time on thiamin content of the low-moisture products is shown in Figures 51 - 53. It can be seen that 6 month

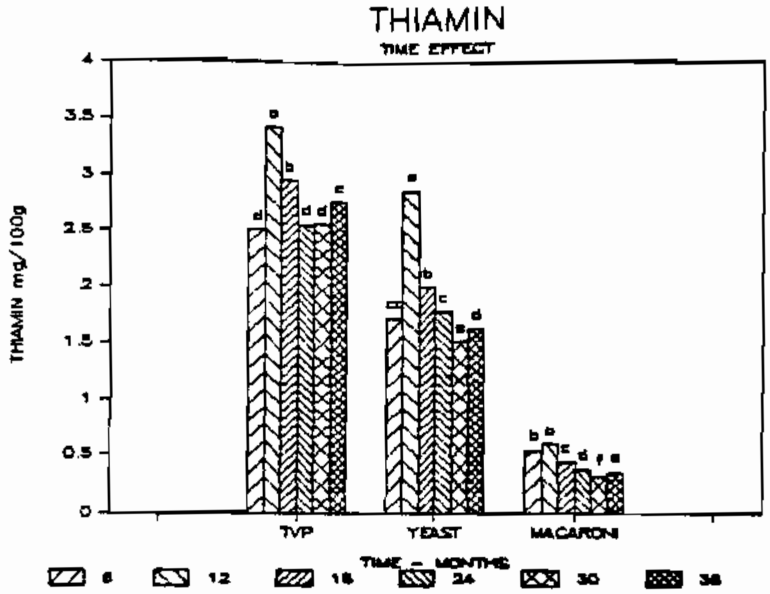

Figure 51 - Effect of storage time on thiamin content of low-moisture products: TVP, yeast, macaroni. Significant differences, p =.05 indicated by different letters above treatment.

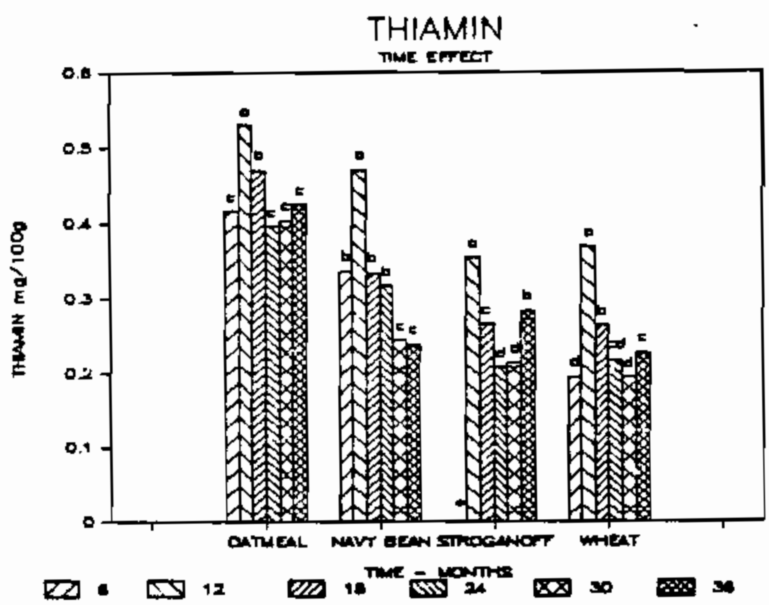

Figure 52 - Effect of storage time on thiamin content of low-moisture products: oatmeal, navy bean, stroganoff, wheat. Significant differences, p = .05 indicated by different letters above treatment. * not tested due to sample unavailability.

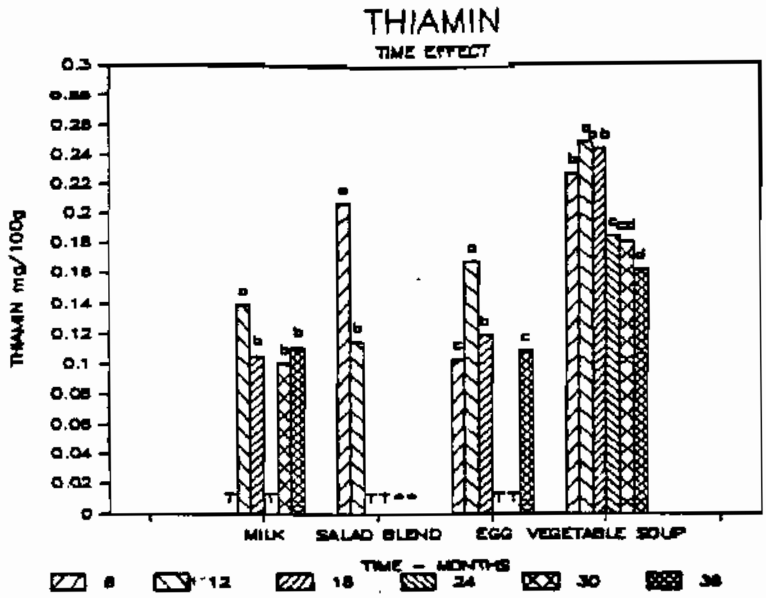

Figure 53 – Effect of storage time on thiamin content of low-moisture products: milk, salad blend, egg, vegetable soup. Significant differences, p = .05 indicated by different letters above treatment. T trace amount (0.1 mg/100g. * not tested due to trace amounts on previous tests.

values were lower for all products tested except salad blend. Thiamin values for the 12 to 30 month time periods declined steadily. There appears to be a small rise in thiamin content for most samples at 36 months, perhaps connected to different research assistants doing the analyses. It is not believed that thiamin content increases after 30 months.

Figures 54 - 56 show the effect of storage temperature on thiamin retention. The effect of temperature is significant and in accordance to Arrhenius kinetics for all products except milk, where thiamin amounts were very small. Differences between thiamin content of products stored at 40 and 70°F were not nearly as large as between products stored at 70 and 100°F. In four products,

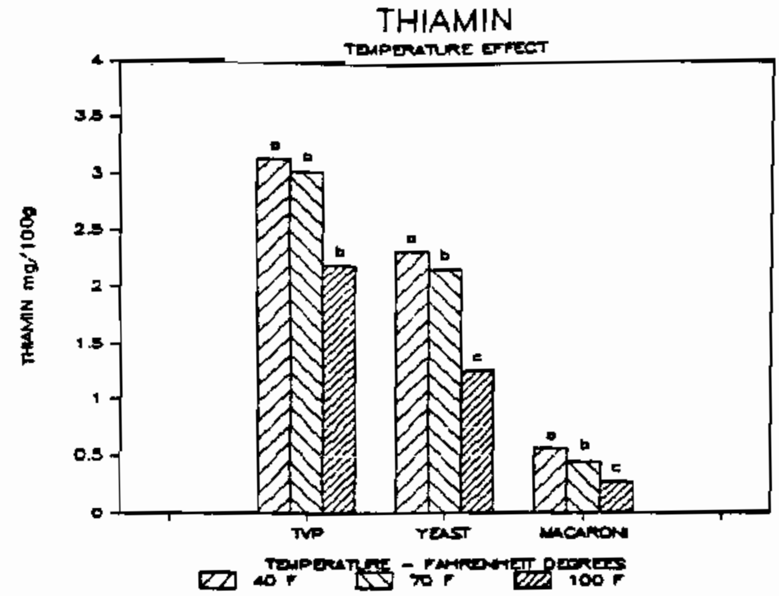

Figure 54 - Effect of storage temperature on thiamin content of low-moisture products: TVP, yeast, macaroni. Significant differences, p = .05 indicated by different letters above treatment.

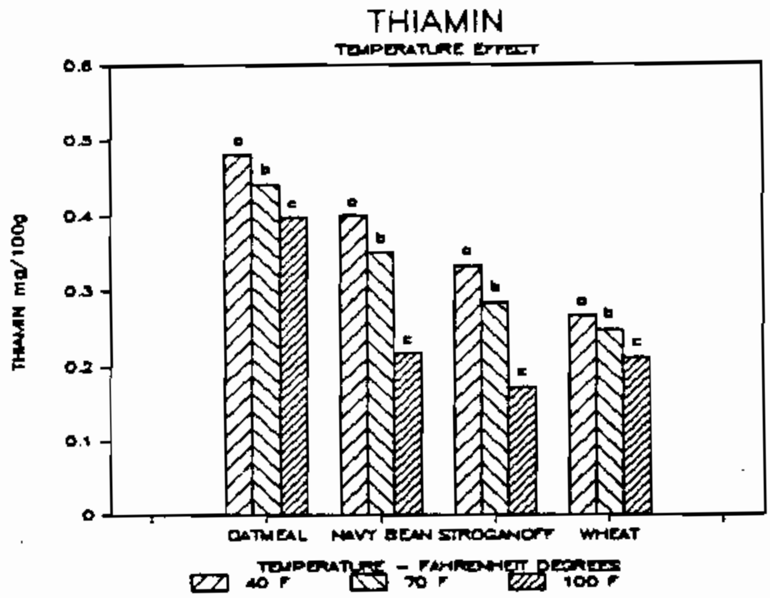

Figure 55 - Effect of storage temperature on thiamin content of low-moisture products: oatmeal, navy bean, stroganoff, wheat. Significant differences, p = .05 indicated by different letters above treatment.

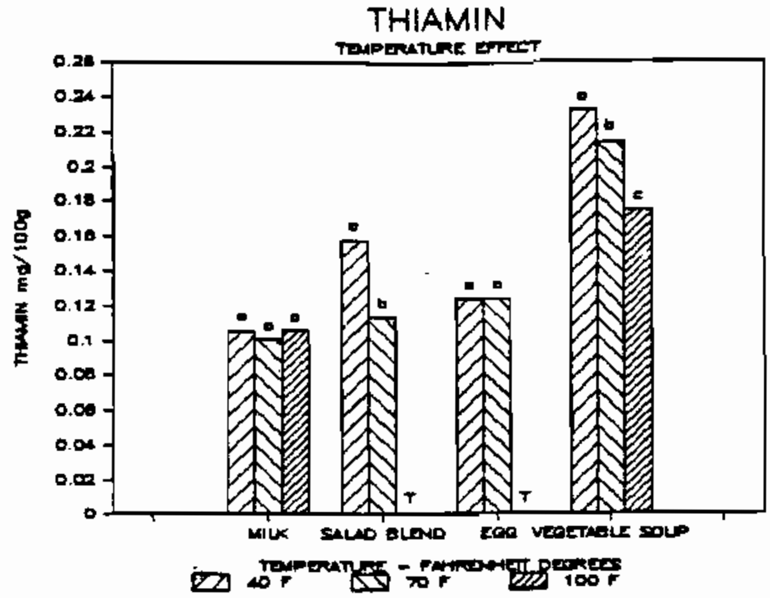

Figure 56 - Effect of storage temperature on thiamin content of low-moisture products: milk, salad blend, egg, vegetable soup. Significant differences, p = .05 indicated by different letters above treatment. T trace amount, < 0.1 mg/100g.

yeast, TVP, milk and eggs the difference between 40 and 70°F was not significant. Nonenzymatic browning is a major pathway of thiamin degradation (Dwivedi and Arnold, 1973; Dennison et al., 1977). Villota et al. (1980a) lists the activation energy of non-enzymatic browning to be 25-50 kcal/mole. The activation energy of lipid oxidation is 10-25 kcal/mole. The difference in activation energy may explain why the greatest temperature difference for thiamin degradation was between 70 and 100°F whereas for beta-carotene the greatest temperature difference was between 40 and 70°F.

The effect of the can atmosphere on thiamin content of low-moisture products is shown in Figures 57 - 59. A reduced oxygen environment had a significant protective effect on thiamin retention in all products studied except milk and vegetable soup. Differences

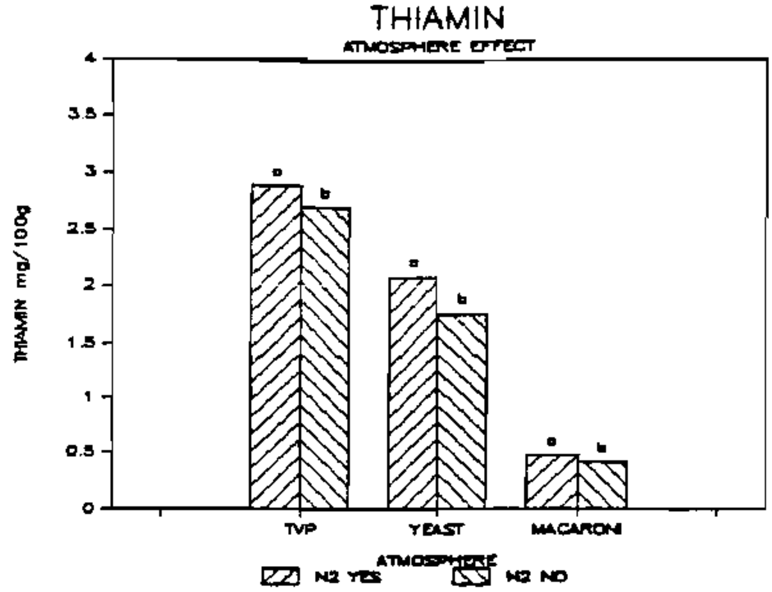

Figure 57 - Effect of interior can oxygen on thiamin content of low-moisture products: TVP, yeast, macaroni. Significant differences, p = .05 indicated by different letters above treatment.

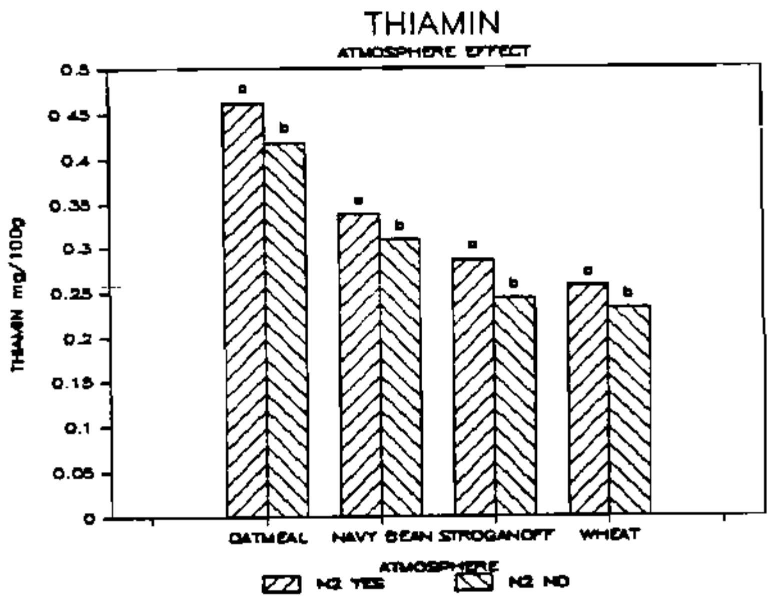

Figure 58 - Effect of interior can oxygen on thiamin content of low-moisture products: oatmeal, navy bean, stroganoff, wheat. Significant differences, p = .05 indicated by different letters above treatment.

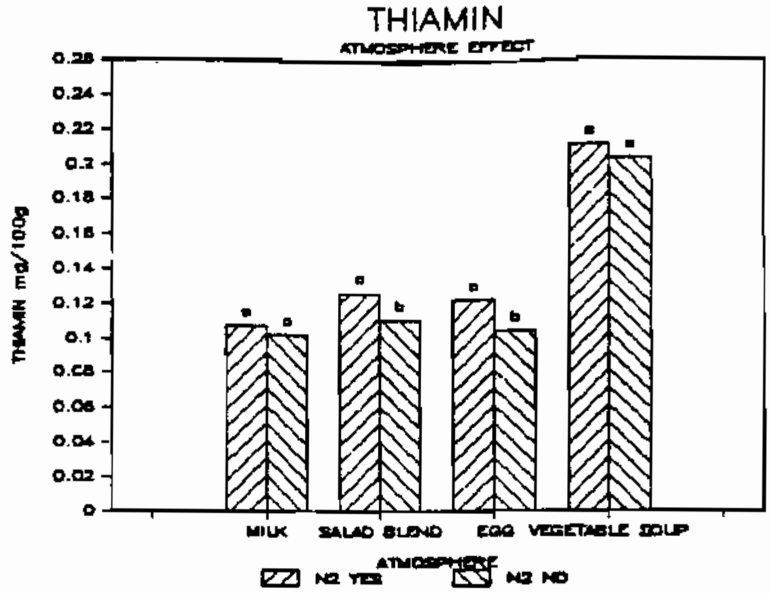

Figure 59 - Effect of interior can oxygen on thiamin content of low-moisture products: milk, salad blend, egg, vegetable soup. Significant differences, p = .05 indicated by different letters above treatment.

in thiamin due to atmosphere were not as dramatic as for beta-carotene where oxidation was the principle means of destruction. Results obtained by Dennison et al. (1977) which suggest thiamin destruction in dehydrated foods is independent of oxygen at 86°F.

Figures 60 - 92 show the time-temperature, time-atmosphere and atmosphere-temperature interactions for the individual products.

Eggs: Figure 60 shows the effect of storage time and temperature on the thiamin content of dehydrated eggs. Six month values are assumed to be low. A decrease in thiamin is seen from the 12 to 30 month period. At 24 months and beyond many values were trace (< 0.1 mg/100g). A significant atmosphere effect (Figure 61) was seen only at 12 months. Significant differences do not apply for trace amounts. The temperature-atmosphere interaction is not significant

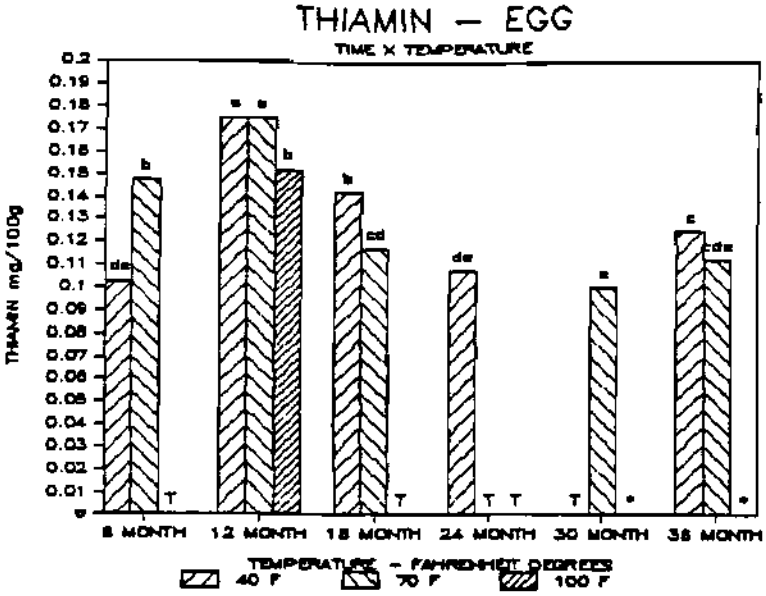

Figure 60 - Effect of storage time and temperature on thiamin content of dehydrated egg. Significant differences, p = .05 indicated by different letters above treatment. T trace amount, < 0.1 mg/100g. * not tested due to trace amount on previous test.

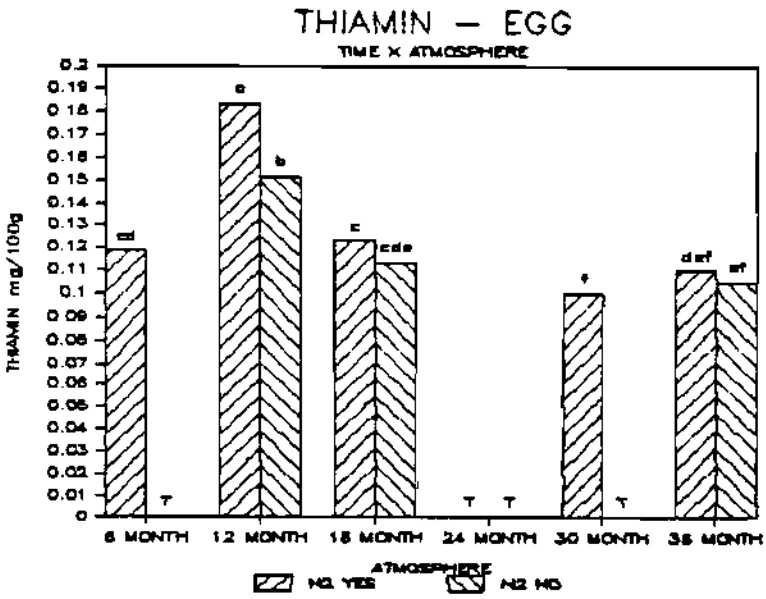

Figure 61 - Effect of storage time and interior can oxygen on thiamin content of dehydrated egg. Significant differences, p = .05 indicated by different letters above treatment. T trace amount, < 0.1 mg/100g.

(Figure 62). Mean thiamin values were nearly identical at 40 and 70°F and only trace amounts were obtained at 100°F.

Macaroni: Thiamin values for macaroni appeared to be low at 6 months, especially at 40°F (Figure 63). There was a decrease in thiamin at all temperatures from 12 to 30 months and values were significantly higher at the lower temperatures. Values at 36 months were a little higher than at 30 months but the temperature effect was still evident. A significant atmosphere effect (Figure 64) was seen at all time periods except the 12 month period. There is a large atmosphere difference at 40°F (Figure 65) and a lesser but still significant difference at 70°F. The atmosphere effect was not significant at 100°F.

Milk: Trace values for thiamin in dry milk at 6 months (Figure 66) are presumed lower than the real values, since thiamin values were significantly higher at 12 months. The slightly higher 12 month 100°F value is not significant. Dry milk contained very little thiamin after 12 months. The time-temperature interaction was not significant. Atmosphere differences at each time period were not significant (Figure 67). In Figure 68 nitrogen packed 100°F samples were significantly higher but this is mostly due to the questionable value at 12 months. Values for thiamin in nonfat dry milk were minimal in most cases which makes the effects difficult to compare.

Navy beans: The effect of storage time and temperature on the thiamin content of dry navy beans is seen in Figure 69. Six

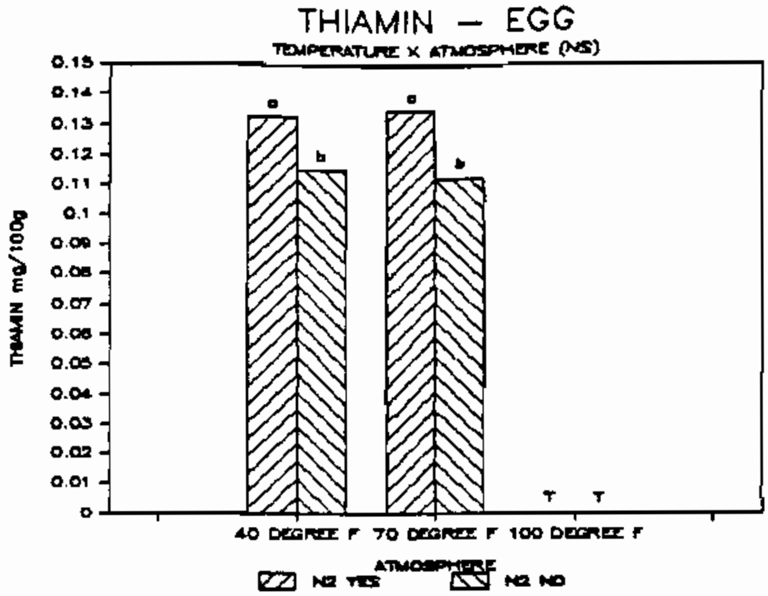

Figure 62 - Effect of storage temperature and interior can oxygen on thiamin content of dehydrated egg. Significant differences, p = .05 indicated by different letters above treatment. T trace amount, < 0.1 mg/100g. Interaction not significant.

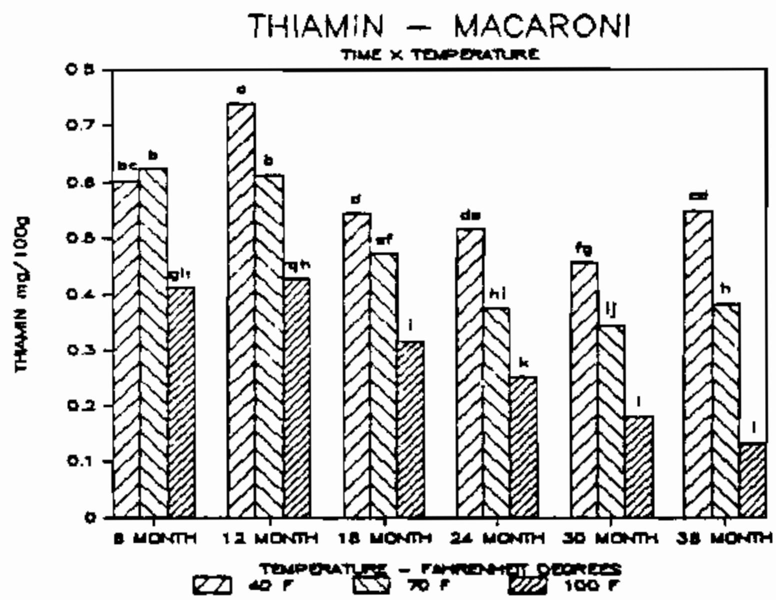

Figure 63 - Effect of storage time and temperature on thiamin content of dry macaroni. Significant differences, p = .05 indicated by different letters above treatment.

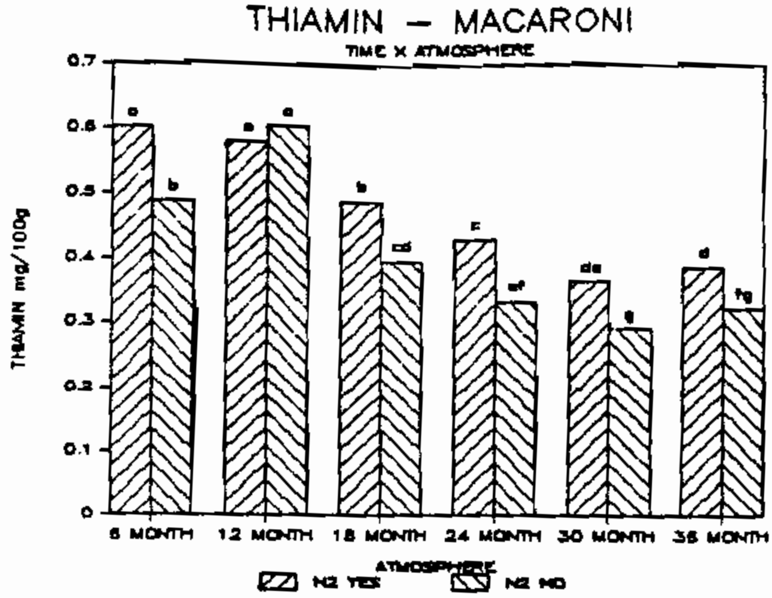

Figure 64 - Effect of storage time and interior can oxygen on thiamin content of dry macaroni. Significant differences, p = .05 indicated by different letters above treatment.

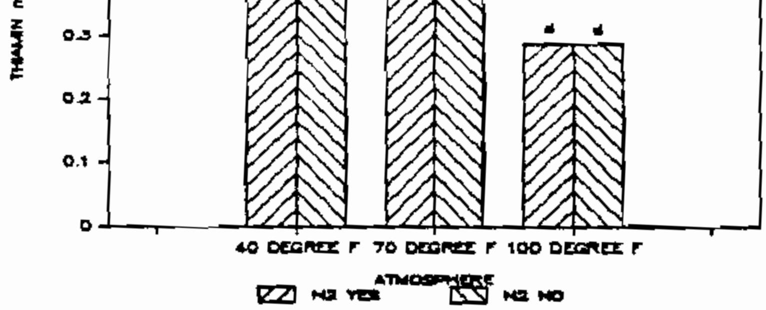

Figure 65 - Effect of storage temperature and interior can oxygen on thiamin content of dry macaroni. Significant differences, p = .05 indicated by different letters above treatment.

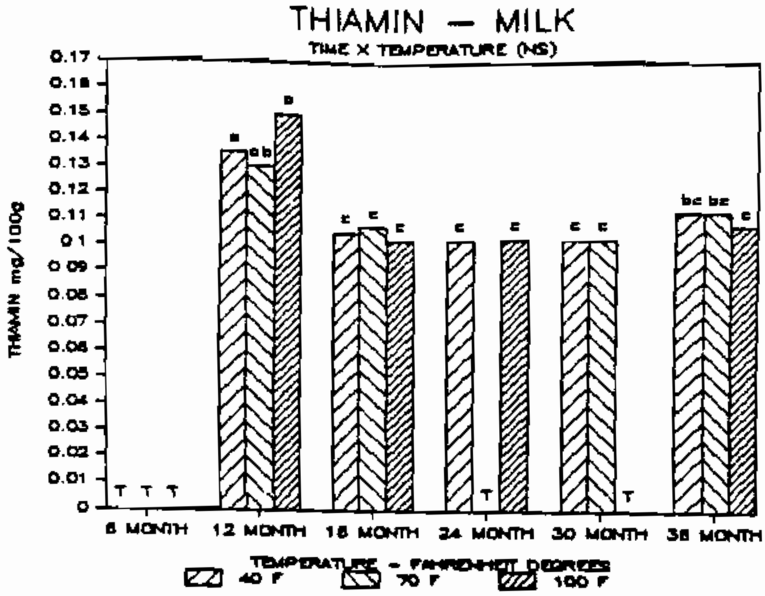

Figure 66 - Effect of storage time and temperature on thiamin content of dry milk. Significant differences, p = .05 indicated by different letters above treatment. T trace amount, < 0.1 mg/100g. Interaction not significant.

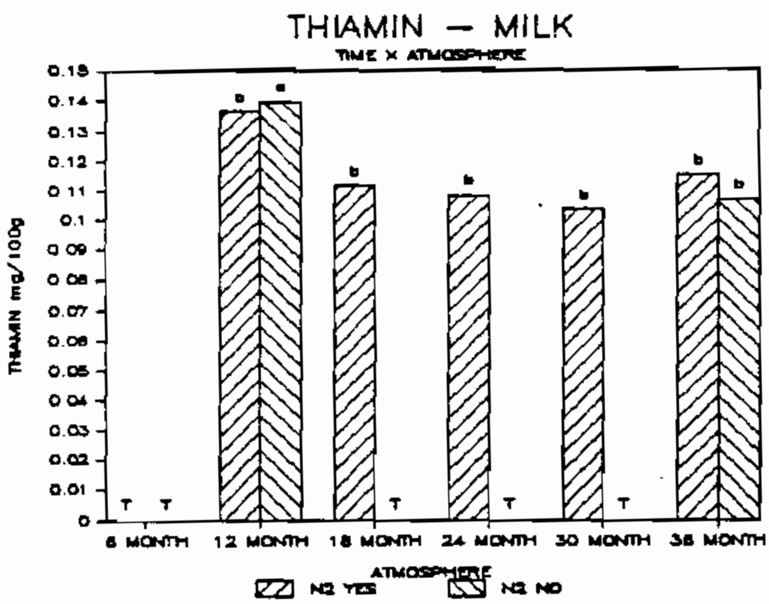

Figure 67 - Effect of storage time and interior can oxygen on thiamin content of dry milk. Significant differences, p = .05 indicated by different letters above treatment. T trace amount, < 0.1 mg/100g.

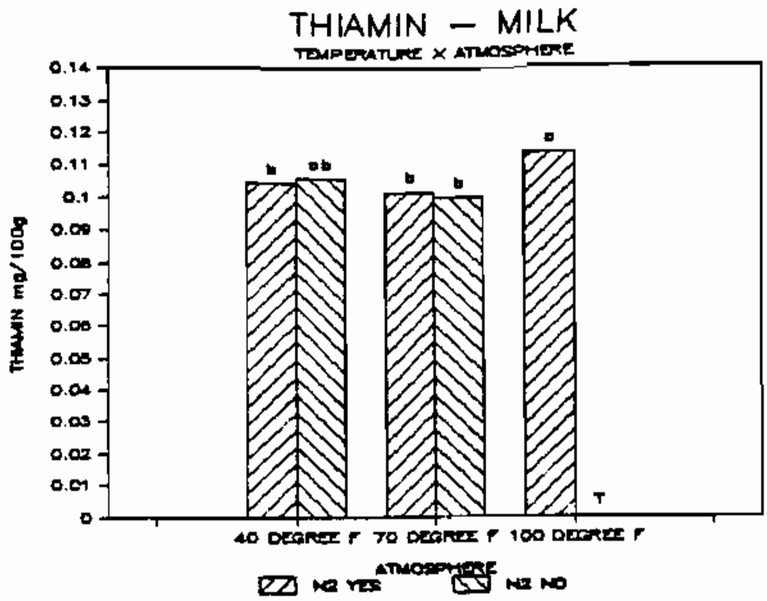

Figure 68 - Effect of storage temperature and interior can oxygen on thiamin content of dry milk. Significant differences, p = .05 indicated by different letters above treatment. T trace amount, < 0.1 mg/100g.

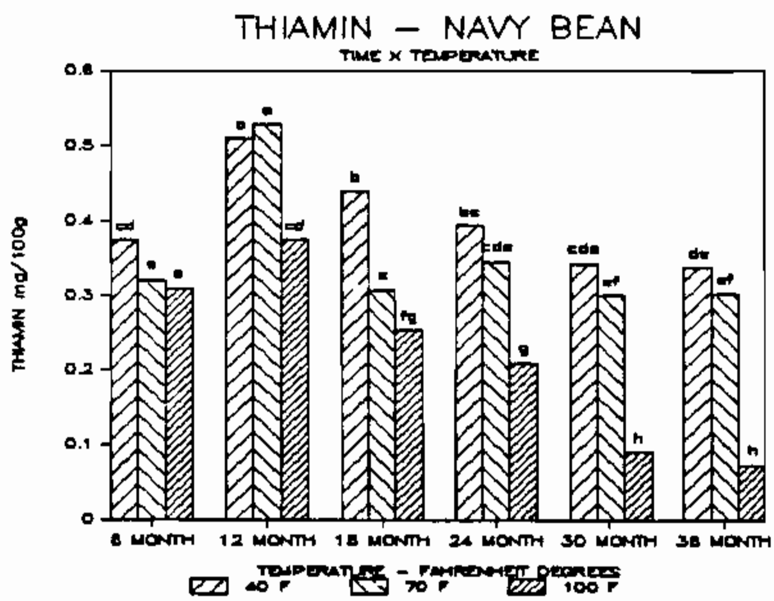

Figure 69 - Effect of storage time and temperature on thiamin content of dry navy beans. Significant differences, p = .05 indicated by different letters above treatment.

month values again appeared to be low. There was a steady decrease in most values from 12 to 36 months. Thiamin content of 40 and 70^{O}F samples varied significantly only at 6 and 18 months. The 100^{O}F samples were significantly lower than the 40 and 70^{O}F samples at all testing periods except 6 months and the difference increased with time. The time-atmosphere interaction is not significant (Figure 70). The 30 months storage period was the only time period where there was a significant atmosphere effect. Atmosphere differences were greatest at 40^{O}F and were not significant at 100^{O}F (Figure 71).

Oatmeal: Figure 72 shows the effects of time and temperature on thiamin content of dry oatmeal. Six month values were presumed low. The effect of temperature decreased with time. At 30 and 36 months the temperature effect was no longer significant. Nitrogen-packed samples contained significantly more thiamin only at 12 months (Figure 73). Atmosphere effects were not significant at 40^{O}F but were at 70 and 100^{O}F (Figure 74). Thiamin in oatmeal appeared to be more stable than in any other product, especially at the higher temperatures. Oatmeal also yielded less browning than most products; the 100^{O}F samples were not significantly darker than the 40 and 70^{O}F samples (Figure 148).

Salad blend: Thiamin in salad blend deteriorated rapidly (Figures 75, 76). Only trace amounts were present after 18 months. Thiamin was not tested at 30 and 36 months. Temperature and atmosphere effects were significant at both 6 and 12 months. The protective effect of reduced oxygen was significant at 40^{O}F but not at 70^{O}F (Figure 77).

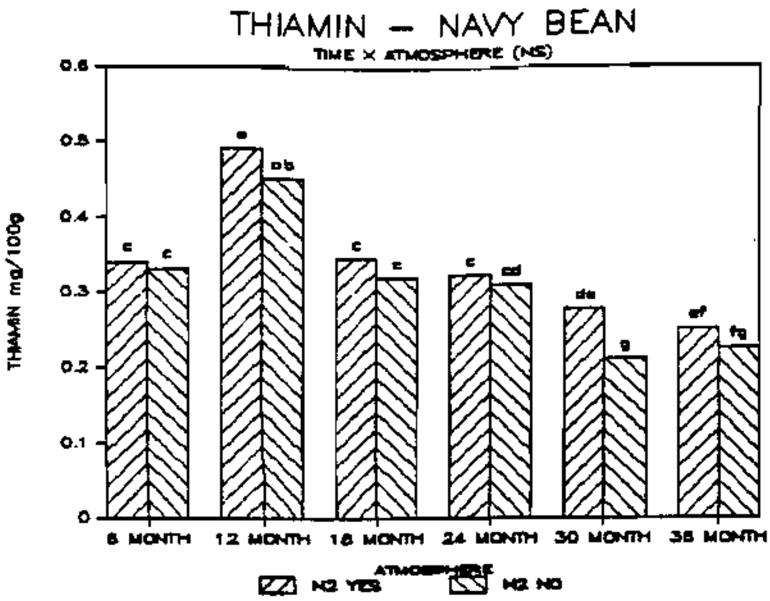

Figure 70 - Effect of storage time and interior can oxygen on thiamin content of dry navy beans. Significant differences, p = .05 indicated by different letters above treatment. Interaction not significant.

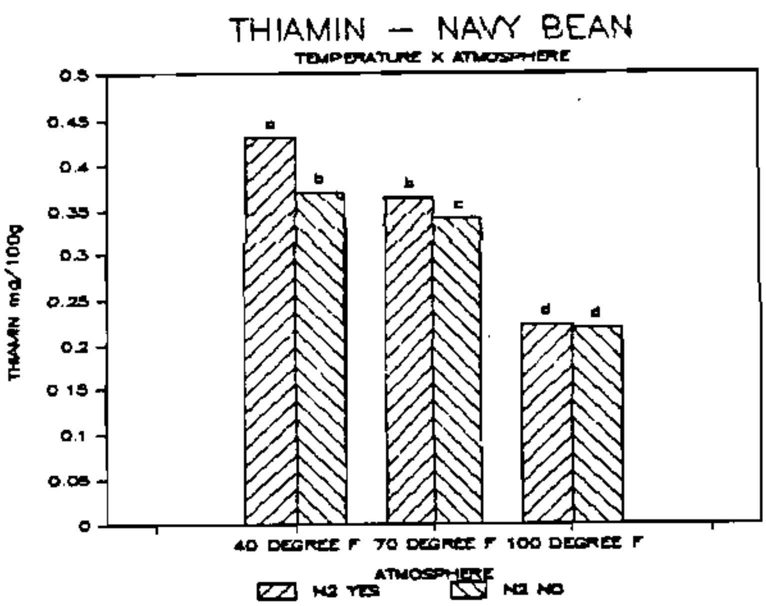

Figure 71 - Effect of storage temperature and interior can oxygen on thiamin content of dry navy beans. Significant differences, p = .05 indicated by different letters above treatment.

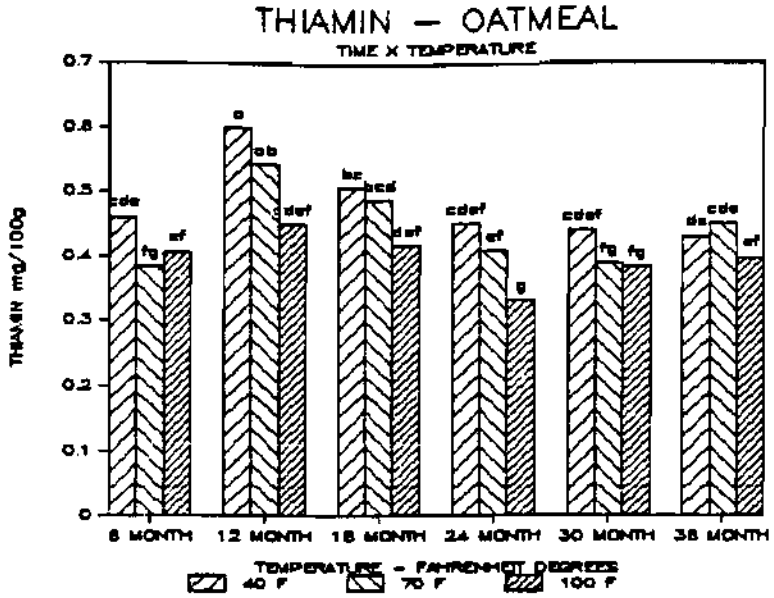

Figure 72 - Effect of storage time and temperature on thiamin content of dry oatmeal. Significant differences, p = .05 indicated by different letters above treatment.

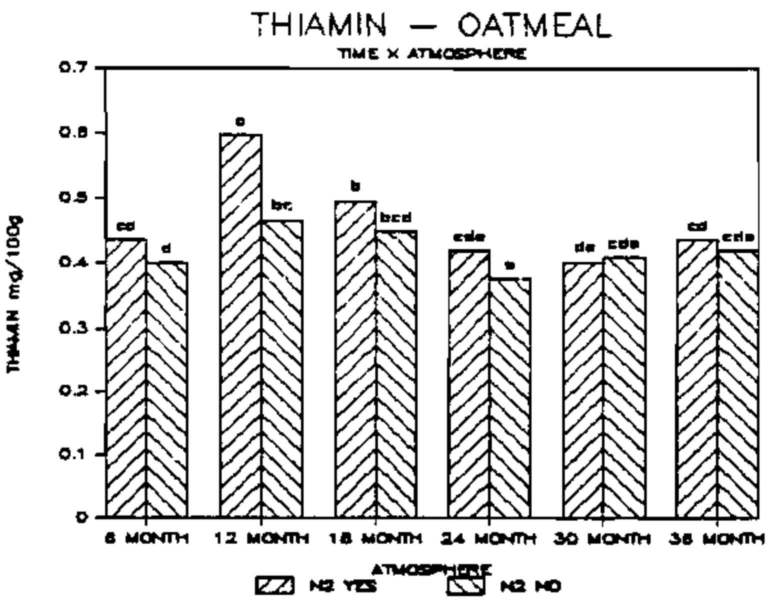

Figure 73 - Effect of storage time and interior can oxygen on thiamin content of dry oatmeal. Significant differences, p = .05 indicated by different letters above treatment.

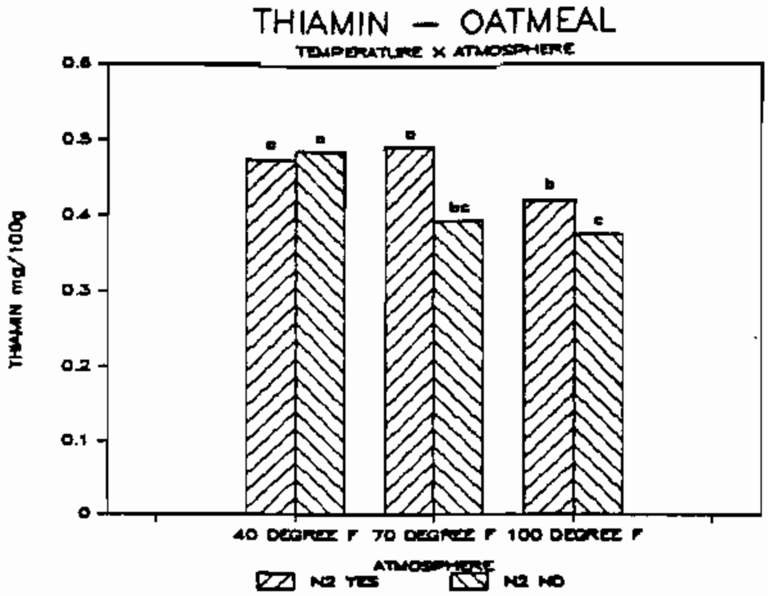

Figure 74 - Effect of storage temperature and interior can oxygen on thiamin content of dry oatmeal. Significant differences, p = .05 indicated by different letters above treatment.

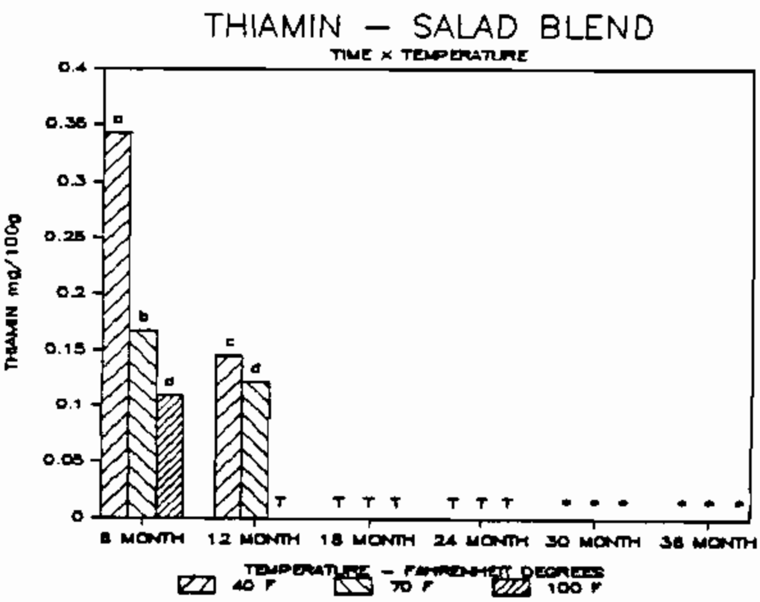

Figure 75 - Effect of storage time and temperature on thiamin content of dehydrated salad blend. Significant differences, p = .05 indicated by different letters above treatment. T trace amount, < 0.1 mg/100g. * not tested due to trace amount on previous tests.

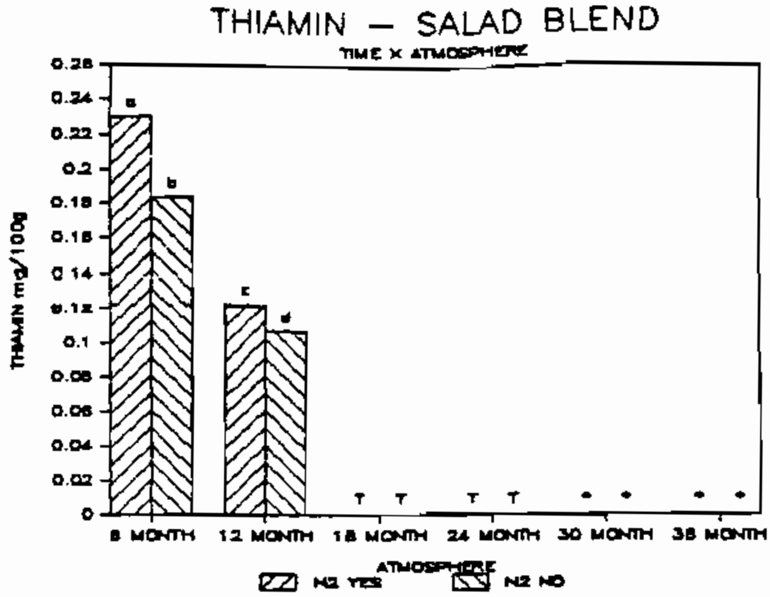

Figure 76 - Effect of storage time and interior can oxygen on thiamin content of dehydrated salad blend. Significant differences, p = .05 indicated by different letters above treatment. T trace amount, < 0.1 mg/100g. * not tested due to trace amount on previous tests.

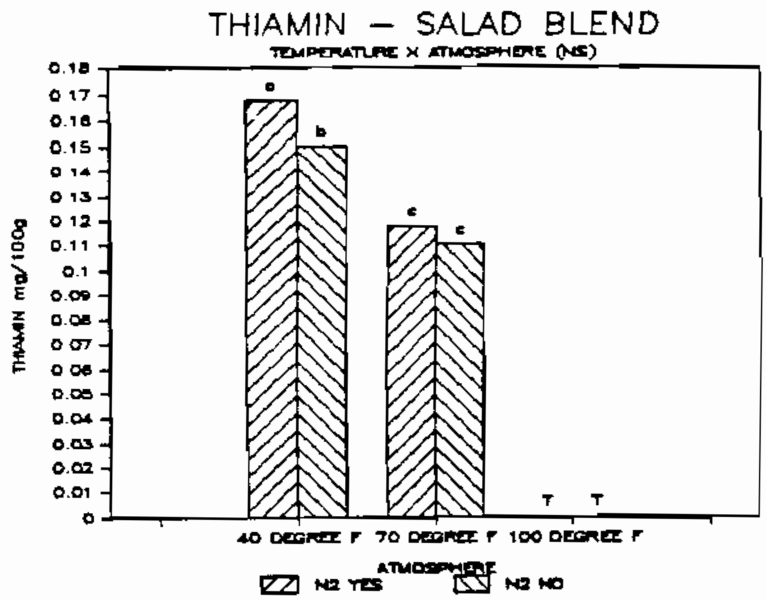

Figure 77 - Effect of storage temperature and interior can oxygen on thiamin content of dehydrated salad blend. Significant differences, p = .05 indicated by different letters above treatment. T trace amount, < 0.1 mg/100g. Interaction not significant.

Stroganoff: Figure 78 shows the effect of storage time and temperature on thiamin content of dry stroganoff. Sufficient sample for testing was not available at 6 months. There was a decrease in thiamin content from 12 to 24 months with an anomalous increase at 30 and 36 months. Thiamin was destroyed more rapidly at the higher temperatures. Thiamin differences were greater between 100 and 70°F than between 70 and 40°F. There was a significant atmosphere effect at all time periods (Figure 79) and at all temperatures (Figure 80) but the interactions were not significant. Thiamin was retained better in the nitrogen-packed samples.

TVP: Thiamin values for low-moisture TVP were believed to be low at 6 months (Figure 81). Analyzed thiamin was higher at 12 months, after which there was generally a decline. Averaged over all storage periods (Figure 54) the difference in thiamin of TVP stored at 40 and 70°F was not significant, but there was a large and significant drop between 70 and 100°F. Thiamin in the air-packed samples was significantly lower at all time periods except 6 months (Figure 82). The effect of atmosphere was only significant at 40°F (Figure 83). Nonenzymatic browning was not visually discernable in TVP due to the inherent brown color, however it was presumed to have been the pathway of thiamin destruction at 100°F. There are sufficient reducing groups available in TVP to allow nonenzymatic browning.

Vegetable soup: The effect of storage time and temperature on thiamin content of dehydrated vegetable noodle soup is shown in

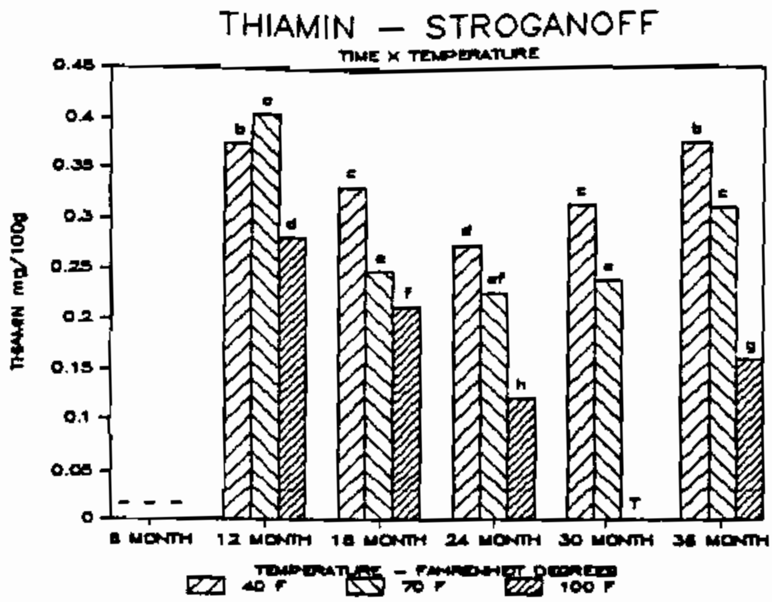

Figure 78 - Effect of storage time and temperature on thiamin content of dry stroganoff. Significant differences, p = .05 indicated by different letters above treatment. T trace amount, < 01. mg/100g. - not tested due to sample unavailability.

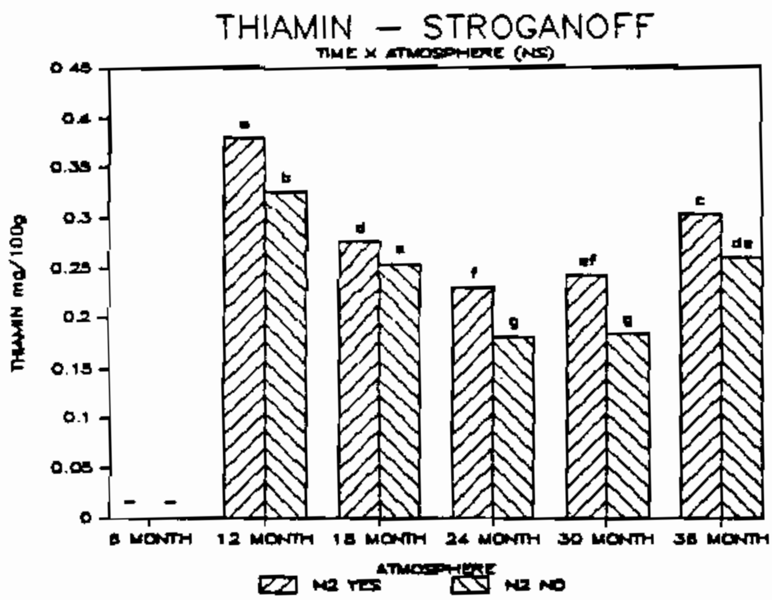

Figure 79 - Effect of storage time and interior can oxygen on thiamin content of dry stroganoff. Significant differences, p = .05 indicated by different letters above treatment. - not tested due to sample unavailability. Interaction not significant.

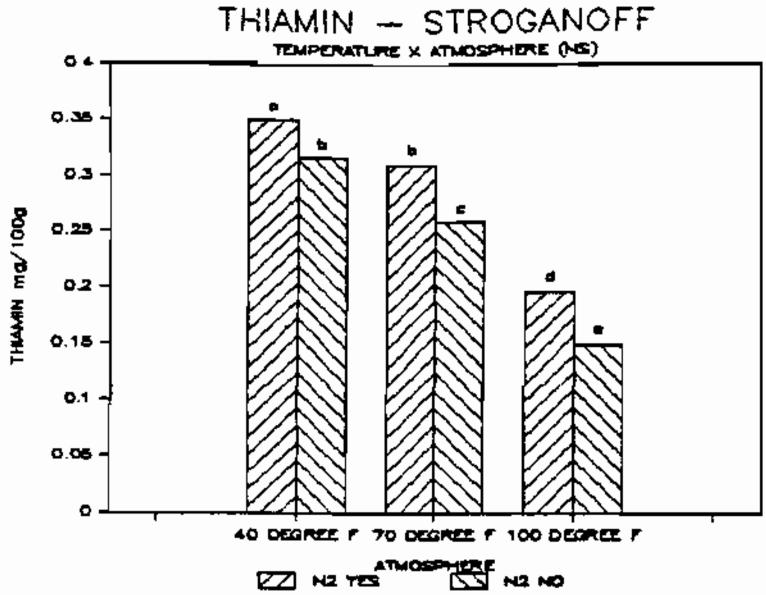

Figure 80 - Effect of storage temperature and interior can oxygen on thiamin content of dry stroganoff. Significant differences, p = .05 indicated by different letters above treatment. Interaction not significant.

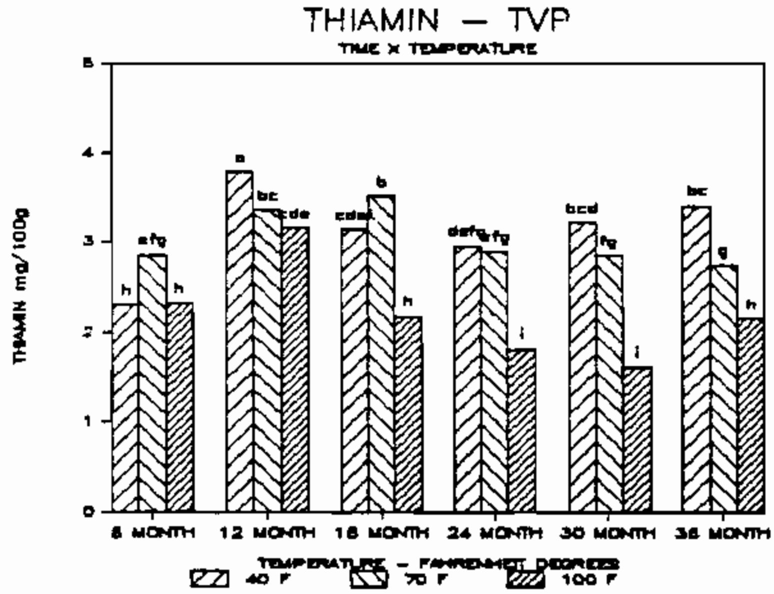

Figure 81 - Effect of storage time and temperature on thiamin content of dry TVP. Significant differences, p = .05 indicated by different letters above treatment.

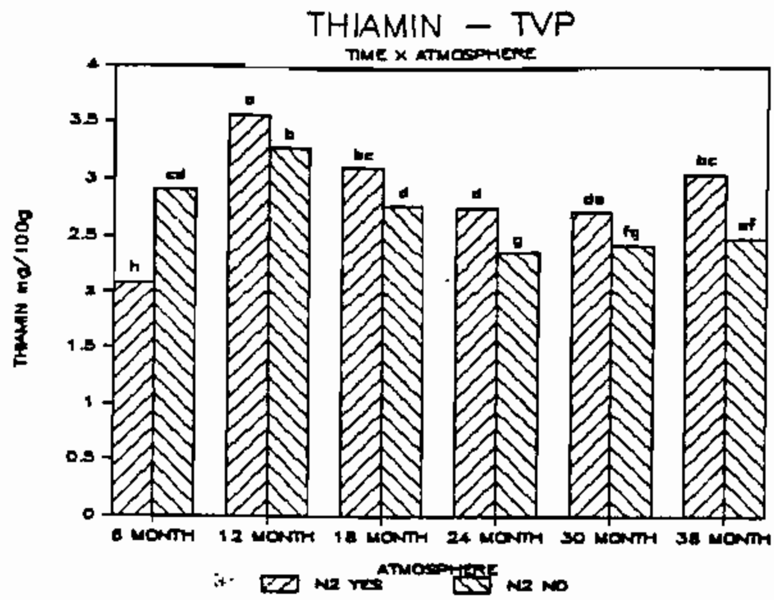

Figure 82 - Effect of storage time and interior can oxygen on thiamin content of dry TVP. Significant differences, p = .05 indicated by different letters above treatment. Interaction not significant.

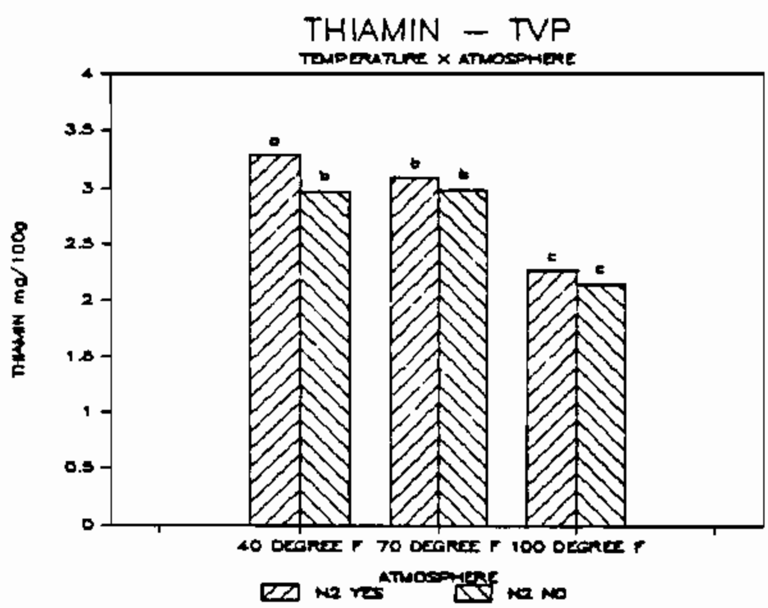

Figure 83 - Effect of storage temperature and interior can oxygen on thiamin content of dry TVP. Significant differences, p = .05 indicated by different letters above treatment.

Figure 84. Thiamin values for 40 and 70°F storage at 6 months appear to be low. The protective effect of low storage temperature (40°F) becomes more evident with time. The thiamin value of 100°F air-packed vegetable soup at 6 months was 0.5 mg/100g (Table 8) which is exceptionally high compared to other values. The vegetable soup was a heterogeneous mixture of vegetables, noodles and seasoning. Perhaps this reading was not from a representative soup sample. Its accuracy is questioned and consequently the derived graphs are possibly distorted with this data included. The nitrogen-packed samples retained significantly more thiamin after 24 months than air-packed samples (Figure 85). The high value for the air-packed sample at 6 months is believed incorrect. Nitrogen-packed samples retained significantly more thiamin at 40°F (Figure 86). At 70°F the difference was not significant and the difference at 100°F would not have been significant had it not been for the high 6 month value.

<u>Wheat</u>: Figure 87 shows the effect of storage time and temperature on thiamin content of wheat. Six month values were thought to be low since there was a large increase in thiamin at all temperatures from 6 to 12 months. There was a general decrease in thiamin content from 12 to 30 months. The thiamin content was lower at 100°F than at 40 or 70°F for all time periods except at 6 and 12 months. The temperature-atmosphere interaction was not significant (Figure 88), however at 40°F the nitrogen-packed sample retained significantly more thiamin. The time-atmosphere interaction was

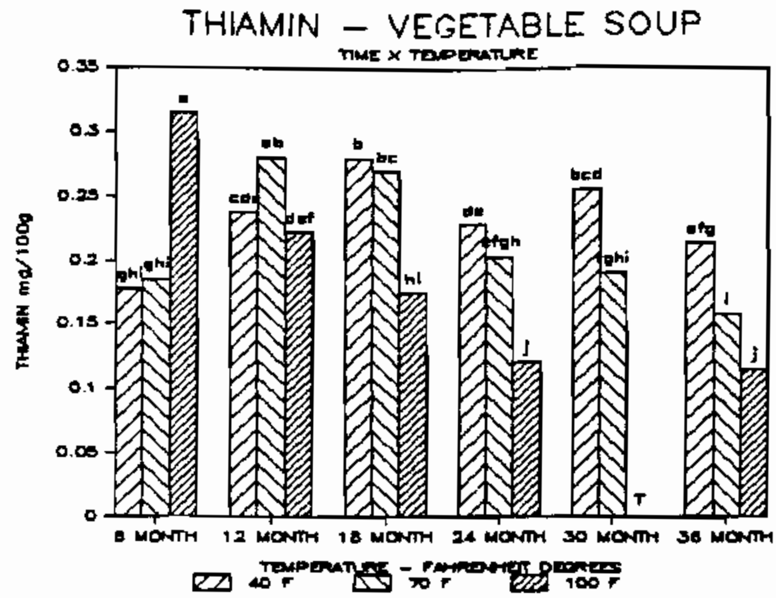

Figure 84 - Effect of storage time and temperature on thiamin content of dehydrated vegetable soup. Significant differences, p = .05 indicated by different letters above treatment. T trace amount, < 0.1 mg/100g.

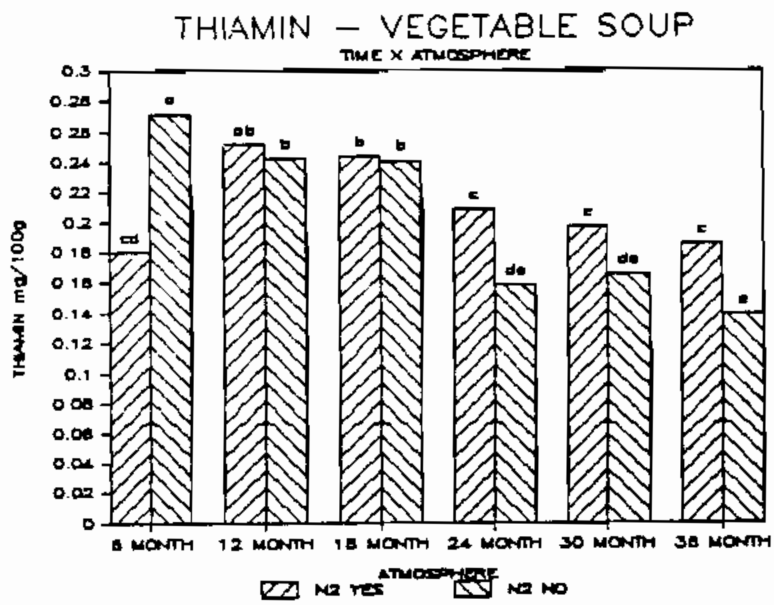

Figure 85 - Effect of storage time and interior can oxygen on thiamin content of dehydrated vegetable soup. Significant differences, p = .05 indicated by different letters above treatment.

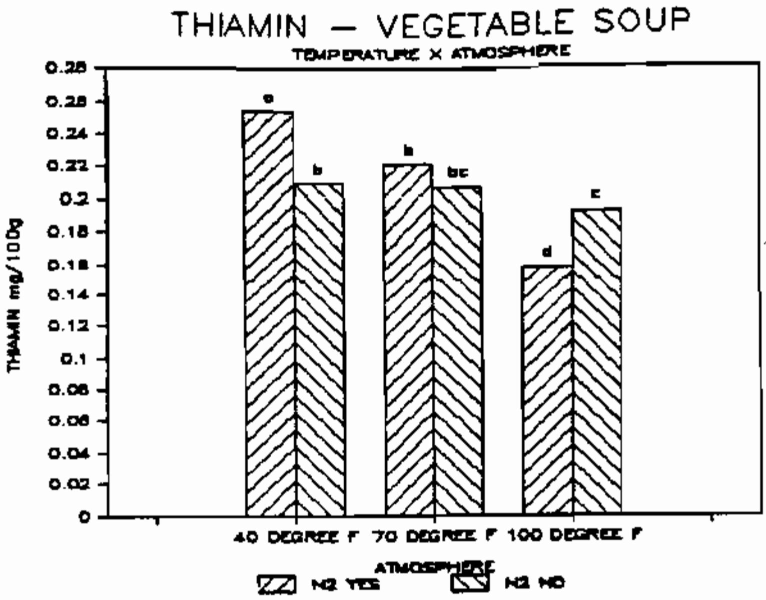

Figure 86 - Effect of storage temperature and interior can oxygen on thiamin content of dehydrated vegetable soup. Significant differences, p = .05 indicated by different letters above treatment.

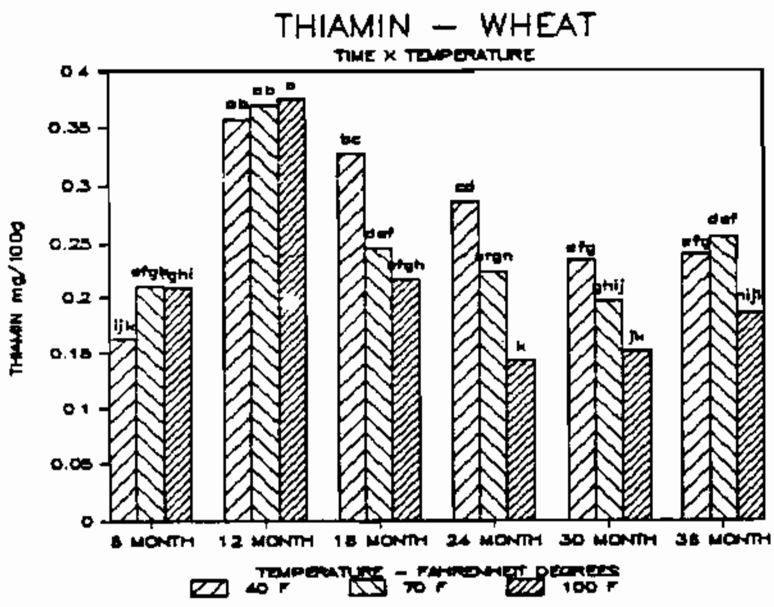

Figure 87 - Effect of storage time and temperature on thiamin content of dry wheat. Significant differences, p = .05 indicated by different letters above treatment.

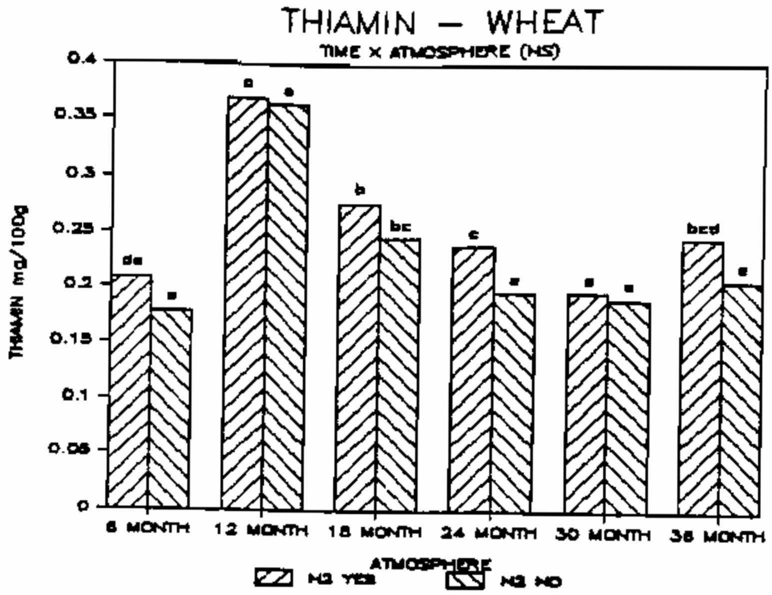

Figure 88 - Effect of storage time and interior can oxygen on thiamin content of dry wheat. Significant differences, p = .05 indicated by different letters above treatment. Interaction not significant.

not significant (Figure 89). Nitrogen-packing preserved a significantly greater thiamin content at 6, 18, 24 and 36 months.

<u>Yeast</u>: The effect of storage time and temperature on thiamin content of yeast is shown in Figure 90. Six month values are believed to be low. Thiamin content decreased from 12 to 36 months and was lower in samples stored at higher temperatures. Thiamin was significantly lower in air-packed samples at all time periods (Figure 91). The temperature-atmosphere interaction was not significant (Figure 92). Thiamin content of nitrogen-packed samples was greater than air-packed samples by approximately the same amount at all temperatures.

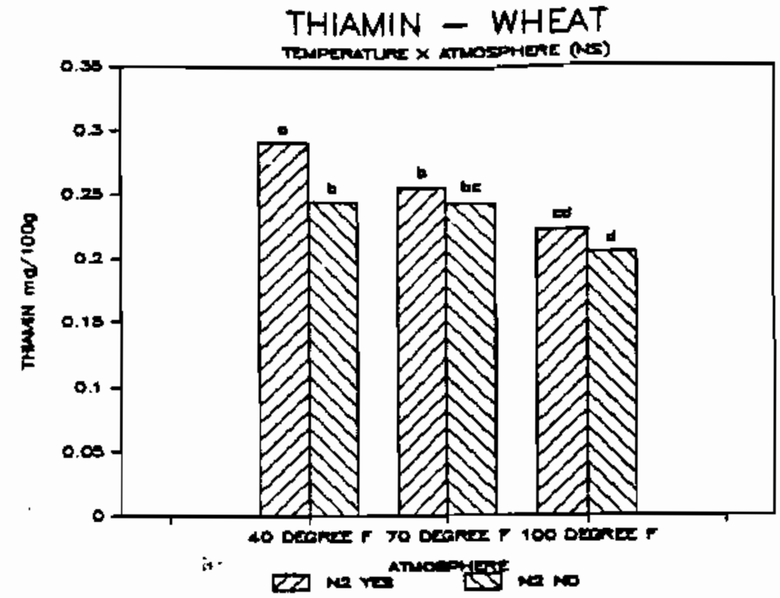

Figure 89 - Effect of storage temperature and interior can oxygen on thiamin content of dry wheat. Significant differences, p = .05 indicated by different letters above treatment. Interaction not significant.

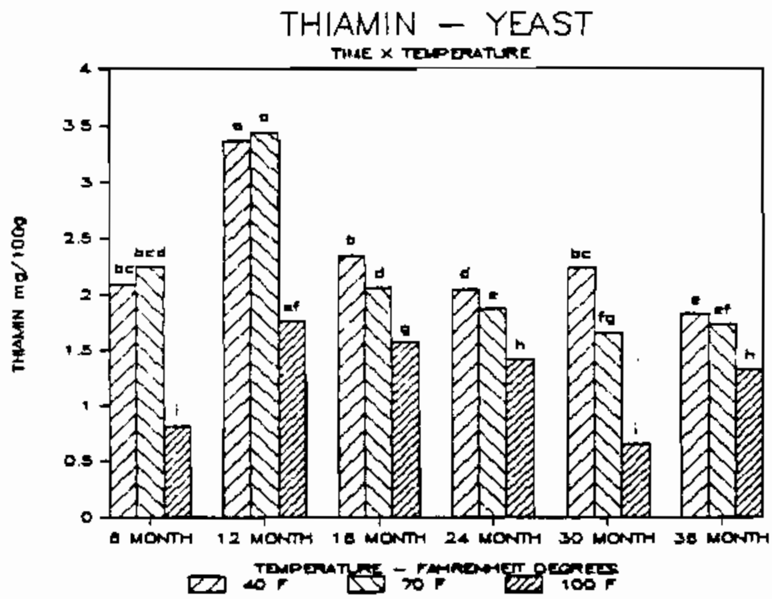

Figure 90 - Effect of storage time and temperature on thiamin content of dry yeast. Significant differences, p = .05 indicated by different letters above treatment.

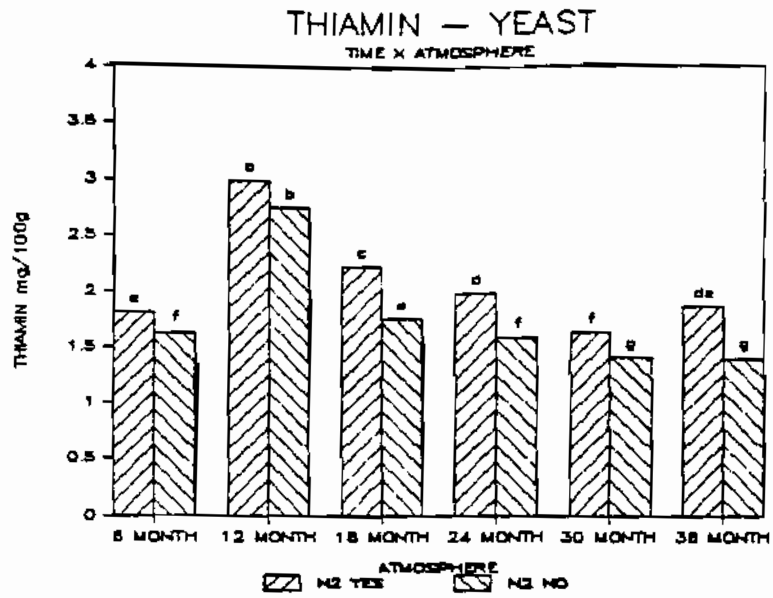

Figure 91 - Effect of storage time and interior can oxygen on thiamin content of dry yeast. Significant differences, p = .05 indicated by different letters above treatment.

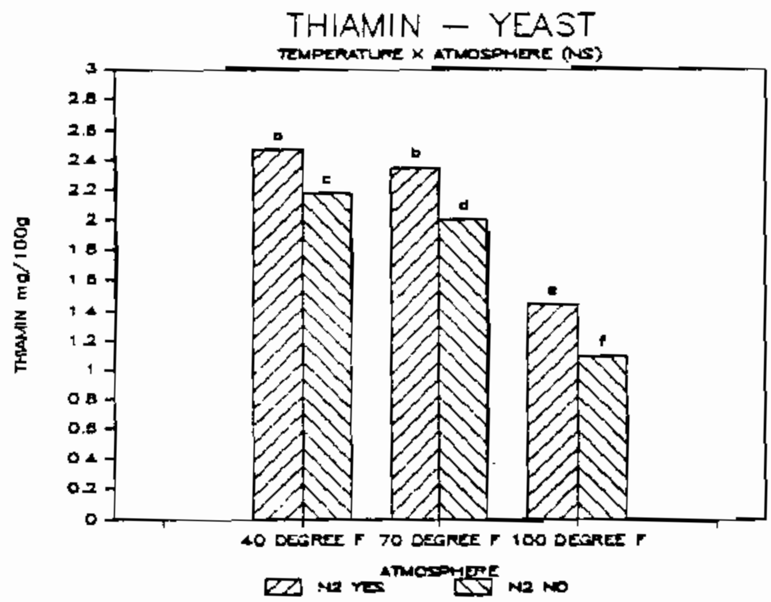

Figure 92 - Effect of storage temperature and interior can oxygen on thiamin content of dry yeast. Significant differences, p = .05 indicated by different letters above treatment. Interaction not significant.

For most products the oxygen effect at 100°F was not significant. Dennison et al. (1977) also reported thiamin destruction to be independent of oxygen at 86°F. Thiamin destruction at high temperatures is believed to be from nonenzymatic browning. Legault et al. (1951) reported little difference in the rate of nonenzymatic browning of air- and nitrogen-packed dehydrated products. This pathway is evidently anaerobic. Nonenzymatic browning in oatmeal was so small that it was possible to see a oxygen effect at 100°F.

Ascorbic acid

Ascorbic acid is probably the most labile of all the vitamins contained in foods. Kramer (1977) states that it is undoubtedly the most temperature-sensitive nutrient, particularly in non-acid foods and in the presence of oxygen. Ascorbic acid content was determined for eight low-moisture products in this study: apples, bananas, carrots, green beans, peaches, potatoes, salad blend and tomatoes. Potatoes at 6, 12 and 18 months storage retained only trace amounts of ascorbic acid regardless of storage treatment and were not tested during subsequent time periods. The treatment means for the other products are listed in Table 9. Trace values were less than 5 mg/100g.

Initial values were not accurate. Due to a typographical error in a copy of the procedure, 9 M H_2SO_4 was used instead of 9 N H_2SO_4 for making the 2% 2,4-dinitrophenylhydrazine reagent. Acid dehydration and decomposition of the dehydroascorbic acid may have occurred. Formation of the osazone was incomplete and

TABLE 9 - ASCORBIC ACID CONTENT OF LOW-MOISTURE PRODUCTS, TREATMENT MEANS.

		ASCORBIC ACIC, mg/100g					
	TIME	40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
APPLE	INITIAL	11.6					
	6 MONTH	38.9	37.9	31.1	34.9	14.7	18.0
	12 MONTH	8.8	6.7	5.3	trace	8.8	7.5
	18 MONTH	6.1	trace	6.2	trace	6.4	5.2
	24 MONTH	6.4	5.0	5.8	trace	5.9	trace
	30 MONTH	6.9	*	6.6	*	6.2	*
	36 MONTH	trace	*	5.1	*	trace	*
BANANA	INITIAL	6.2					
	6 MONTH	26.8	23.2	28.8	23.6	21.6	13.2
	12 MONTH	22.2	20.2	20.6	18.2	19.6	13.6
	18 MONTH	11.4	11.0	13.2	11.3	10.5	7.3
	24 MONTH	13.0	11.0	12.0	10.8	10.2	6.5
	30 MONTH	16.7	13.8	15.0	10.3	11.9	6.1
	36 MONTH	11.3	10.8	9.2	6.2	6.5	trace
CARROT	INITIAL	3.6					
	6 MONTH	48.9	40.8	35.4	16.8	14.8	8.8
	12 MONTH	12.8	10.6	9.2	6.3	trace	trace
	18 MONTH	13.7	12.6	13.0	11.3	11.6	10.6
	24 MONTH	12.2	11.2	12.0	9.5	10.6	8.9
	30 MONTH	14.7	12.0	11.6	8.6	10.5	9.0
	36 MONTH	12.1	8.2	10.9	7.2	7.2	5.4
GR BEAN	INITIAL	13.2					
	6 MONTH	46.5	39.5	33.2	28.4	28.1	20.8
	12 MONTH	34.2	25.8	31.6	18.8	15.8	11.7
	18 MONTH	42.6	29.9	35.1	21.0	22.1	17.0
	24 MONTH	41.5	27.9	28.4	16.2	17.3	14.2
	30 MONTH	48.5	38.3	34.8	17.2	20.5	15.9
	36 MONTH	41.4	31.8	32.9	19.6	17.3	13.0

trace = < 5 mg/100g.
* not tested due to trace amounts on previous tests.

TABLE 9 - CONTINUED

	TIME	ASCORBIC ACIC, mg/100g					
		40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
	INITIAL	1.1					
P	6 MONTH	19.1	18.2	14.6	16.6	20.0	16.1
E	12 MONTH	8.9	7.0	8.6	7.2	6.1	5.0
A	18 MONTH	8.1	10.2	7.6	8.4	9.2	8.2
C	24 MONTH	7.8	6.2	7.2	6.0	5.9	trace
H	30 MONTH	7.9	7.1	8.7	8.6	5.9	trace
	36 MONTH	5.6	trace	5.0	trace	5.3	trace
S	INITIAL	71.9					
	6 MONTH	308.5	208.8	208.6	113.7	53.2	27.8
B	12 MONTH	199.0	138.7	187.1	108.9	43.4	14.4
L	18 MONTH	188.4	161.2	156.6	107.6	31.1	18.6
E	24 MONTH	185.1	158.6	151.8	105.9	29.2	16.7
N	30 MONTH	233.2	175.2	169.8	97.7	31.8	17.7
D	36 MONTH	223.0	190.4	160.1	74.3	14.7	7.4
T	INITIAL	31.9					
O	6 MONTH	167.8	161.1	168.6	166.0	38.3	30.2
M	12 MONTH	149.9	137.8	102.8	99.1	30.6	21.2
A	18 MONTH	149.3	159.8	119.6	107.8	35.2	25.8
T	24 MONTH	132.7	123.2	109.7	102.1	33.6	16.6
O	30 MONTH	132.2	126.8	99.7	91.8	30.0	21.1
	36 MONTH	138.2	128.2	58.0	43.1	22.8	14.0

values were very low. This mistake was detected and corrected prior to 6 month testing. The initial values were not used in the analysis of the data and are not included on the graphs.

Figures 93 and 94 show the effect of storage time on ascorbic acid content of the dehydrated products. As with <u>beta</u>-carotene it appeared that much of the vitamin was destroyed in a short storage time and that the rest was in a relatively stable state. There was generally a large drop in ascorbic acid content from 6 to 12 months with little change thereafter. It was assumed that much of the ascorbic acid was lost by 6 months.

The effect of storage temperature on ascorbic acid content is shown in Figures 95 and 96. Ascorbic acid is very temperature sensitive and its degradation increases rapidly with increasing temperature. Kirk (1981) reports the activation energy to be 16 kcal/mole for the destruction of ascorbic acid in low-moisture foods (a_w = .24). The ascorbic acid in the fruits in this study (Figure 95) appears to be more stable at higher temperatures than that in vegetables (Figure 96); tomatoes and salad blend in particular. This may be misleading however, since the fruits were higher in sugar content. These sugars, especially in products stored at high temperatures are easily caramelized, causing a darkening of the solution if the H_2SO_4 is added too rapidly. Some of the 100^oF values for the fruits appeared to be high (Table 9). This may be due to charring of some of the sugars present.

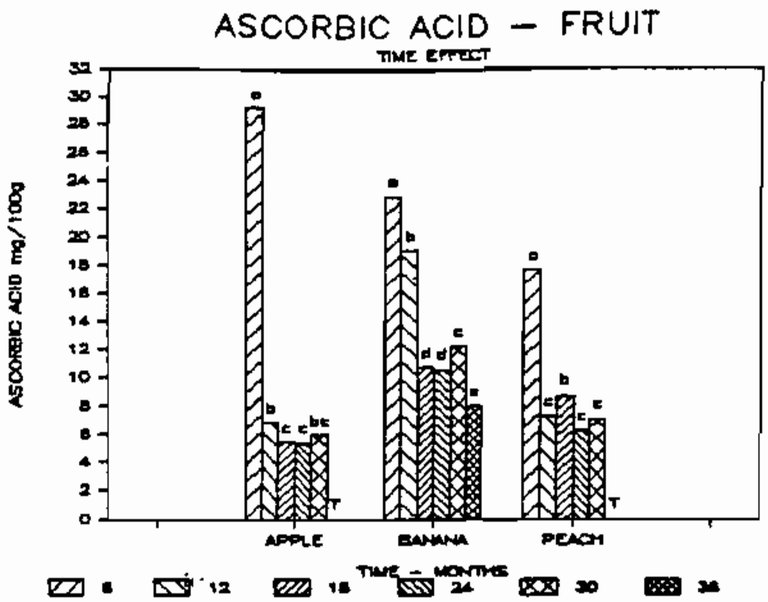

Figure 93 - **Effect of storage time on ascorbic acid content of low-moisture products: apple, banana, peach.** Significant differences, p = .05 indicated by different letters above treatment. T trace amount, < 5 mg/100g.

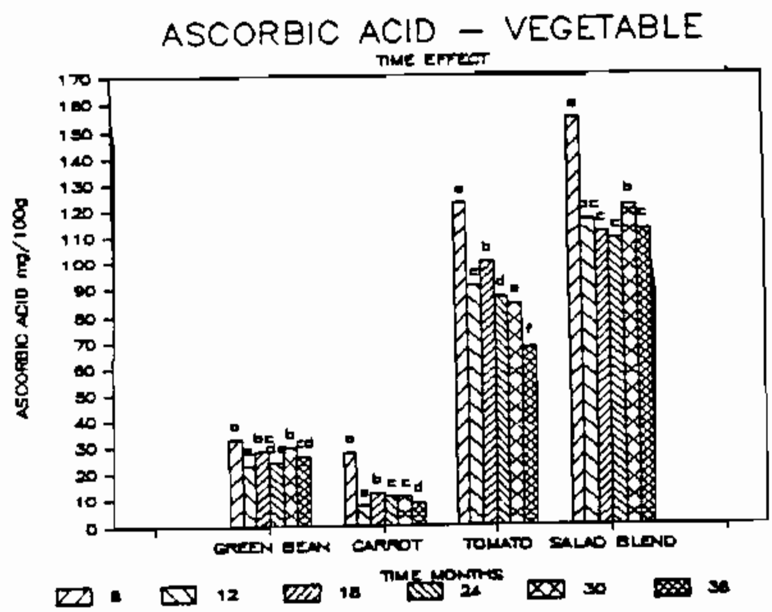

Figure 94 - **Effect of storage time on ascorbic acid content of low-moisture products: green bean, carrot, tomato, salad blend.** Significant differences, p = .05 indicated by different letters above treatment.

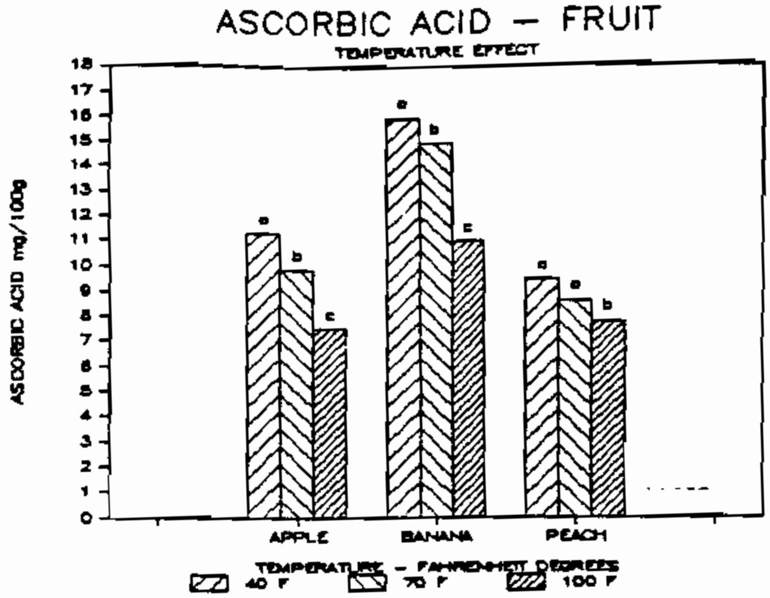

Figure 95 - Effect of storage temperature on ascorbic acid content of low-moisture products: apple, banana, peach. Significant differences, p = .05 indicated by different letters above treatment.

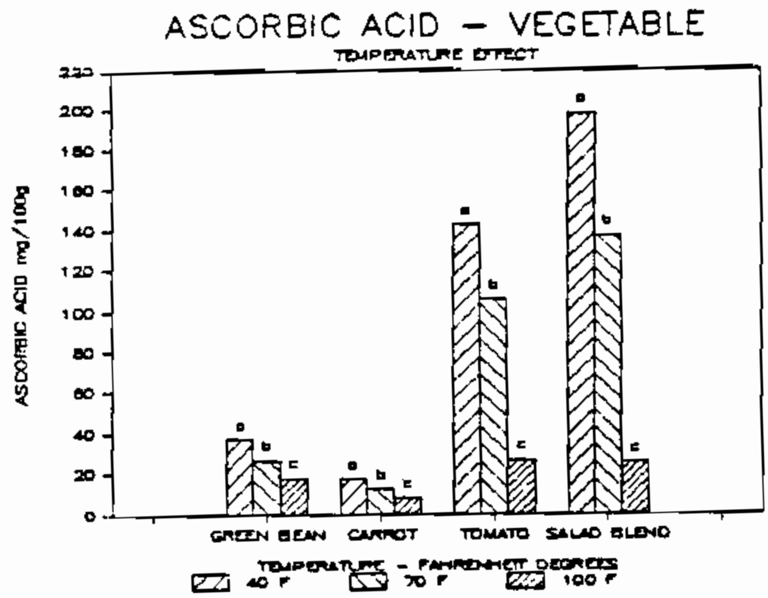

Figure 96 - Effect of storage temperature on ascorbic acid content of low-moisture products: green bean, carrot, tomato, salad blend. Significant differences, p = .05 indicated by different letters above treatment.

Figures 97 and 98 show the effect of interior can atmosphere on the ascorbic acid content of the low-moisture products. With the exception of apples, products packed in nitrogen retained significantly more ascorbic acid. This effect was quite small in peaches and tomatoes (pH 4.1) having a low pH, but larger in bananas (pH 5.9), salad blend, carrots and green beans, having a higher pH. Riemer and Karel (1978a&b) found no oxygen effect in ascorbic acid degradation in dehydrated tomato juice at pH 4.1, however Dennison and Kirk (1978) found oxygen to be a main factor in the degradation of a dehydrated model food system at pH 6.8. Ascorbic acid is more stable at pH 3-4.5 than at pH 6-7 (Borenstein, 1975). The pathway of degradation may be dependent on pH. The pKa for ascorbic acid is 4.087 (Lee et al., 1977).

Bananas had also been processed in oil. The high oil content would accelerate oxidation of ascorbic acid.

Figures 99 - 119 show the time-temperature, time-atmosphere, and atmosphere-temperature interactions for the ascorbic acid content of the individual products.

Apples: The temperature effect in dehydrated apples was very visible at 6 months (Figure 99), but after 12 months ascorbic acid content was minimal regardless of storage temperture. Air-packed samples retained more ascorbic acid than the nitrogen-packed samples at 6 months (Figure 100); however at longer storage times nitrogen-packed samples retained more. The overall effect of nitrogen on ascorbic acid in dehydrated apples was not significant (Figure

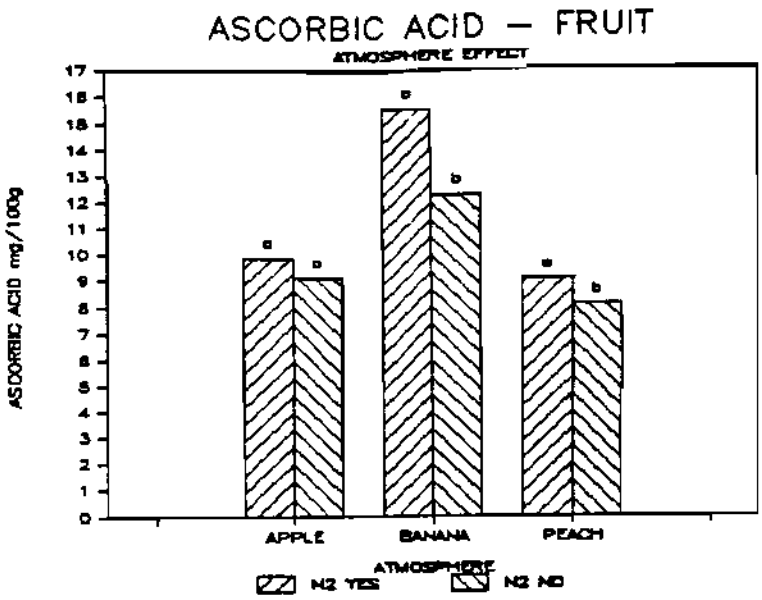

Figure 97 - Effect of interior can oxygen on ascorbic acid content of low-moisture products: apple, banana, peach. Significant differences, p = .05 indicated by different letters above treatment.

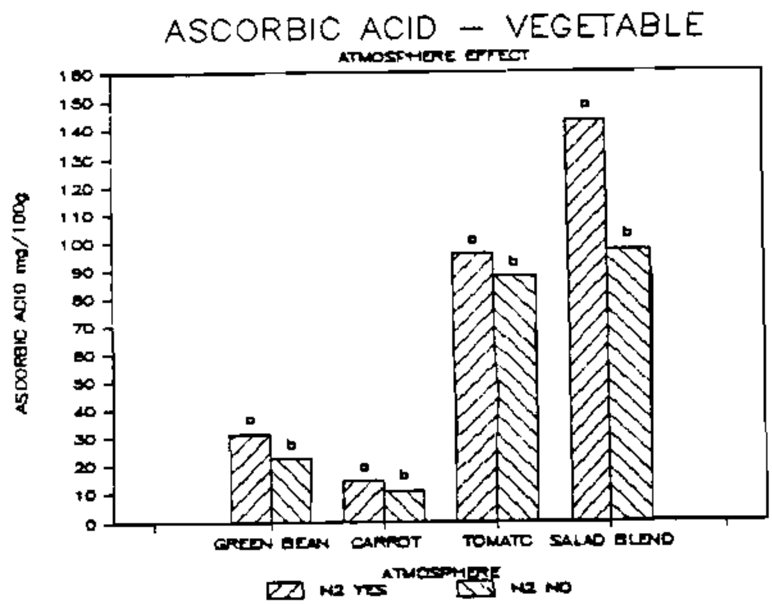

Figure 98 - Effect of interior can oxygen on ascorbic acid content of low-moisture products: green bean, carrot, tomato, salad blend. Significant differences, p = .05 indicated by different letters above treatment.

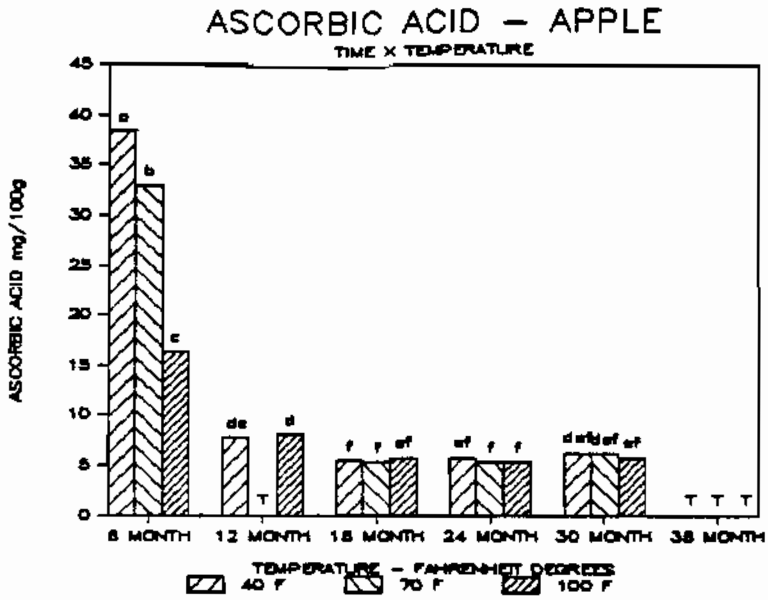

Figure 99 - Effect of storage time and temperature on ascorbic acid content of dehydrated apples. Significant differences, p = .05 indicated by different letters above treatment. T trace amount, < 5 mg/100g.

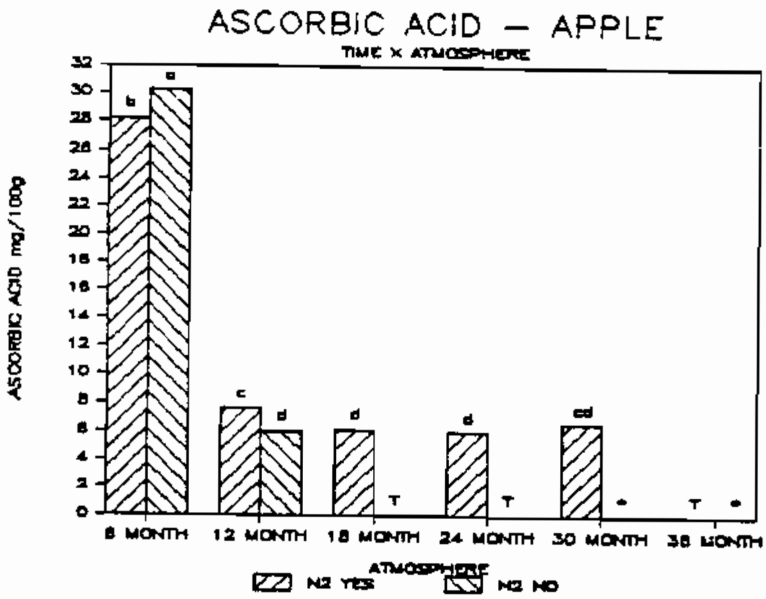

Figure 100 - Effect of storage time and interior can oxygen on ascorbic acid content of dehydrated apples. Significant differences, p = .05 indicated by different letters above treatment. T trace amount, < 5 mg/100g. * not tested due to trace amount on previous tests.

97). Nitrogen-packed samples retained significantly more ascorbic acid only at 40°F (Figure 101). The temperature-atmosphere interaction was not significant.

Bananas: Low-moisture bananas stored at 100°F retained significantly less ascorbic acid than bananas stored at 40 or 70°F at all time periods (Figure 102). Bananas stored at 40°F did not always contain more ascorbic acid than those stored at 70°F. Ascorbic acid decreased during the first three storage periods and then leveled off after 18 months. Samples packed in nitrogen retained significantly more ascorbic acid at all time periods (Figure 103). The atmosphere effect was significant at all three temperatures (Figure 104) but greatest at 100°F.

Carrots: There was a definite temperature effect on ascorbic acid content in dehydrated carrots at 6 months (Figure 105), but not much change regardless of temperature after 12 months. Nitrogen-packed samples contained significantly more ascorbic acid at all time periods (Figure 106). This effect was greatest at 6 months before the ascorbic acid leveled off. Nitrogen-packed carrots retained more ascorbic acid at all three temperatures (Figure 107); the difference was greatest at 70°F.

Green beans: There was a definite temperature effect on ascorbic acid content of dehydrated green beans at all storage times (Figure 108). Samples stored at 40°F contained significantly more ascorbic acid than those stored at 70°F, which contained significantly more than those stored at 100°F. The ascorbic

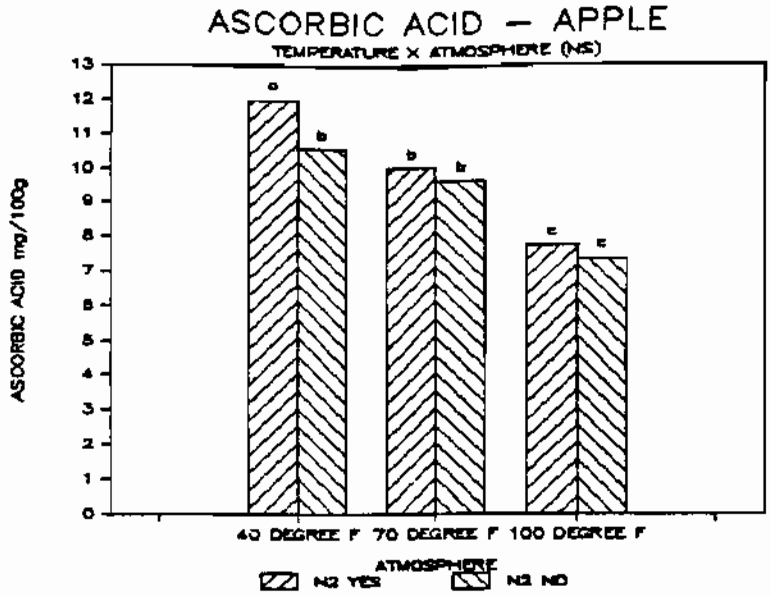

Figure 101 - **Effect of storage temperature and interior can oxygen on ascorbic acid content of dehydrated apples.** Significant differences, p = .05 indicated by different letters above treatment. Interaction not significant.

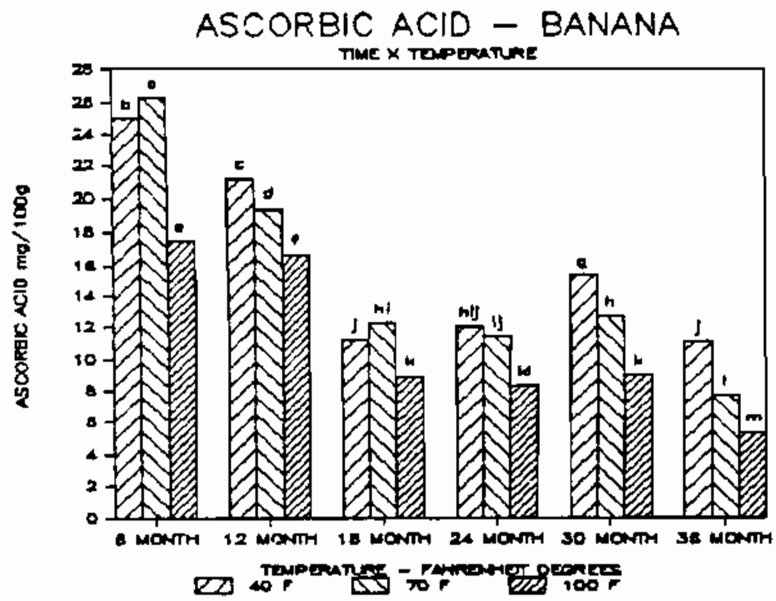

Figure 102 - **Effect of storage time and temperature on ascorbic acid content of dehydrated bananas.** Significant differences, p = .05 indicated by different letters above treatment.

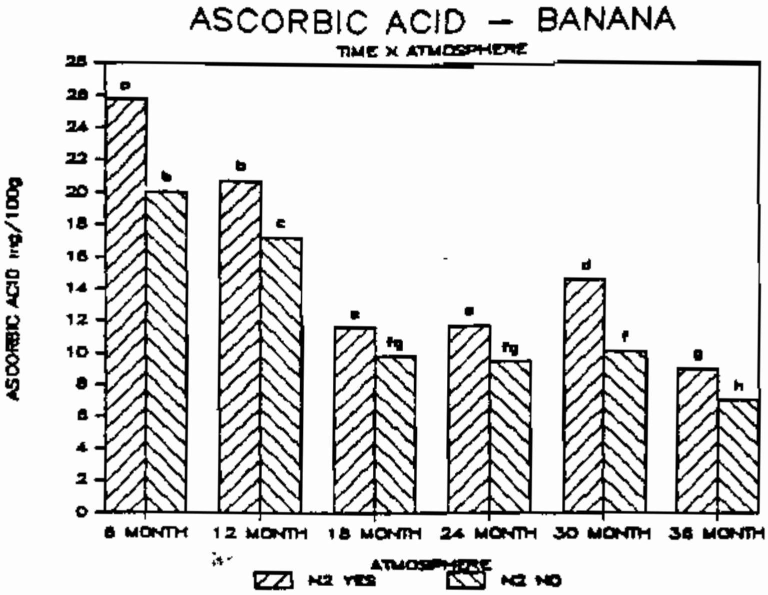

Figure 103 - Effect of storage time and interior can oxygen on ascorbic acid content of dehydrated bananas. Significant differences, p = .05 indicated by different letters above treatment.

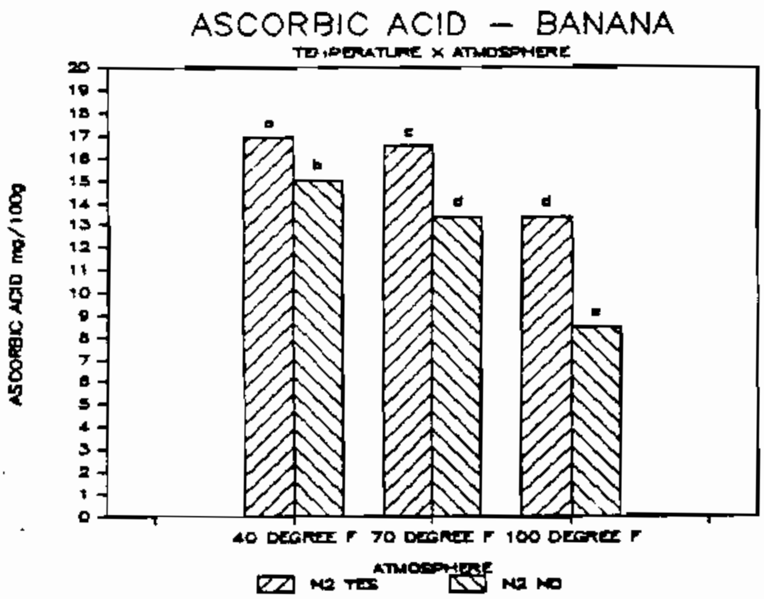

Figure 104 - Effect of storage temperature and interior can oxygen on ascorbic acid content of dehydrated bananas. Significant differences, p = .05 indicated by different letters above treatment.

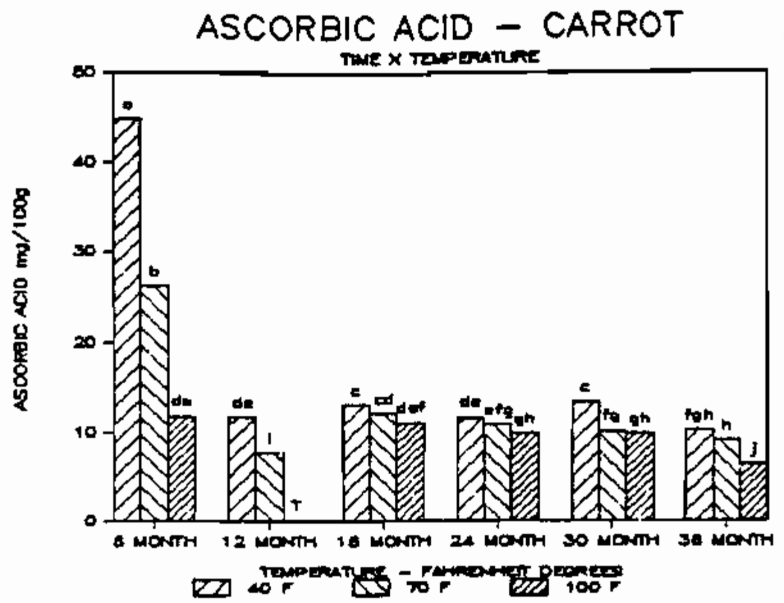

Figure 105 - Effect of storage time and temperature on ascorbic acid content of dehydrated carrots. Significant differences, p = .05 indicated by different letters above treatment. T trace amount, < 5 mg/100g.

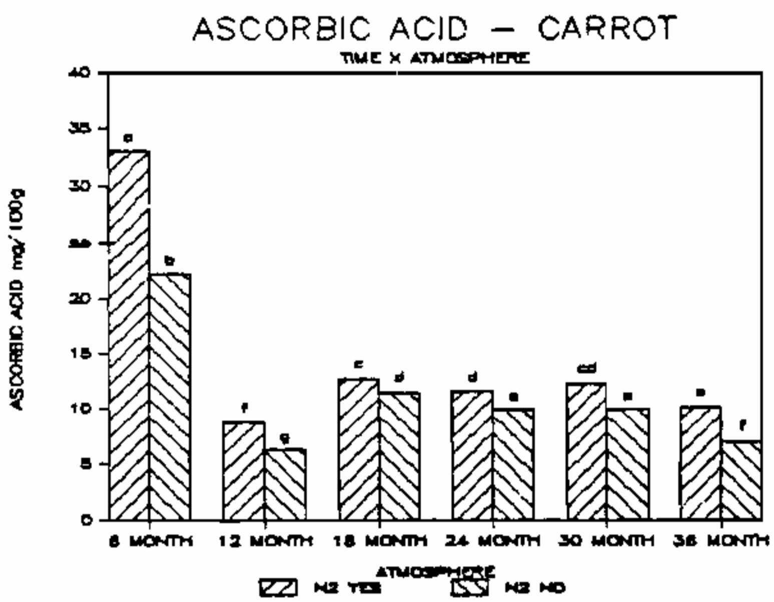

Figure 106 - Effect of storage time and interior can atmosphere on ascorbic acid content of dehydrated carrots. Significant differences, p = .05 indicated by different letters above treatment.

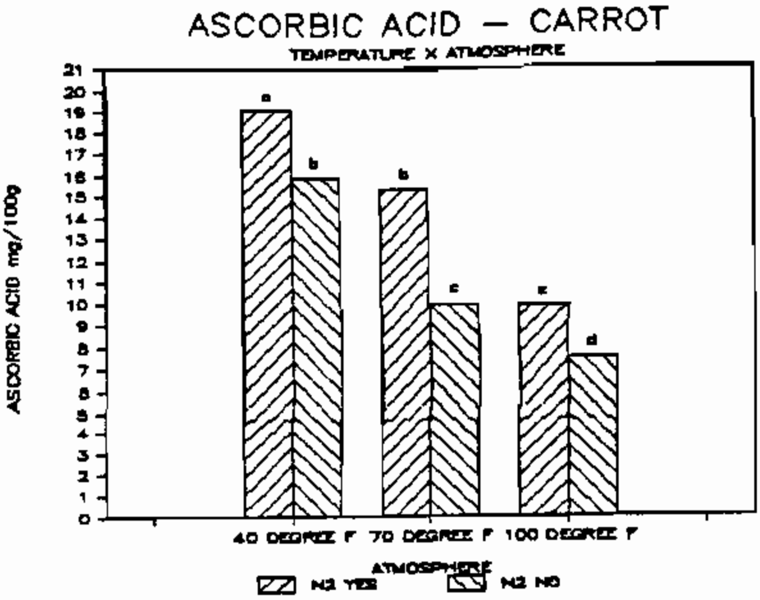

Figure 107 - Effect of storage temperature and interior can oxygen on ascorbic acid content of dehydrated carrots. Significant differences, p = .05 indicated by different letters above treatment.

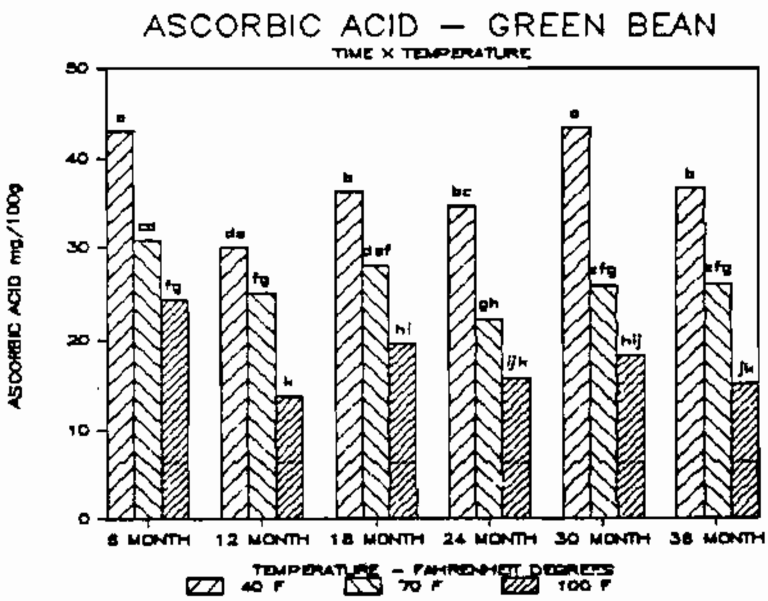

Figure 108 - Effect of storage time and temperature on ascorbic acid content of dehydrated green beans. Significant differences, p = .05 indicated by different letters above treatment.

acid content appeared to be relatively stable after 6 months. Nitrogen-packed samples retained significantly more ascorbic acid than air-packed at all time periods. The time-atmosphere interaction was not significant (Figure 109). Nitrogen-packed samples also retained significantly more ascorbic acid at all three temperatures (Figure 110).

Peaches: At 6 months low-moisture peaches stored at 40°F contained more ascorbic acid than those stored at 70°F (Figure 111), however peaches stored at 100°F appeared to contain more ascorbic acid than those stored at 70°F. The high 100°F values may be from interfering sugars. Ascorbic acid content declined rapidly from 6 to 12 months (Figures 111 and 112) but changed very little after 12 months. The time-atmosphere interaction was not significant (Figure 112). Ascorbic acid was generally less in air-packed samples but this difference was only significant at 12 months. The atmosphere effect was only significant at 100°F (Figure 113).

Salad blend: There was a decline in ascorbic acid content of low-moisture salad blend from 6 to 12 months (Figure 114), but relatively little change after that time. The temperature effect was very large at all time periods. Very little ascorbic acid is retained at 100°F, while dehydrated salad blend stored at 40°F is an excellent source of ascorbic acid even after 36 months storage. The effect of atmosphere on ascorbic acid content is quite large at all time periods (Figure 115) and temperatures

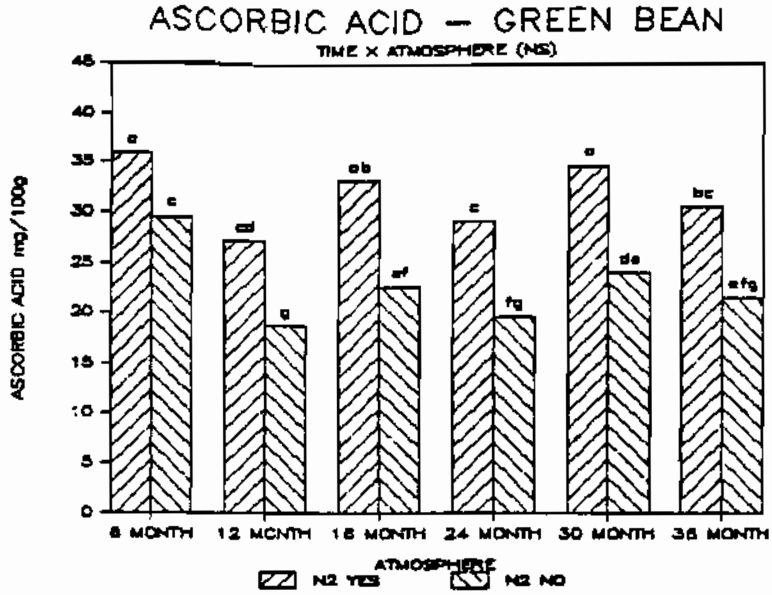

Figure 109 - Effect of storage time and interior can oxygen on ascorbic acid content of dehydrated green beans. Significant differences, p = .05 indicated by different letters above treatment. Interaction not significant.

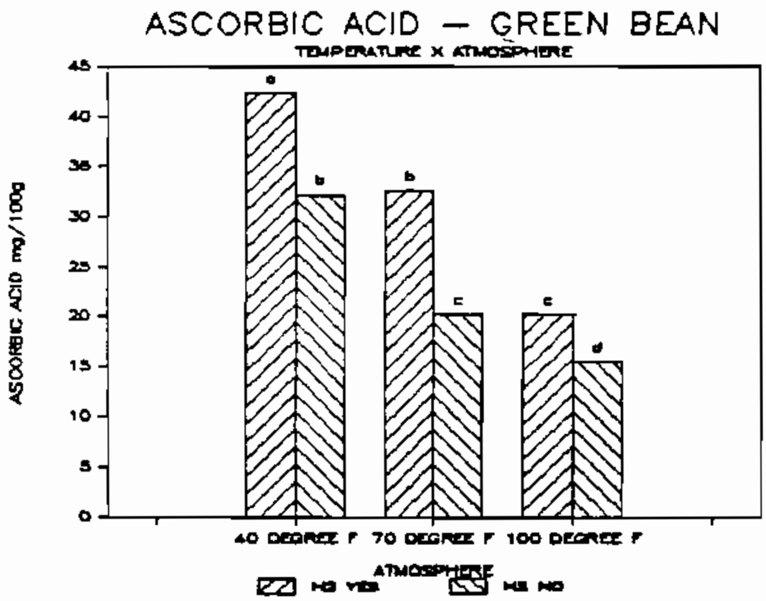

Figure 110 - Effect of storage temperature and interior can oxygen on ascorbic acid content of dehydrated green beans. Significant differences, p = .05 indicated by different letters above treatment.

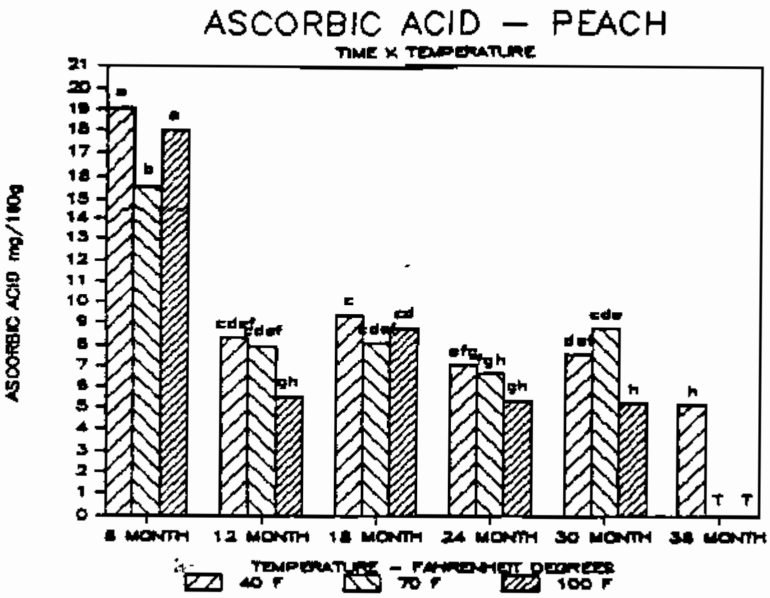

Figure 111 - Effect of storage time and temperature on ascorbic acid content of dehydrated peaches. Significant differences, p = .05 indicated by different letters above treatment. T trace amount, < 5 mg/100g.

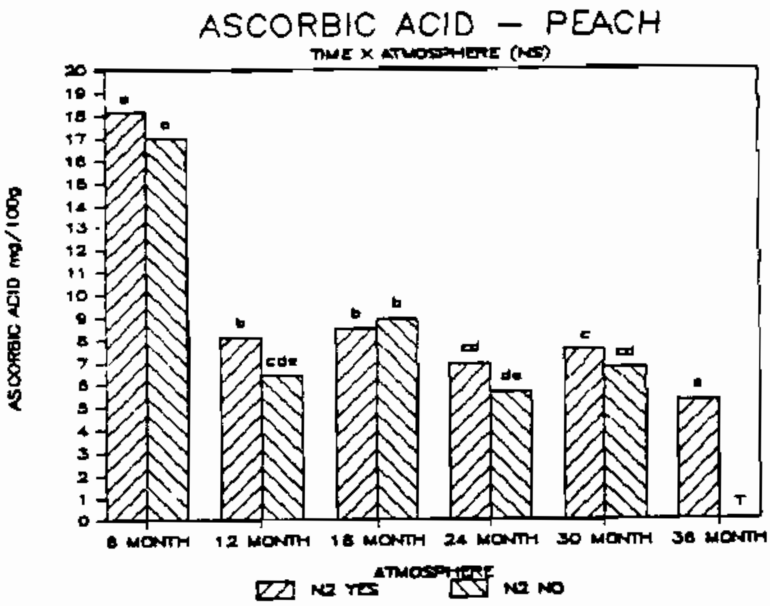

Figure 112 - Effect of storage time and interior can oxygen on ascorbic acid content of dehydrated peaches. Significant differences, p = .05 indicated by different letters above treatment. T trace amount, < 5 mg/100g. Interaction not significant.

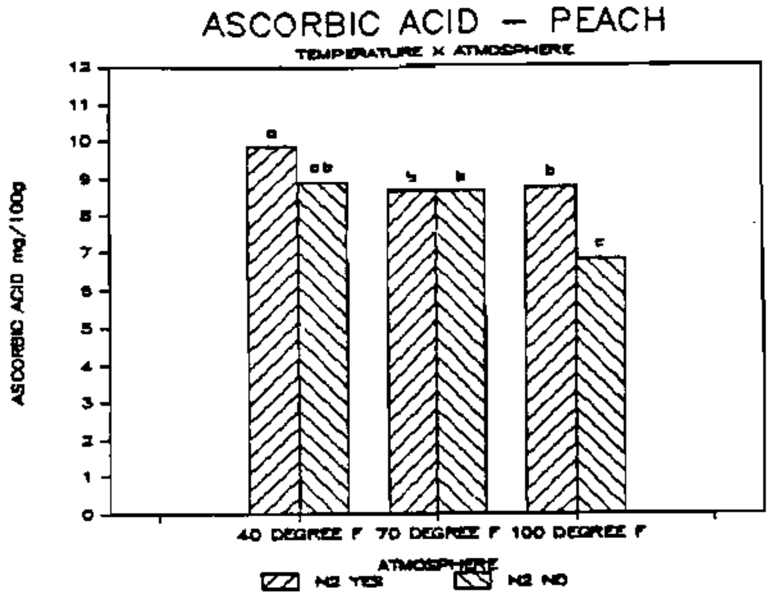

Figure 113 - Effect of storage temperature and interior can oxygen on ascorbic acid content of dehydrated peaches. Significant differences, p = .05 indicated by different letters above treatment.

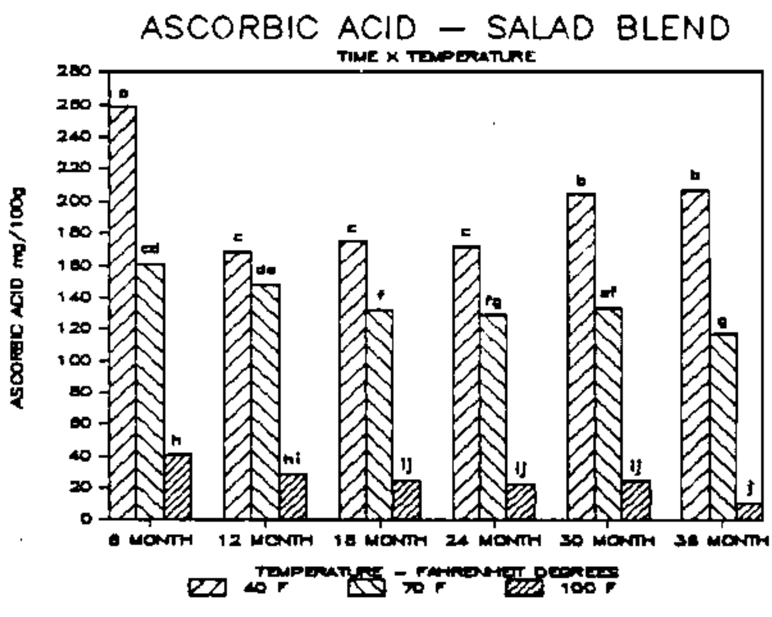

Figure 114 - Effect of storage time and temperature on ascorbic acid content of dehydrated salad blend. Significant differences, p = .05 indicated by different letters above treatment.

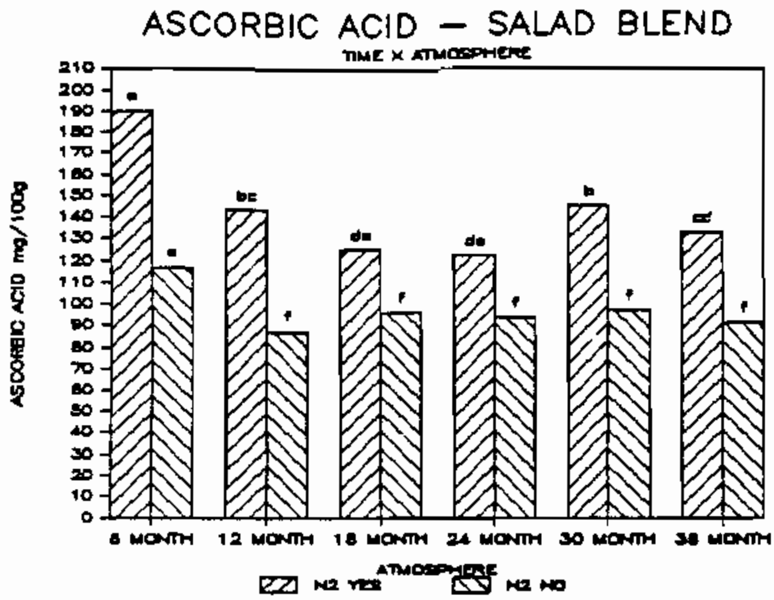

Figure 115 - Effect of storage time and interior can oxygen on ascorbic acid content of dehydrated salad blend. Significant differences, p = .05 indicated by different letters above treatment.

(Figure 116). Air-packed samples contain 25-50% less ascorbic acid than nitrogen-packed samples.

Tomatoes: Figure 117 shows the effect of storage time and temperature on ascorbic acid content of low-moisture tomato flakes. Ascorbic acid was destroyed very rapidly at 100°F. It was more stable at 40 and 70°F but did continue to decrease with time. The effect of nitrogen was significant at all storage periods (Figure 118), however relative to the ascorbic acid concentration it was small. Figure 119 shows that the effect of atmosphere was small but significant at all three temperatures. Heberlein and Clifcorn (1944) reported an initial value of ca. 205 mg/100g ascorbic acid in dehydrated tomato juice. After 1 months storage at 70°F their

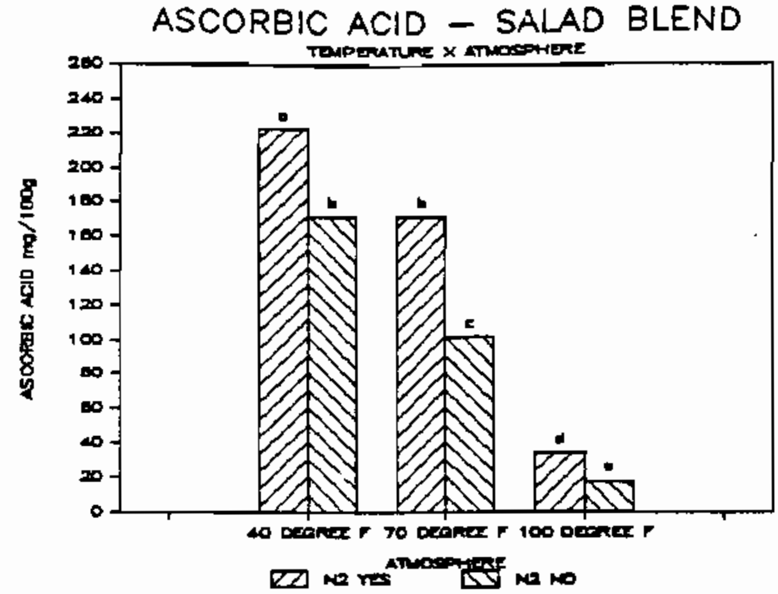

Figure 116 - Effect of storage temperature and interior can oxygen on ascorbic acid content of dehydrated salad blend. Significant differences, p = .05 indicated by different letters above treatment.

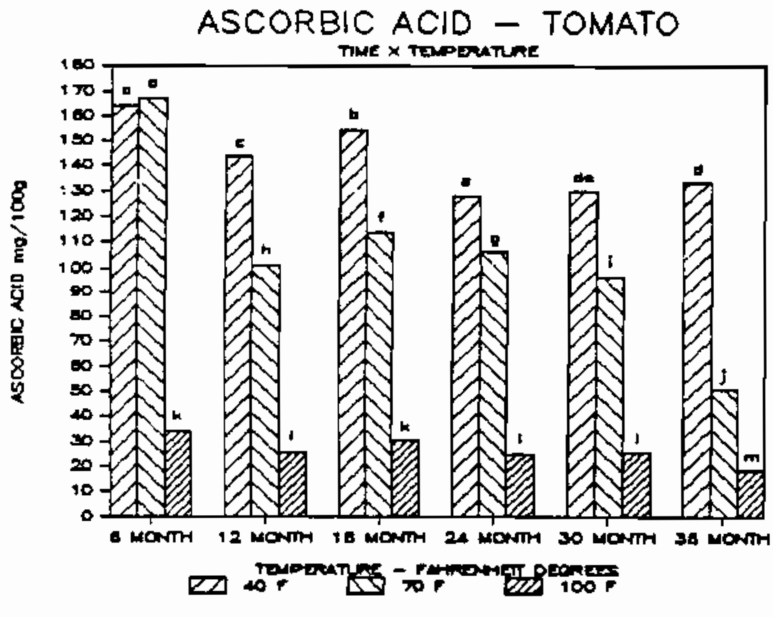

Figure 117 - Effect of storage time and temperature on ascorbic acid content of dehydrated tomatoes. Significant differences, p = .05 indicated by different letters above treatment.

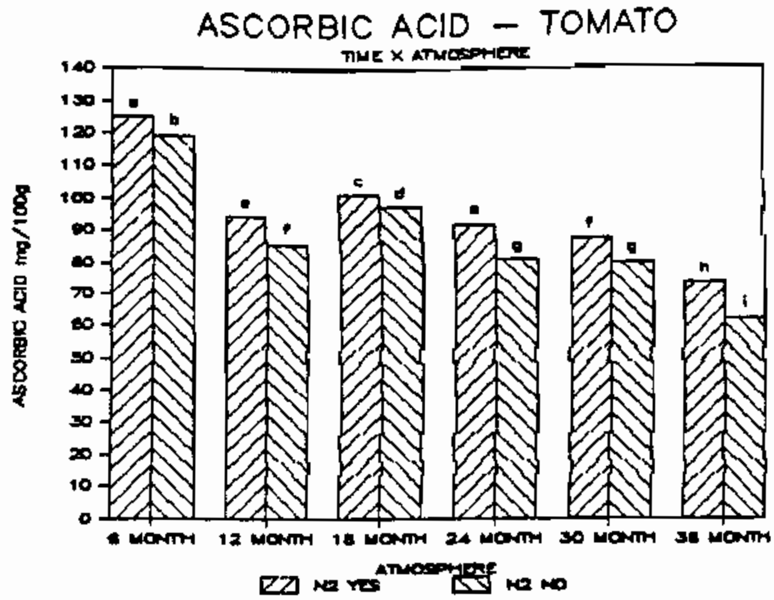

Figure 118 - **Effect of storage time and interior can oxygen on ascorbic acid content of dehydrated tomatoes.** Significant differences, p = .05 indicated by different letters above treatment.

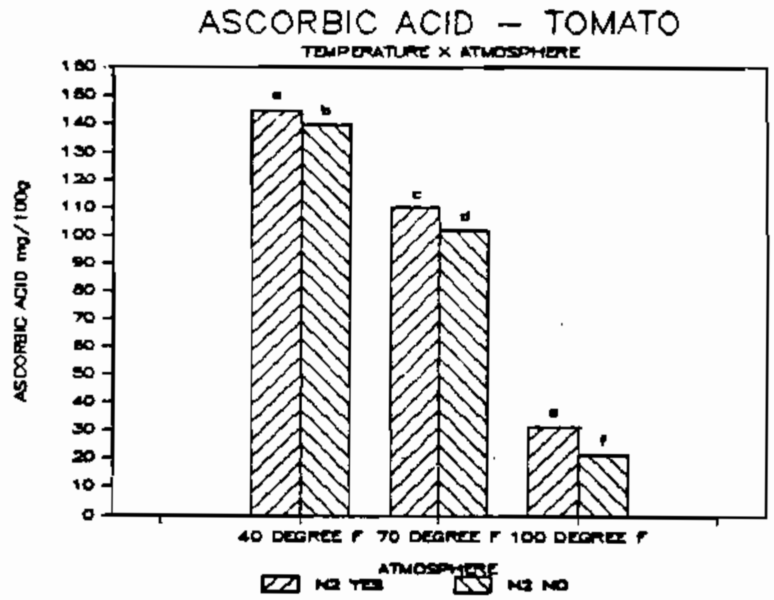

Figure 119 - Effect of storage temperature and interior can oxygen on ascorbic acid content of dehydrated tomatoes. Significant differences, p = .05 indicated by different letters above treatment.

nitrogen-packed sample had decreased to ca. 180mg/100g and the air-packed sample had decreased to ca. 150 mg/100g. These values remained relatively constant for the remainder of the one year study. The 70^{o}F, 6 month nitrogen- and air-packed samples in this study contained 169 and 166 mg/100g ascorbic acid respectively (Table 9). Although the atmosphere effect was greater in the Heberlein and Clifcorn (1944) study, the ascorbic acid content of the dehydrated tomato samples are quite close.

Taste panel

Taste panels were conducted at 6 month intervals to determine consumer acceptability of the low-moisture products. Sample flavor, color, texture and overall acceptability were evaluated. Preference was indicated on a line scale with very poor at the left and very good at the right (Appendix F). Marks were later translated into a numeric percentage (0 very poor - 100 very good).

Taste panel data were transformed using the arcsine(square root(x/100)) prior to statistical analyses. Values listed in tables and graphs are the reverted means of the transformed data. Due to the mathematics involved there is a slight discrepancy ($<$ 1%) between these values and the means of the original data.

Taste panel data from the first year of the study were lost due to a computer malfunction which destroyed the tape. Printouts of the treatment means were retained. Mean values from the 6 and 12 month tests are listed in the tables and graphs, however due to the loss of the individual data they could not be included in the statistical analyses. Statistical analyses include only 18, 24, 30 and 36 month data.

Samples receiving an average overall acceptability score of less than 40 were determined unfit for consumption and not taste tested thereafter. Butter, carrot, egg, green bean, milk, peach, potato, salad blend, stroganoff, tomato, and vegetable soup 100°F samples were determined unfit for consumption after 6 months storage. Apple 100°F samples were determined unfit after 24 months. None of these samples were included in the statistical analyses.

Different taste panels were used to evaluate the products at each time period. There is no way to distinguish between the variance due to time and that due to panel preferences. This effect is listed in all places as a time effect but in actuality is the combined time and panel effect. It is not assumed that any of the products would increase significantly in acceptability with time, even though it appears as if they did in some instances. These increases are most likely due to panel preference. The time effect graphs are included, but will generally be ignored because no discrimination can be made between the two effects.

Product browning was present in many 100°F samples. Christensen (1983) reported that appropriately colored foods were perceived by taste panels to have a stronger intensity and better quality aroma and flavor, while judgments of texture quality were not affected by color. The poor color of some samples in this study may have prejudiced the flavor scores, however this was felt to be not inappropriate when determining acceptability.

Yeast samples were not evaluated by the taste panels, however yeast activity was tested. Yeast activity test procedures and results are included in appendix G.

Multivariate analysis: All four dependent variables (flavor, color, texture and overall acceptability) were considered together to determine differences due to treatment in the multivariate analysis. Table 10 gives the level of significance (p-value) for each of the main effects.

There was a significant temperature effect in bananas, butter, carrots, eggs, macaroni, navy beans, oatmeal, peanut butter, peaches, salad blend, stroganoff, TVP, vegetable soup and wheat. Since 100^{o}F samples were not included in the analyses for butter, carrots, eggs, peaches, salad blend, stroganoff and vegetable soup, significant differences in these products were between 40 and 70^{o}F samples. The multivariate analysis did not differentiate at what temperatures the differences were significant for bananas, macaroni, navy beans, oatmeal, peanut butter, TVP and wheat. Samples stored at 100^{o}F were not included in the analyses of any of the five products where temperature was not significant; had they been, the effect probably would have been significant.

The atmosphere effect was not significant in 9 of the 19 products; apples, milk, navy beans, oatmeal, peaches, stroganoff, tomatoes, vegetable soup, and wheat.

Apples: Table 11 lists the mean scores from the taste panels for dehydrated apple samples. Apple 100^{o}F samples were considered

Table 10 - Taste panel results, level of significance (p value) for main effects, as determined by multivariate analysis.

Product	Time	Temperature	Atmosphere
Apple*	**p = .003**	p = .286	p = .712
Banana	**p = .012**	**p = .000**	**p = .000**
Butter*	**p = .000**	**p = .001**	**p = .040**
Carrot*	**p = .005**	**p = .000**	**p = .000**
Egg*	**p = .000**	**p = .000**	**p = .000**
Green bean*	**p = .004**	p = .447	**p = .003**
Macaroni	**p = .000**	**p = .000**	**p = .009**
Milk*	**p = .000**	p = .359	p = .662
Navy bean	**p = .000**	**p = .000**	p = .126
Oatmeal	**p = .000**	**p = .000**	p = .976
Peanut butter	p = .106	**p = .015**	**p = .000**
Peach*	**p = .000**	**p = .000**	p = .065
Potato*	p = .870	p = .413	**p = .002**
Salad blend*	**p = .021**	**p = .000**	**p = .014**
Stroganoff*	**p = .001**	**p = .000**	p = .760
Tomato*	**p = .003**	p = .633	p = .320
TVP	p = .077	**p = .000**	**p = .048**
Veg. soup*	**p = .028**	**p = .000**	p = .062
Wheat	**p = .004**	**p = .001**	p = .711

Numbers in bold type are significantly different $p < .05$.
* 100^{o}F samples not included in the analysis.

TABLE 11- APPLE TASTE PANEL, TREATMENT MEANS.

		TASTE PANEL RESPONSE**					
	TIME	40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
FLAVOR	INITIAL	52.00					
	6 MONTH	53.10	53.57	51.43	56.43	50.48	48.10
	12 MONTH	58.81	56.43	61.43	58.57	54.29	47.62
	18 MONTH	64.29	56.16	61.83	67.11	50.77	51.15
	24 MONTH	54.04	66.09	68.72	52.26	30.75	27.75
	30 MONTH	66.59	67.69	61.16	61.58	*	*
	36 MONTH	63.75	62.39	63.99	63.16	*	*
COLOR	INITIAL	76.00					
	6 MONTH	71.67	71.43	67.86	67.38	49.05	45.00
	12 MONTH	70.47	69.76	68.57	69.76	55.71	48.33
	18 MONTH	75.62	74.68	67.36	69.79	39.23	42.69
	24 MONTH	79.02	83.87	79.49	72.23	19.50	17.50
	30 MONTH	75.16	76.00	69.27	75.97	*	*
	36 MONTH	68.68	73.01	71.97	66.82	*	*
TEXTURE	INITIAL	56.00					
	6 MONTH	50.95	60.00	49.29	57.14	53.57	54.52
	12 MONTH	56.19	56.67	57.38	58.57	56.19	54.29
	18 MONTH	58.20	60.27	62.12	61.72	55.77	46.15
	24 MONTH	56.66	56.39	63.60	47.60	41.75	37.00
	30 MONTH	65.80	61.79	57.91	63.64	*	*
	36 MONTH	60.71	65.25	51.76	57.61	*	*
OVERALL	INITIAL	56.00					
	6 MONTH	52.62	57.38	50.95	55.24	50.48	48.81
	12 MONTH	59.52	58.10	60.71	59.52	53.10	49.52
	18 MONTH	62.55	61.50	60.49	66.30	46.15	46.15
	24 MONTH	60.21	65.34	68.77	54.47	27.50	26.00
	30 MONTH	67.55	65.57	61.19	65.12	*	*
	36 MONTH	61.68	64.38	58.17	61.97	*	*

* not tested due to low scores on previous tests.
** 100 = very good, 0 = very poor.

unfit for consumption after 24 months. There was no significant difference in flavor, color, texture or overall acceptability between the 40 and 70°F samples (Figure 121), or between the nitrogen- and air-packed samples (Figure 122).

Bananas: Treatment means from the banana taste panels are listed in Table 12. All samples were tested at all time periods. Bananas stored at 100°F were rated significantly lower in flavor than those stored at 40 or 70°F (Figure 124). There were no noticeable differences in color or texture due to temperature. Differences in overall acceptability were significant between all three temperatures. Nitrogen-packed bananas were judged superior to air-packed samples in flavor and overall acceptability (Figure 125). The sliced bananas were processed with coconut oil and sugar and contained

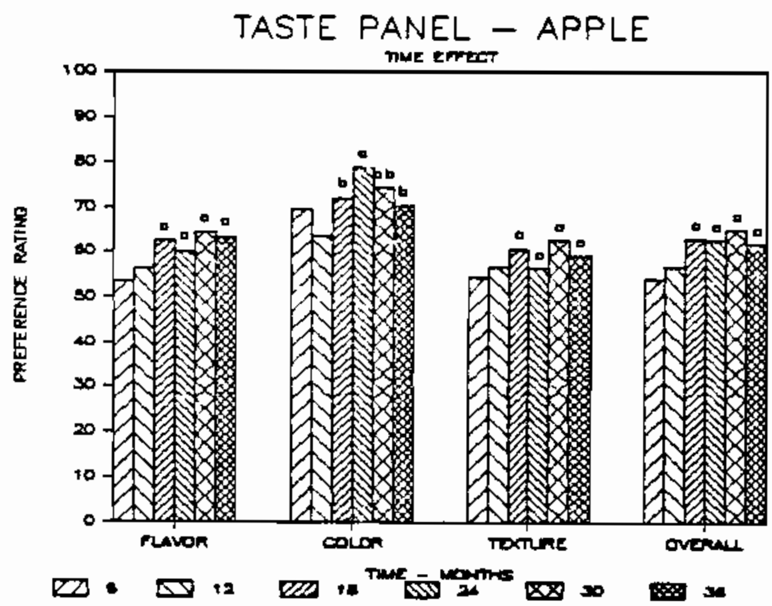

Figure 120 - Effect of storage time on dehydrated apple acceptability. Significant differences, p = .05 indicated by different letters above treatment.

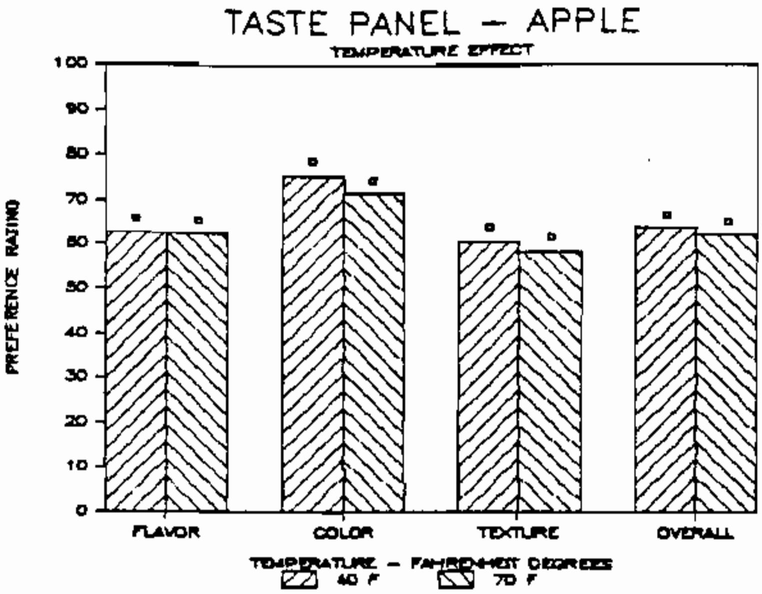

Figure 121 - **Effect of storage temperature on dehydrated apple acceptability.** Significant differences, p = .05 indicated by different letters above treatment.

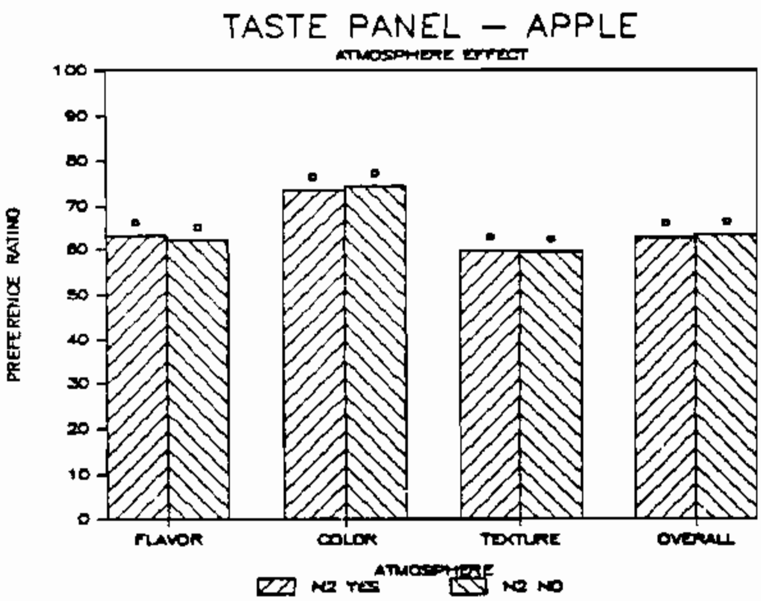

Figure 122 - **Effect of interior can oxygen on dehydrated apple acceptability.** Significant differences, p = .05 indicated by different letters above treatment.

TABLE 12 - BANANA TASTE PANEL, TREATMENT MEANS.

	TIME	TASTE PANEL RESPONSE** 40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
F	INITIAL	74.00					
L	6 MONTH	74.17	67.50	69.72	70.00	68.61	67.78
A	12 MONTH	64.29	64.05	65.00	63.10	68.57	55.95
V	18 MONTH	74.81	79.39	73.18	77.25	73.24	70.18
O	24 MONTH	74.88	76.04	74.78	62.15	62.81	42.10
R	30 MONTH	76.10	78.12	70.91	67.18	59.22	39.43
	36 MONTH	69.07	72.41	72.16	66.60	58.38	42.89
	INITIAL	76.00					
C	6 MONTH	77.22	77.22	77.78	76.67	74.17	82.22
O	12 MONTH	73.57	67.86	63.10	67.62	69.29	73.57
L	18 MONTH	74.96	76.29	76.01	77.22	75.46	74.11
O	24 MONTH	74.17	74.35	72.57	70.84	78.39	77.02
R	30 MONTH	74.20	78.45	71.40	72.72	63.62	65.89
	36 MONTH	67.63	71.18	76.75	72.91	68.00	67.70
T	INITIAL	74.00					
E	6 MONTH	73.06	72.22	72.22	71.94	72.22	73.33
X	12 MONTH	72.62	68.33	70.00	70.95	73.57	69.52
T	18 MONTH	79.09	81.96	79.71	78.55	79.81	80.80
U	24 MONTH	77.92	76.07	75.40	71.90	72.84	71.70
R	30 MONTH	77.43	76.53	74.49	75.11	70.54	67.95
E	36 MONTH	72.03	72.96	74.06	74.72	69.97	66.62
O	INITIAL	80.00					
V	6 MONTH	72.78	69.72	70.00	70.83	69.72	71.11
E	12 MONTH	70.00	64.29	68.10	65.71	70.48	62.14
R	18 MONTH	75.48	78.81	73.92	75.19	73.85	71.17
A	24 MONTH	74.07	74.38	74.46	63.28	66.42	48.47
L	30 MONTH	76.11	77.72	71.17	68.77	61.05	48.48
L	36 MONTH	70.24	71.51	73.62	64.41	62.56	48.14

** 100 = very good, 0 = very poor.

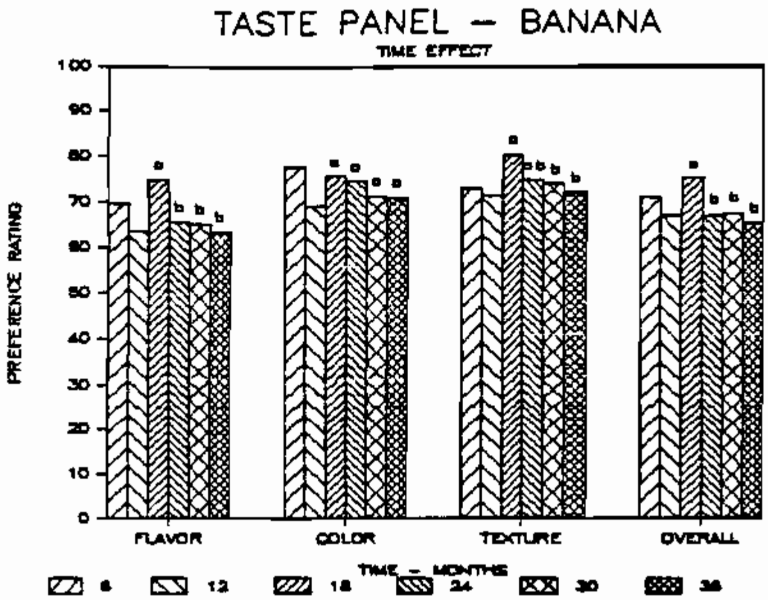

Figure 123 - Effect of storage time on dehydrated banana acceptability. Significant differences, p = .05 indicated by different letters above treatment.

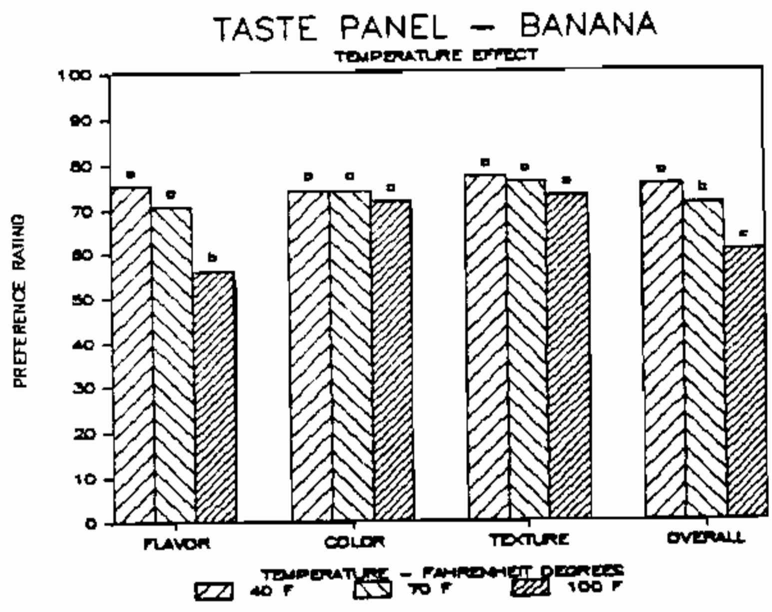

Figure 124 - Effect of storage temperature on dehydrated banana acceptability. Significant differences, p = .05 indicated by different letters above treatment.

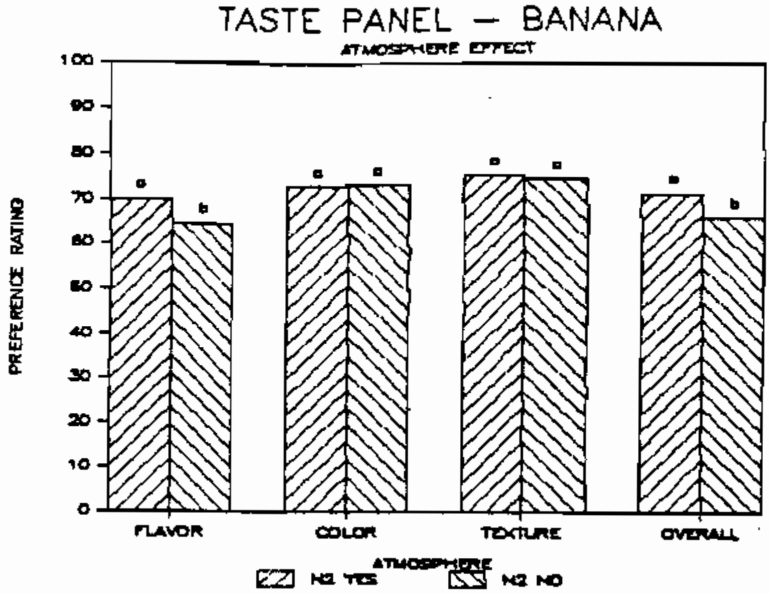

Figure 125 - Effect of interior can oxygen on dehydrated banana acceptability. Significant differences, $p = .05$ indicated by different letters above treatment.

no antioxidants. Rancidity was very noticeable in air-packed samples stored at 100°F for 24 months and longer (Table 12).

Butter: Table 13 lists the treatment means from the butter taste panels. The air-packed 100°F sample was judged unacceptable at 6 months. The nitrogen-packed 100°F sample was barely acceptable and should have continued to have been tested, however both samples were not tested after 6 months and not included in the analyses. The color was not adversely affected by 100°F heat during the first 6 months. The 70°F samples were judged significantly lower in flavor and overall acceptability than the 40°F samples, but not in color or texture (Figure 127). There was no significant atmosphere effect (Figure 128), even though the butter product contained a significant amount of lipid. It also contained BHA, propyl gallate and citric acid as antioxidants.

TABLE 13 - BUTTER TASTE PANEL, TREATMENT MEANS.

	TIME	TASTE PANEL RESPONSE** 40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
F	INITIAL	60.00					
L	6 MONTH	64.76	65.24	61.19	62.86	40.71	32.38
A	12 MONTH	59.75	62.25	60.50	52.75	*	*
V	18 MONTH	71.30	71.21	62.49	67.57	*	*
O	24 MONTH	61.95	54.76	53.61	41.98	*	*
R	30 MONTH	60.49	60.34	52.31	41.07	*	*
	36 MONTH	71.38	71.81	67.31	56.04	*	*
	INITIAL	74.00					
C	6 MONTH	74.52	74.76	73.57	74.29	71.43	72.38
O	12 MONTH	73.00	70.25	70.25	74.00	*	*
L	18 MONTH	75.98	74.32	75.91	76.35	*	*
O	24 MONTH	77.52	79.07	76.06	78.58	*	*
R	30 MONTH	71.68	71.84	69.26	70.39	*	*
	36 MONTH	77.97	77.77	77.56	81.76	*	*
T	INITIAL	48.00					
E	6 MONTH	62.14	68.10	66.43	63.81	57.62	56.19
X	12 MONTH	62.50	59.25	60.25	60.50	*	*
T	18 MONTH	70.08	69.61	66.07	70.49	*	*
U	24 MONTH	60.10	63.84	58.77	53.01	*	*
R	30 MONTH	54.73	59.37	54.53	50.45	*	*
E	36 MONTH	69.36	70.55	64.56	66.64	*	*
O	INITIAL	56.00					
V	6 MONTH	64.76	65.24	61.19	63.57	46.19	39.29
E	12 MONTH	62.75	62.25	59.00	56.25	*	*
R	18 MONTH	71.13	69.97	64.01	68.26	*	*
A	24 MONTH	62.50	58.26	55.35	45.69	*	*
L	30 MONTH	60.07	62.37	55.87	46.55	*	*
L	36 MONTH	71.84	72.08	68.15	63.17	*	*

* not tested due to low scores on previous tests.
** 100 = very good, 0 = very poor.

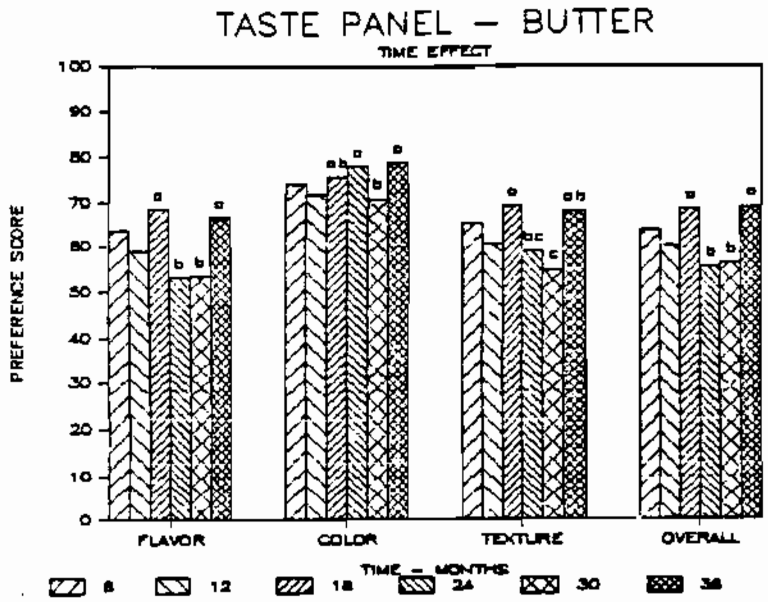

Figure 126 - Effect of storage time on dehydrated butter acceptability. Significant differences, p = .05 indicated by different letters above treatment.

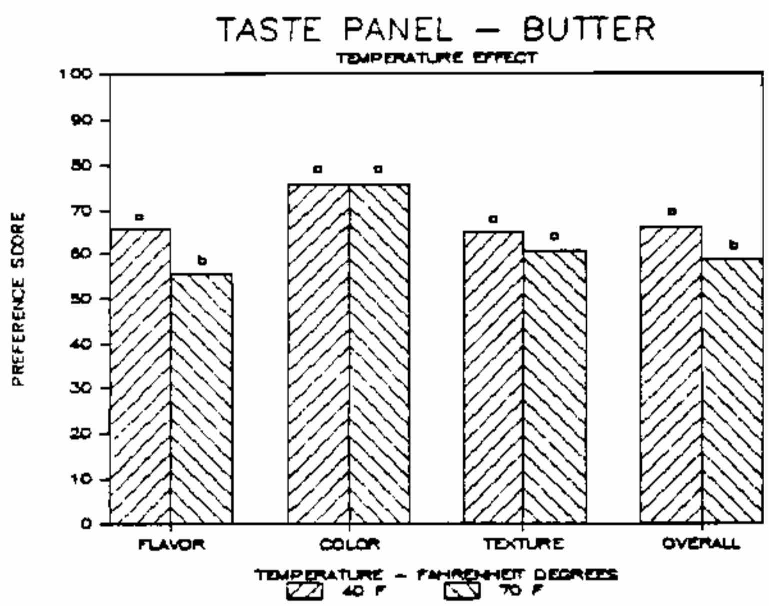

Figure 127 - Effect of storage temperature on dehydrated butter acceptability. Significant differences, p = .05 indicated by different letters above treatment.

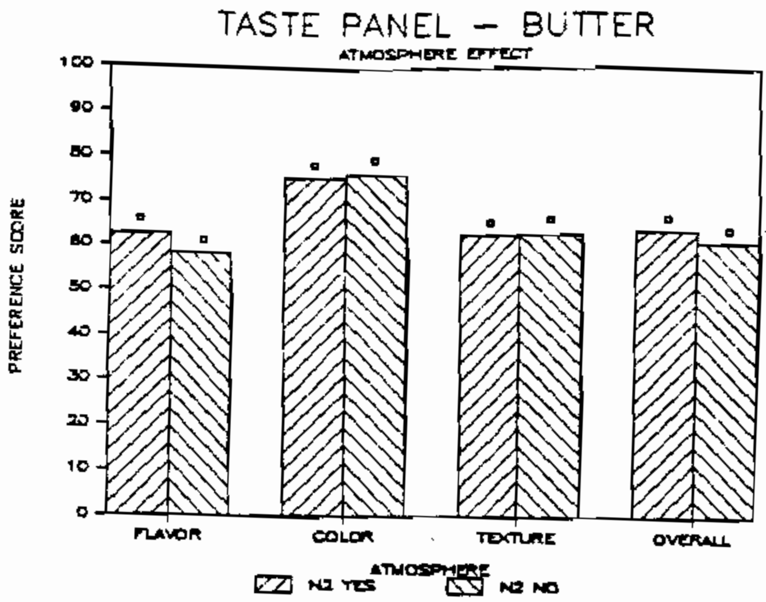

Figure 128 - Effect of interior can oxygen on dehydrated butter acceptability. Significant differences, p = .05 indicated by different letters above treatment.

<u>Carrots</u>: Table 14 lists the treatment means from the carrot taste panels. Values were unacceptable for both 100°F samples at 6 months and not included in the analyses. Carrots stored at 70°F were rated significantly lower in color and overall acceptability than those at 40°F (Figure 130). The effect of temperature on flavor and texture was not significant. Nitrogen-packed samples were rated significantly better than air-packed samples in flavor, color and overall acceptability (Figure 131). The effect of atmosphere on texture was not significant. Carrot samples stored for 30 months are pictured in Figures 132 and 133. Browning is evident, especially at 100°F in Figure 132. Bleaching of carotene in the air-packed sample can be seen in Figure 133.

TABLE 14 - CARROT TASTE PANEL, TREATMENT MEANS.

	TIME	TASTE PANEL RESPONSE** 40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
F	INITIAL	50.00					
L	6 MONTH	68.57	67.86	69.52	53.81	33.81	33.33
A	12 MONTH	64.74	58.95	60.53	56.05	*	*
V	18 MONTH	69.71	62.74	65.83	57.49	*	*
O	24 MONTH	65.78	60.45	62.09	60.09	*	*
R	30 MONTH	66.51	60.48	62.68	60.84	*	*
	36 MONTH	74.55	59.79	66.85	50.74	*	*
	INITIAL	76.00					
C	6 MONTH	78.33	75.00	69.29	65.24	23.10	17.14
O	12 MONTH	74.74	65.26	68.95	62.89	*	*
L	18 MONTH	68.31	58.67	70.20	50.43	*	*
O	24 MONTH	63.46	60.99	60.14	42.74	*	*
R	30 MONTH	74.02	57.64	71.59	46.55	*	*
	36 MONTH	79.03	60.56	70.14	42.39	*	*
T	INITIAL	60.00					
E	6 MONTH	64.05	65.00	64.29	59.76	35.95	38.33
X	12 MONTH	63.95	60.53	56.32	56.58	*	*
T	18 MONTH	70.46	65.99	66.30	62.72	*	*
U	24 MONTH	60.76	58.39	58.95	60.96	*	*
R	30 MONTH	67.21	66.63	64.94	66.69	*	*
E	36 MONTH	75.47	69.13	71.68	60.94	*	*
O	INITIAL	56.00					
V	6 MONTH	67.14	65.00	67.62	55.71	28.57	28.81
E	12 MONTH	63.42	59.21	60.00	56.05	*	*
R	18 MONTH	68.61	60.26	64.24	57.24	*	*
A	24 MONTH	63.28	58.60	59.19	54.32	*	*
L	30 MONTH	67.61	59.65	65.11	57.65	*	*
L	36 MONTH	75.60	62.15	67.76	50.54	*	*

* not tested due to low scores on previous tests.
** 100 = very good, 0 = very poor.

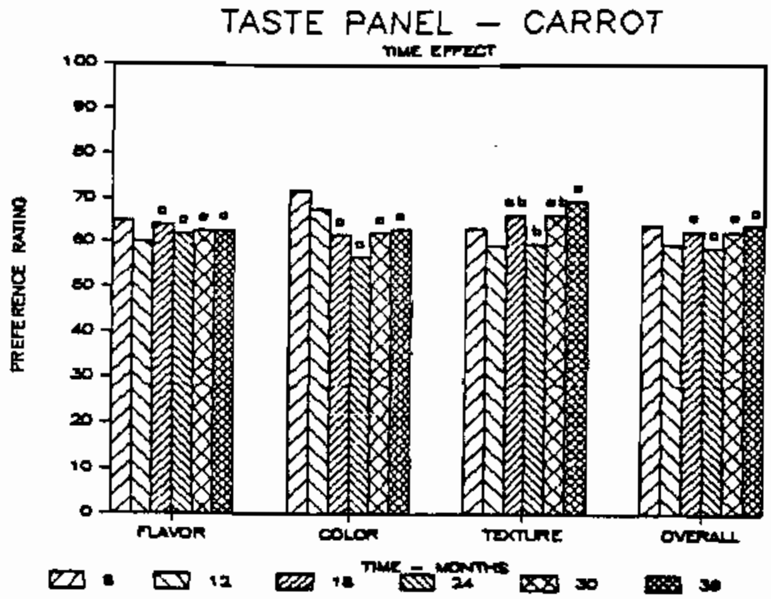

Figure 129 - Effect of storage time on dehydrated carrot acceptability. Significant differences, p = .05 indicated by different letters above treatment.

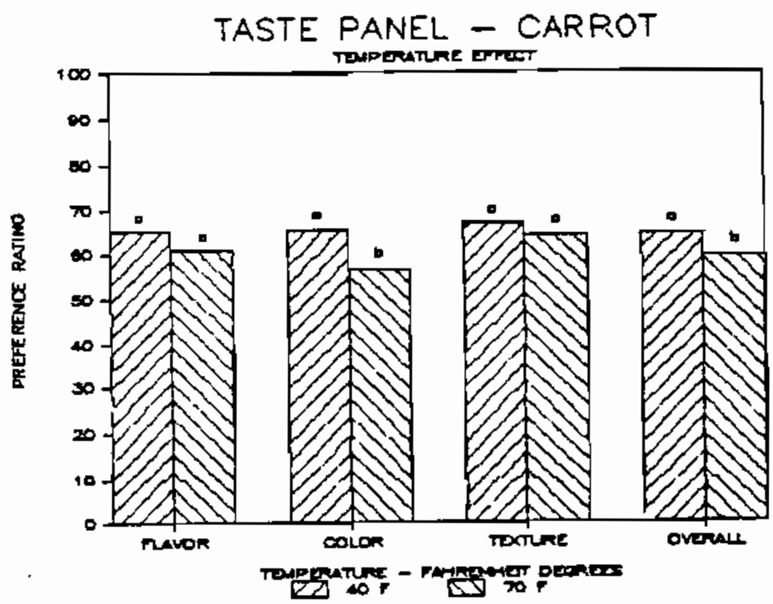

Figure 130 - Effect of storage temperature on dehydrated carrot acceptability. Significant differences, p = .05 indicated by different letters above treatment.

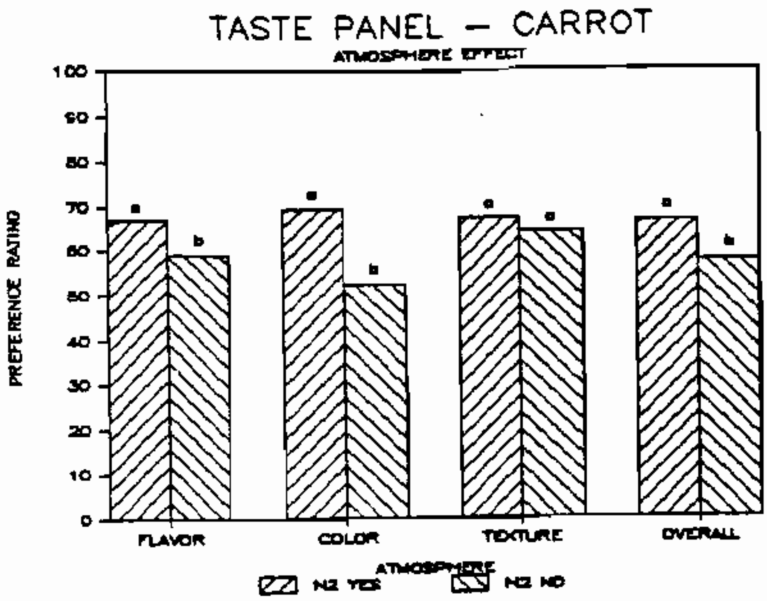

Figure 131 - **Effect of interior can oxygen on dehydrated carrot acceptability.** Significant differences, p = .05 indicated by different letters above treatment.

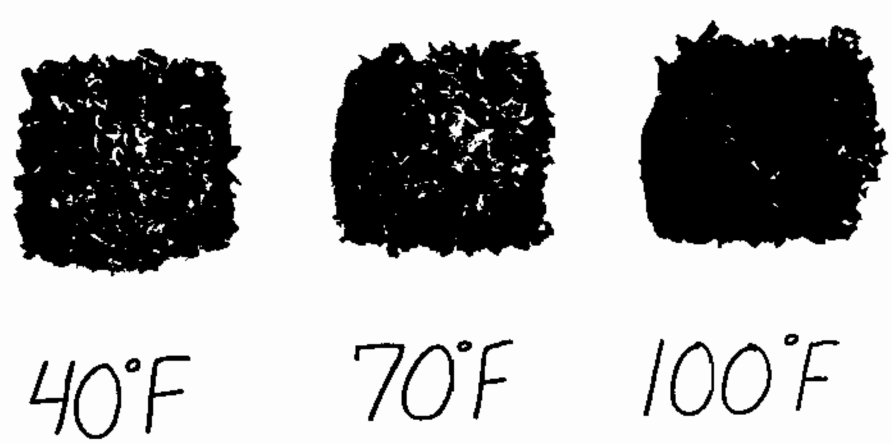

Figure 132 - Dehydrated nitrogen-packed carrot samples after 30 months storage at 40°F, 70°F and 100°F.

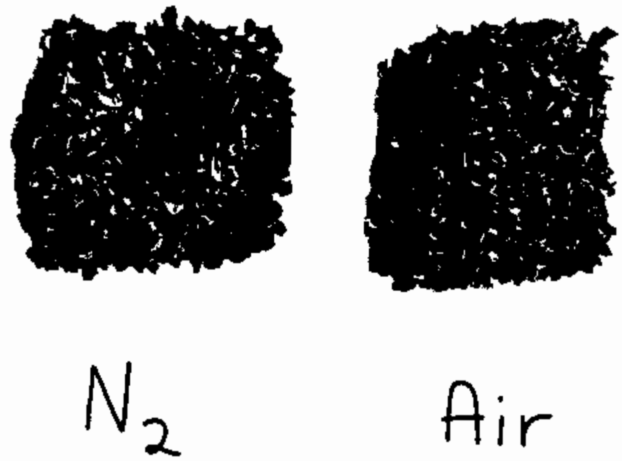

Figure 133 - Dehydrated nitrogen- and air-packed carrot samples after 30 months storage at 70°F.

Eggs: Table 15 lists the treatment means from the egg taste panels. Samples stored at 100°F were very brown and received unacceptable scores at 6 months. Samples stored at 70°F rated significantly lower than 40°F samples in flavor, color and overall acceptability (Figure 135). Nitrogen-packed samples rated significantly higher in flavor and overall acceptability than air-packed samples (Figure 136). Clumping and color difference due to storage temperature in eggs stored for 30 months can be seen in Figure 137.

Green beans: Table 16 lists the green bean taste panel treatment means. Samples stored at 100°F received unacceptable scores at 6 months and were not included in the analyses. There were no significant temperature differences between 40 and 70°F samples (Figure 139) or atmosphere differences between the nitrogen- and air-packed samples (Figure 140). Green bean samples stored for 30 months are pictured in Figure 141. The 100°F sample was quite brown.

TABLE 15 - EGG TASTE PANEL, TREATMENT MEANS.

		TASTE PANEL RESPONSE**					
	TIME	40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
FLAVOR	INITIAL	78.00					
	6 MONTH	71.67	64.29	63.81	63.81	34.29	25.71
	12 MONTH	66.19	58.81	59.29	53.57	*	*
	18 MONTH	73.93	63.61	70.31	55.39	*	*
	24 MONTH	67.00	55.41	68.50	46.95	*	*
	30 MONTH	70.79	63.55	70.08	50.23	*	*
	36 MONTH	75.22	62.82	69.16	42.33	*	*
COLOR	INITIAL	86.00					
	6 MONTH	81.43	82.86	83.10	81.43	10.48	8.33
	12 MONTH	80.95	75.48	75.95	75.00	*	*
	18 MONTH	83.41	83.20	83.05	80.39	*	*
	24 MONTH	83.20	81.89	82.47	80.30	*	*
	30 MONTH	82.49	83.48	69.71	74.22	*	*
	36 MONTH	82.24	78.46	66.81	62.38	*	*
TEXTURE	INITIAL	80.00					
	6 MONTH	72.86	70.95	72.62	70.95	60.00	51.67
	12 MONTH	71.67	61.19	64.29	64.76	*	*
	18 MONTH	76.00	69.76	74.12	66.69	*	*
	24 MONTH	65.27	68.02	70.15	63.20	*	*
	30 MONTH	69.46	69.86	68.05	67.78	*	*
	36 MONTH	73.75	64.89	72.63	65.57	*	*
OVERALL	INITIAL	78.00					
	6 MONTH	72.86	68.57	65.24	66.43	30.24	23.57
	12 MONTH	70.00	61.90	63.10	60.24	*	*
	18 MONTH	72.75	64.26	70.93	60.20	*	*
	24 MONTH	67.66	64.07	69.77	55.47	*	*
	30 MONTH	71.68	68.39	68.07	58.19	*	*
	36 MONTH	75.59	64.02	65.79	49.82	*	*

* not tested due to low scores on previous tests.
** 100 = very good, 0 = very poor.

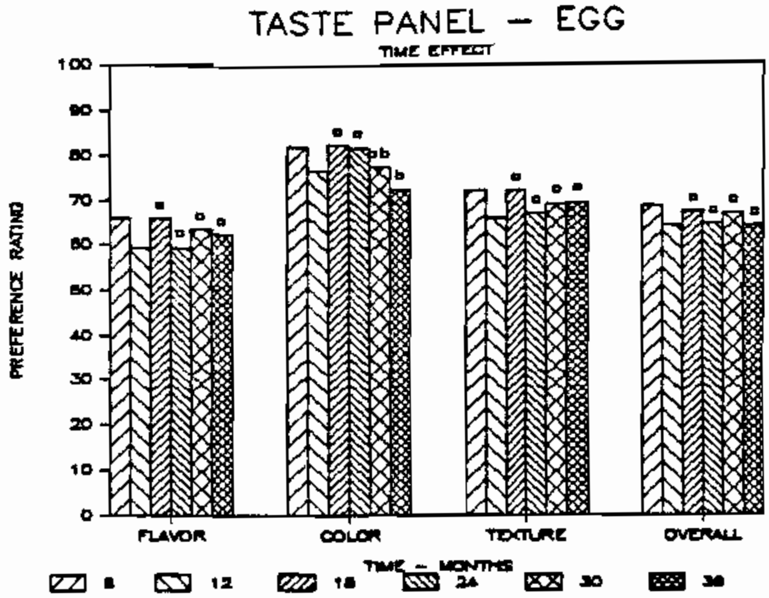

Figure 134 - Effect of storage time on dehydrated egg acceptability. Significant differences, p = .05 indicated by different letters above treatment.

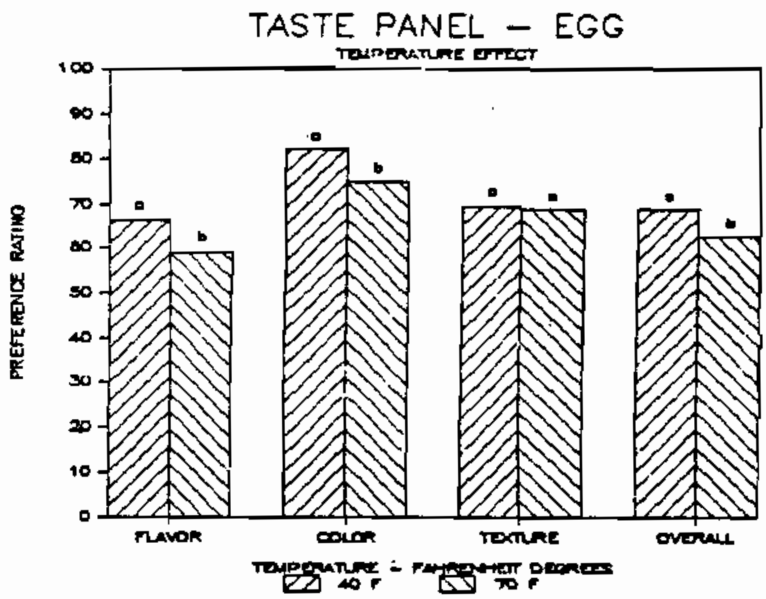

Figure 135 - Effect of storage temperature on dehydrated egg acceptability. Significant differences, p = .05 indicated by different letters above treatment.

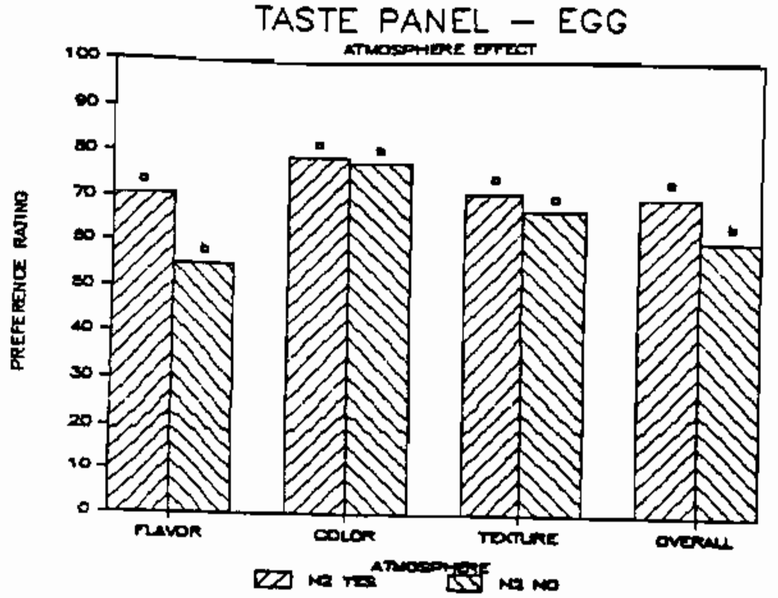

Figure 136 - Effect of interior can oxygen on dehydrated egg acceptability. Significant differences, p = .05 indicated by different letters above treatment.

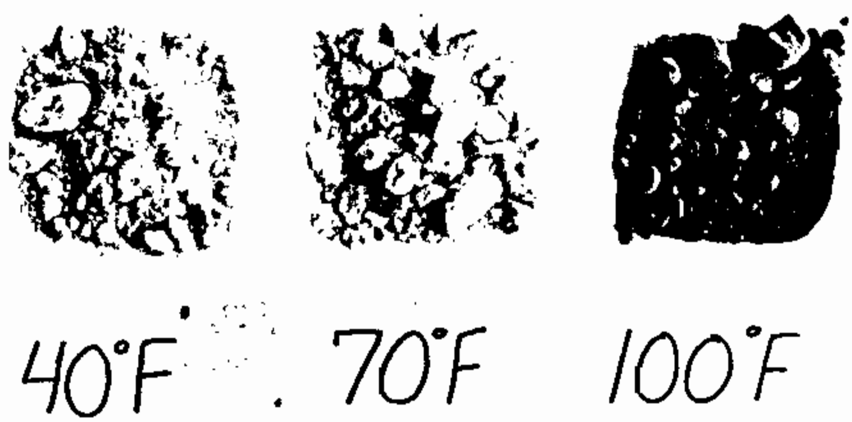

Figure 137 - Dehydrated nitrogen-packed egg samples after 30 months storage at 40°F, 70°F and 100°F.

TABLE 16 - GREEN BEAN TASTE PANEL, TREATMENT MEANS.

	TIME	TASTE PANEL RESPONSE** 40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
FLAVOR	INITIAL	52.00					
	6 MONTH	53.10	52.14	46.90	49.76	35.24	31.43
	12 MONTH	53.00	48.16	53.95	57.11	*	*
	18 MONTH	70.47	59.69	56.62	66.92	*	*
	24 MONTH	51.63	45.32	42.21	43.96	*	*
	30 MONTH	57.43	50.44	56.44	51.10	*	*
	36 MONTH	69.13	56.45	53.21	51.89	*	*
COLOR	INITIAL	70.00					
	6 MONTH	60.00	65.48	55.48	60.24	37.62	51.67
	12 MONTH	63.95	61.50	53.95	64.21	*	*
	18 MONTH	69.98	68.55	55.87	73.98	*	*
	24 MONTH	59.12	68.25	54.36	62.99	*	*
	30 MONTH	65.58	68.41	66.50	63.24	*	*
	36 MONTH	71.95	67.90	63.15	69.06	*	*
TEXTURE	INITIAL	44.00					
	6 MONTH	55.48	54.05	46.19	50.00	31.67	32.38
	12 MONTH	55.26	46.84	49.74	57.11	*	*
	18 MONTH	63.97	59.40	49.50	63.24	*	*
	24 MONTH	49.13	47.67	34.87	52.95	*	*
	30 MONTH	55.07	55.00	53.27	56.71	*	*
	36 MONTH	64.53	57.62	52.40	53.30	*	*
OVERALL	INITIAL	50.00					
	6 MONTH	54.76	53.57	47.62	50.95	33.33	30.95
	12 MONTH	56.32	49.47	53.16	56.05	*	*
	18 MONTH	67.66	59.20	55.41	64.78	*	*
	24 MONTH	51.49	49.20	40.37	49.53	*	*
	30 MONTH	56.35	52.57	55.43	52.82	*	*
	36 MONTH	64.54	58.20	53.57	53.98	*	*

* not tested due to low scores on previous tests.
** 100 = very good, 0 = very poor.

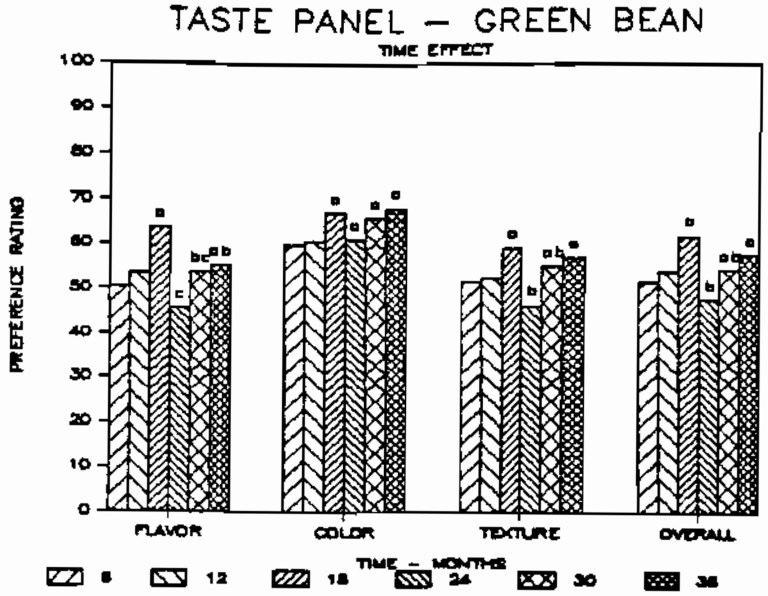

Figure 138 - Effect of storage time on dehydrated green bean acceptability. Significant differences, p = .05 indicated by different letters above treatment.

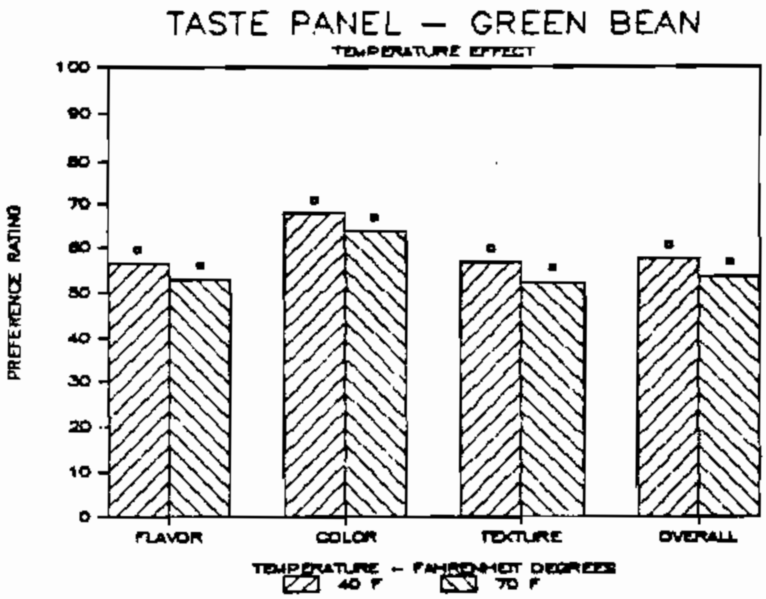

Figure 139 - Effect of storage temperature on dehydrated green bean acceptability. Significant differences, p = .05 indicated by different letters above treatment.

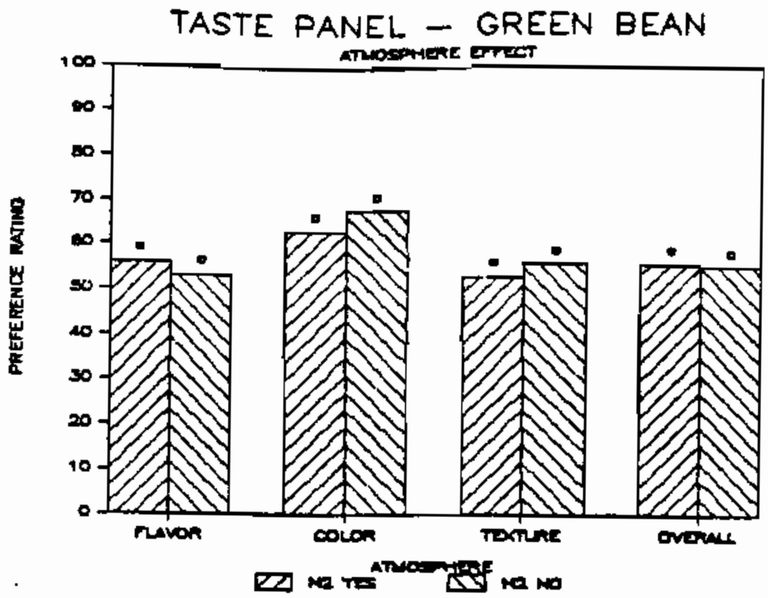

Figure 140 - Effect of interior can oxygen on dehydrated green bean acceptability. Significant differences, p = .05 indicated by different letters above treatment.

Figure 141 - Dehydrated nitrogen-packed green bean samples after 30 months storage at 40°F, 70°F and 100°F.

Macaroni: Treatment means from the macaroni taste panels are listed in Table 17. All samples were tested at all time periods. Browning decreased color acceptability in the 100°F samples (Figure 143). Samples stored at 100°F were also rated lower than 40 and 70°F samples in flavor, texture and overall acceptability. The color of the air-packed macaroni samples was significantly better than the nitrogen-packed samples (Figure 144). The bleaching action of the oxygen retained a preferred lighter color in the macaroni. The other variables were not affected by atmosphere.

Milk: Table 18 lists the milk taste panel treatment means. The 100°F samples were omitted due to very low flavor and overall acceptability responses after 6 months. Nonenzymatic browning was not a problem with the nonfat dried milk. There were no significant differences due to temperature between the 40 and 70°F samples (Figure 146). The atmosphere effect was also not significant (Figure 147). Nonfat milk contains only ca. 0.7% fat (Watt and Merrill, 1963).

Navy beans: Table 19 lists the treatment means from the navy bean taste panels. All samples were tested at all time periods. Flavor, color, texture and overall acceptability were all rated significantly lower in samples stored at 100°F (Figure 149). Differences were greatest for texture; beans stored at 100°F did not soften with extended cooking. There were no significant differences between navy beans stored at 40 or 70°F. The effect of atmosphere on navy bean acceptability was not significant (Figure 150).

TABLE 17 - MACARONI TASTE PANEL, TREATMENT MEANS.

	TIME	TASTE PANEL RESPONSE** 40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
FLAVOR	INITIAL	92.00					
	6 MONTH	73.50	71.50	75.00	74.25	78.75	72.75
	12 MONTH	66.25	63.50	68.25	61.50	67.50	66.25
	18 MONTH	75.73	78.64	77.69	80.05	61.28	69.19
	24 MONTH	70.78	75.88	77.58	57.58	48.48	47.37
	30 MONTH	71.56	70.84	73.36	65.53	45.14	55.09
	36 MONTH	78.16	75.14	80.43	73.70	40.57	56.53
COLOR	INITIAL	92.00					
	6 MONTH	75.50	79.25	76.00	78.25	78.00	78.25
	12 MONTH	70.25	71.00	72.25	71.50	70.50	75.50
	18 MONTH	77.46	82.69	77.01	84.61	41.39	56.12
	24 MONTH	82.03	83.14	79.31	79.74	40.68	40.74
	30 MONTH	75.42	77.23	80.35	78.03	32.79	42.20
	36 MONTH	83.26	85.11	80.93	83.27	26.59	40.18
TEXTURE	INITIAL	86.00					
	6 MONTH	72.50	76.75	75.25	73.75	77.50	76.75
	12 MONTH	62.25	59.50	58.75	53.75	61.75	61.75
	18 MONTH	78.66	79.74	75.31	80.14	75.08	78.55
	24 MONTH	71.20	70.90	76.80	66.49	45.33	44.70
	30 MONTH	61.68	58.66	71.31	71.38	55.40	61.03
	36 MONTH	71.40	68.66	78.99	72.64	40.84	56.90
OVERALL	INITIAL	92.00					
	6 MONTH	71.25	74.50	74.25	74.50	78.00	74.75
	12 MONTH	65.25	63.00	65.50	61.50	63.25	65.50
	18 MONTH	72.69	78.95	73.09	80.64	57.57	65.30
	24 MONTH	73.13	74.74	77.67	62.62	43.20	43.16
	30 MONTH	67.55	67.03	71.66	66.59	44.86	49.91
	36 MONTH	76.84	71.35	78.67	73.63	36.31	51.12

** 100 = very good, 0 = very poor.

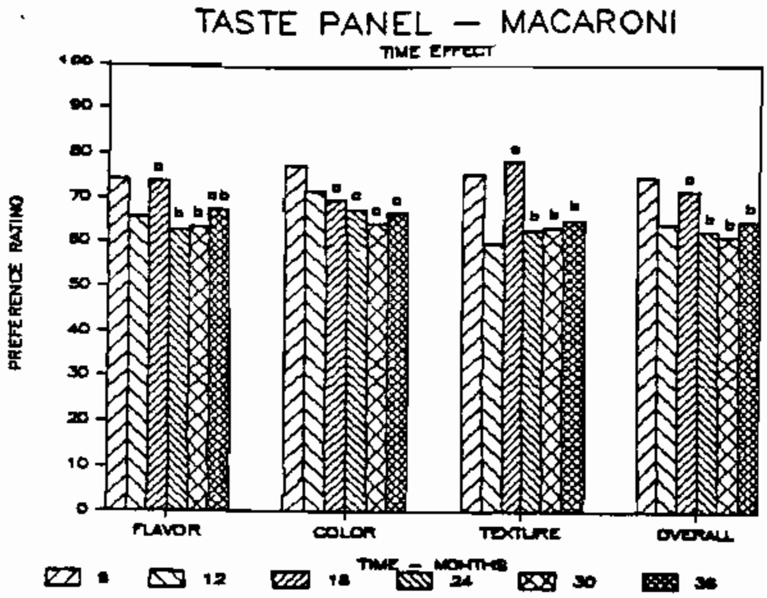

Figure 142 - Effect of storage time on dry macaroni acceptability. Significant differences, p = .05 indicated by different letters above treatment.

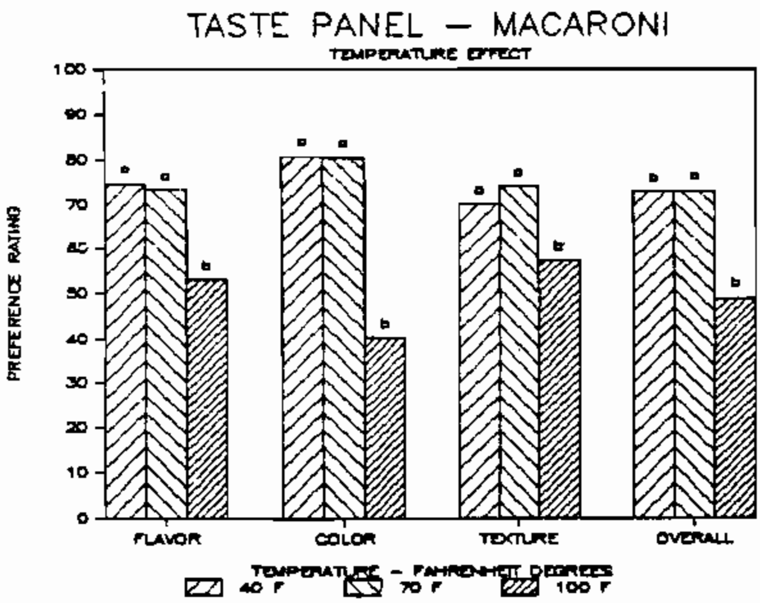

Figure 143 - Effect of storage temperature on dry macaroni acceptability. Significant differences, p = .05 indicated by different letters above treatment.

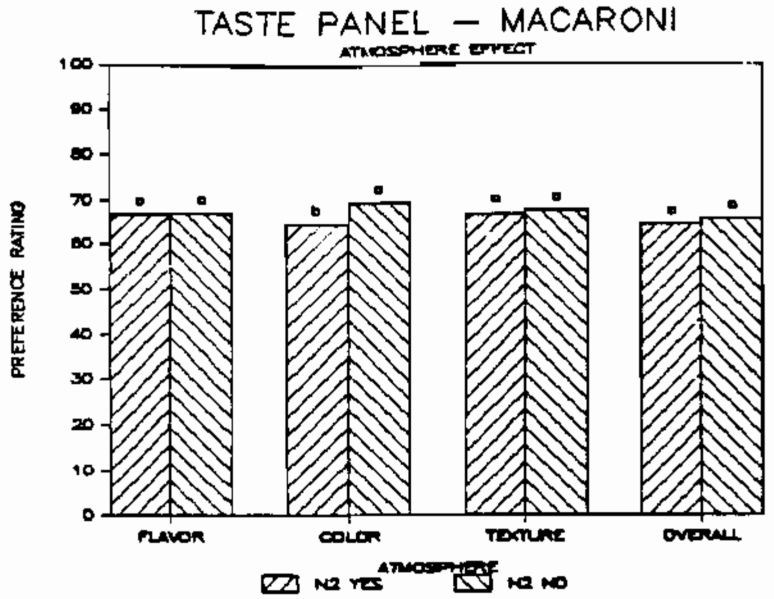

Figure 144 - Effect of interior can oxygen on dry macaroni acceptability. Significant differences, p = .05 indicated by different letters above treatment.

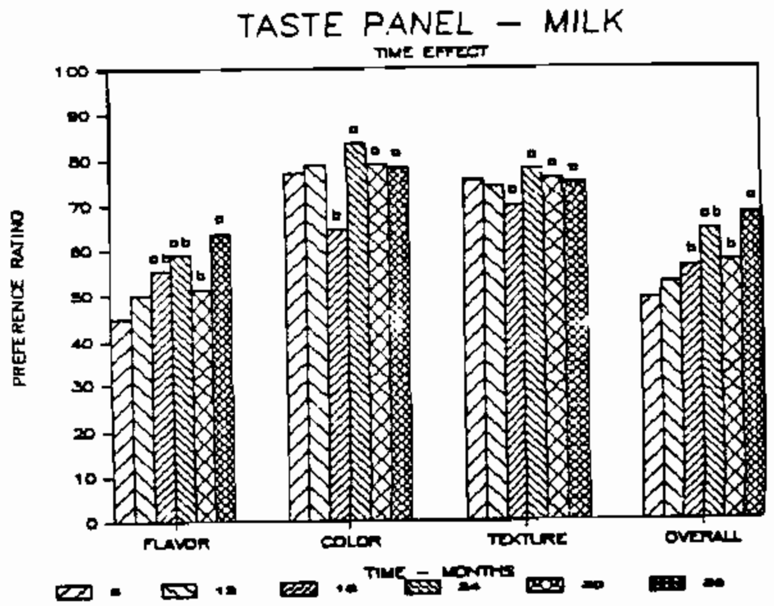

Figure 145 - Effect of storage time on nonfat dry milk acceptability. Significant differences, p = .05 indicated by different letters above treatment.

TABLE 18 - MILK TASTE PANEL, TREATMENT MEANS.

	TIME	TASTE PANEL RESPONSE** 40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
FLAVOR	INITIAL	40.00					
	6 MONTH	41.58	46.32	49.21	42.37	35.26	34.47
	12 MONTH	48.25	47.00	54.00	51.50	*	*
	18 MONTH	51.06	48.73	62.81	58.84	*	*
	24 MONTH	63.95	55.43	61.28	54.99	*	*
	30 MONTH	53.81	53.36	49.36	48.78	*	*
	36 MONTH	67.75	65.09	64.13	57.78	*	*
COLOR	INITIAL	74.00					
	6 MONTH	77.89	78.95	79.47	70.26	77.37	77.89
	12 MONTH	79.50	77.50	79.00	78.50	*	*
	18 MONTH	61.74	64.92	66.43	64.04	*	*
	24 MONTH	84.38	83.69	81.98	83.45	*	*
	30 MONTH	79.58	80.89	75.74	78.37	*	*
	36 MONTH	80.44	78.00	76.88	77.00	*	*
TEXTURE	INITIAL	68.00					
	6 MONTH	75.00	75.26	75.79	74.74	75.00	73.42
	12 MONTH	73.50	73.25	74.50	73.75	*	*
	18 MONTH	67.72	59.13	75.66	75.91	*	*
	24 MONTH	77.92	77.66	77.94	76.66	*	*
	30 MONTH	74.08	77.22	75.42	75.70	*	*
	36 MONTH	76.79	74.35	73.82	73.09	*	*
OVERALL	INITIAL	44.00					
	6 MONTH	46.32	51.05	52.11	45.26	37.63	36.05
	12 MONTH	52.50	49.50	55.50	51.75	*	*
	18 MONTH	49.71	50.88	64.90	58.57	*	*
	24 MONTH	66.90	60.87	67.22	60.95	*	*
	30 MONTH	58.69	57.75	56.28	54.77	*	*
	36 MONTH	71.50	68.89	67.22	62.98	*	*

* not tested due to low scores on previous tests.
** 100 = very good, 0 = very poor.

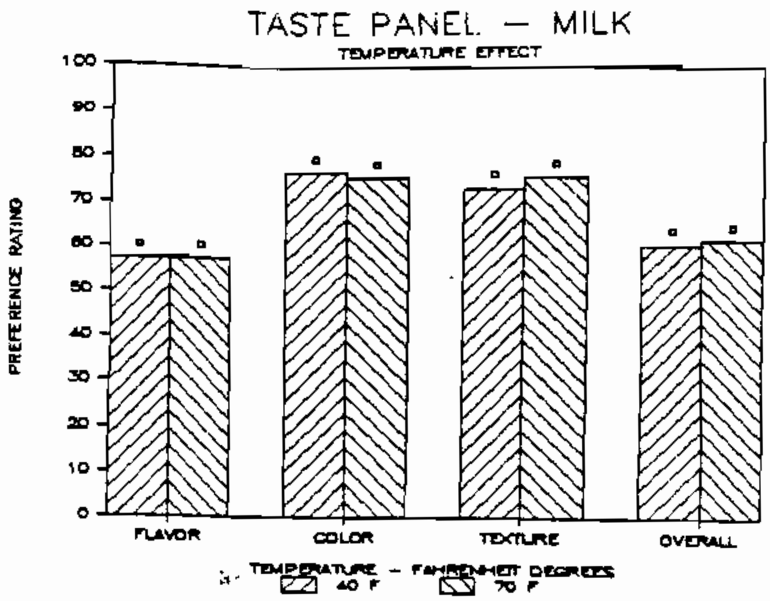

Figure 146 - Effect of storage temperature on nonfat dry milk acceptability. Significant differences, p = .05 indicated by different letters above treatment.

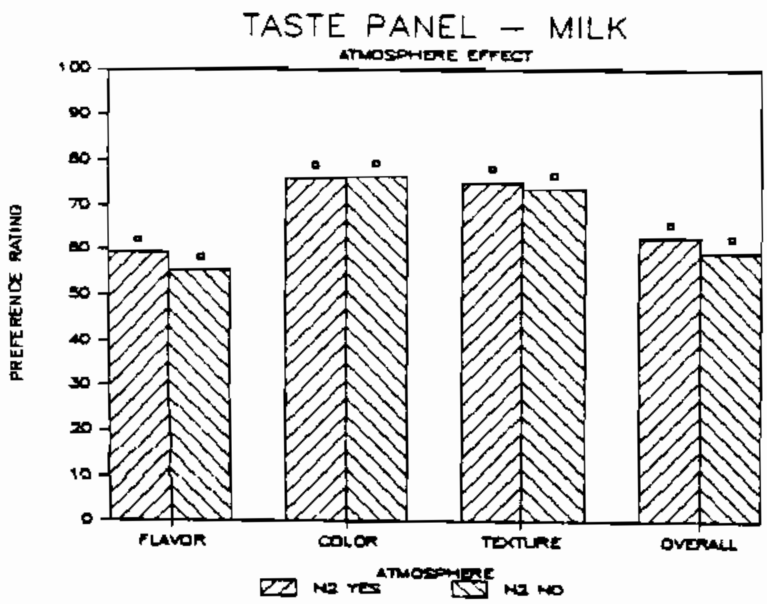

Figure 147 - Effect of interior can oxygen on nonfat dry milk acceptability. Significant differences, p = .05 indicated by different letters above treatment.

TABLE 19 - NAVY BEAN TASTE PANEL, TREATMENT MEANS.

	TIME	40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
		TASTE PANEL RESPONSE**					
FLAVOR	INITIAL	84.00					
	6 MONTH	66.19	67.14	66.19	60.48	68.81	63.57
	12 MONTH	76.00	60.50	68.00	60.25	58.75	63.75
	18 MONTH	76.89	74.75	73.30	79.52	73.63	71.77
	24 MONTH	72.34	68.78	70.47	58.05	55.36	52.13
	30 MONTH	65.70	63.69	65.11	57.48	46.98	48.30
	36 MONTH	76.18	78.34	76.27	69.80	48.46	54.34
COLOR	INITIAL	84.00					
	6 MONTH	80.00	74.76	79.52	75.00	78.57	78.10
	12 MONTH	75.00	64.25	72.25	68.75	70.50	72.00
	18 MONTH	81.05	82.31	81.09	81.15	76.52	77.20
	24 MONTH	71.41	71.43	74.01	66.98	57.34	62.31
	30 MONTH	67.59	65.80	71.70	69.70	54.35	62.87
	36 MONTH	80.07	80.19	79.14	78.61	53.73	71.63
TEXTURE	INITIAL	80.00					
	6 MONTH	63.33	68.57	64.05	58.10	62.14	63.57
	12 MONTH	77.75	49.25	70.25	50.25	51.50	54.75
	18 MONTH	76.14	76.66	66.45	78.53	64.16	60.53
	24 MONTH	69.61	64.59	67.39	55.07	35.01	33.06
	30 MONTH	59.00	66.87	68.68	47.64	28.73	31.74
	36 MONTH	74.13	77.76	78.47	67.46	33.77	41.33
OVERALL	INITIAL	76.00					
	6 MONTH	65.71	66.90	68.71	59.52	66.19	63.81
	12 MONTH	74.00	55.75	67.75	54.75	57.00	59.25
	18 MONTH	76.99	76.37	70.53	79.82	69.47	67.95
	24 MONTH	71.05	66.05	69.35	56.60	45.80	40.73
	30 MONTH	61.61	66.45	66.08	54.76	38.28	42.63
	36 MONTH	74.63	76.13	75.40	69.56	42.31	48.20

** 100 = very good, 0 = very poor.

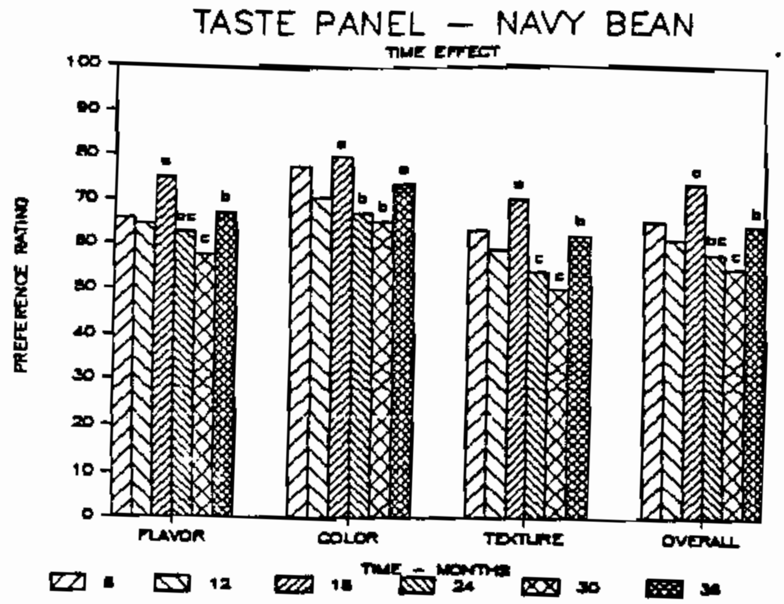

Figure 148 - Effect of storage time on dry navy bean acceptability. Significant differences, p = .05 indicated by different letters above treatment.

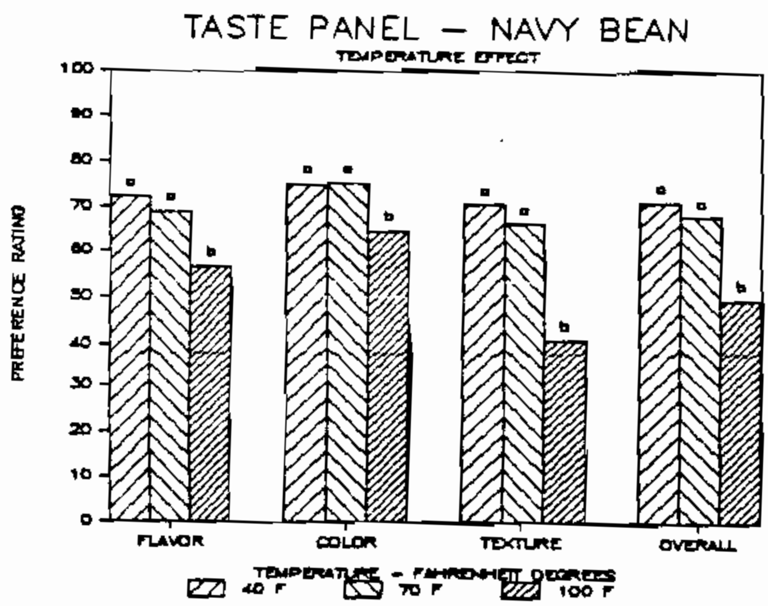

Figure 149 - Effect of storage temperature on dry navy bean acceptability. Significant differences, p = .05 indicated by different letters above treatment.

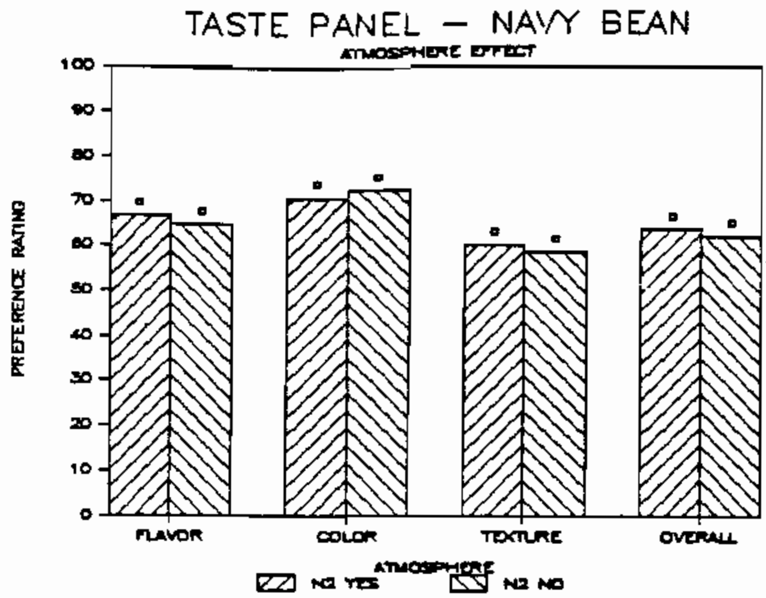

Figure 150 - Effect of interior can oxygen on dry navy bean acceptability. Significant differences, p = .05 indicated by different letters above treatment.

Oatmeal: The oatmeal taste panel treatment means are listed in Table 20. All samples were tested at all time periods. Browning was not detected even in 100°F samples stored for 36 months. Samples stored at 100°F were rated significantly lower than 40 and 70°F samples in flavor and overall acceptability (Figure 152). There were no color or texture differences due to temperature. Atmosphere effects were not significant (Figure 153) in spite of a rather high fat content of ca. 7% in dry oats (Watt and Merrill, 1963).

Peanut butter: Table 21 lists the treatment means for the peanut butter taste panels. All samples were tested at all time periods. No increase in brown color was evident even in 100°F samples stored for 36 months. A slight temperature effect on

TABLE 20 - OATMEAL TASTE PANEL, TREATMENT MEANS.

	TIME	TASTE PANEL RESPONSE** 40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
FLAVOR	INITIAL	90.00					
	6 MONTH	64.75	66.25	69.75	69.00	55.75	59.75
	12 MONTH	57.62	64.29	60.71	60.24	54.76	56.19
	18 MONTH	68.59	73.76	77.50	75.20	62.47	70.08
	24 MONTH	71.19	70.85	64.24	63.36	50.31	54.14
	30 MONTH	73.45	70.12	74.13	75.42	66.94	64.62
	36 MONTH	75.76	76.81	77.41	74.38	69.10	65.48
COLOR	INITIAL	86.00					
	6 MONTH	83.75	81.25	82.50	81.75	81.75	81.00
	12 MONTH	71.90	75.24	73.57	74.52	71.43	72.14
	18 MONTH	85.78	83.66	84.39	85.08	85.72	84.27
	24 MONTH	80.30	81.90	77.85	78.49	77.37	76.96
	30 MONTH	77.97	79.62	79.63	80.91	82.50	80.21
	36 MONTH	81.00	82.07	81.74	81.90	81.70	82.88
TEXTURE	INITIAL	84.00					
	6 MONTH	65.00	72.50	72.50	70.25	67.75	66.00
	12 MONTH	61.43	64.52	61.19	65.00	57.38	59.29
	18 MONTH	79.43	77.82	78.71	79.03	75.68	79.57
	24 MONTH	77.87	74.24	70.54	67.38	62.80	66.02
	30 MONTH	75.41	74.07	75.24	78.20	76.88	76.30
	36 MONTH	79.30	77.81	77.70	75.13	77.94	77.59
OVERALL	INITIAL	86.00					
	6 MONTH	65.25	68.75	69.75	70.00	60.50	62.75
	12 MONTH	60.71	65.71	64.05	62.86	56.43	60.00
	18 MONTH	70.27	74.67	76.86	75.23	65.50	72.74
	24 MONTH	74.48	71.34	65.77	67.79	56.18	59.43
	30 MONTH	74.94	73.83	74.24	76.60	70.82	66.07
	36 MONTH	77.74	76.98	75.58	73.73	73.56	69.77

** 100 = very good, 0 = very poor.

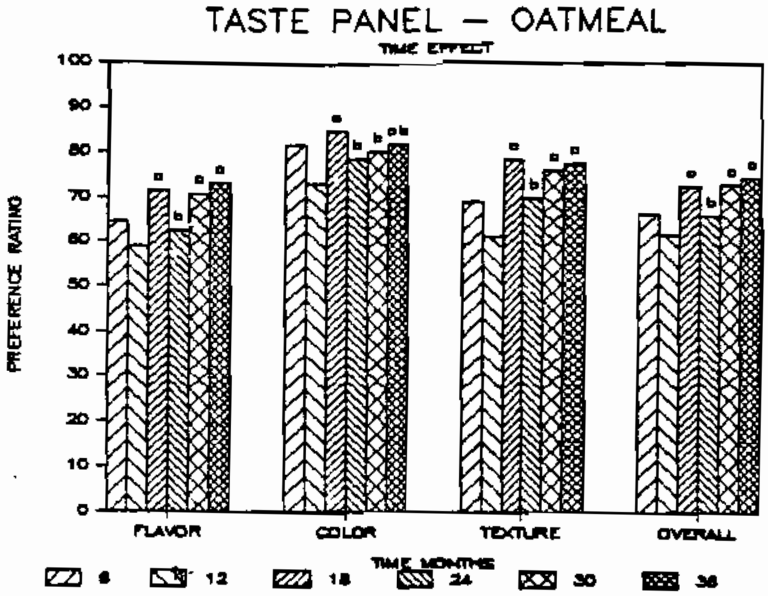

Figure 151 - Effect of storage time on dry oatmeal acceptability. Significant differences, p = .05 indicated by different letters above treatment.

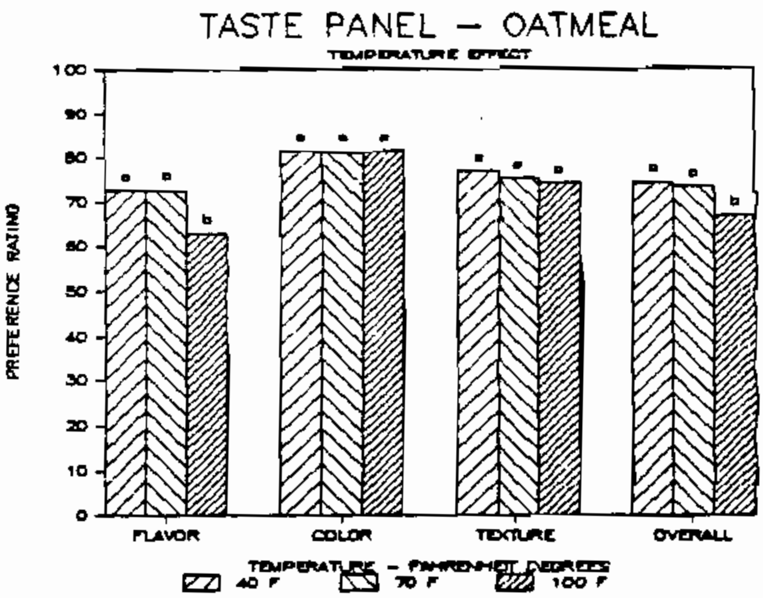

Figure 152 - Effect of storage temperature on dry oatmel acceptability. Significant differences, p = .05 indicated by different letters above treatment.

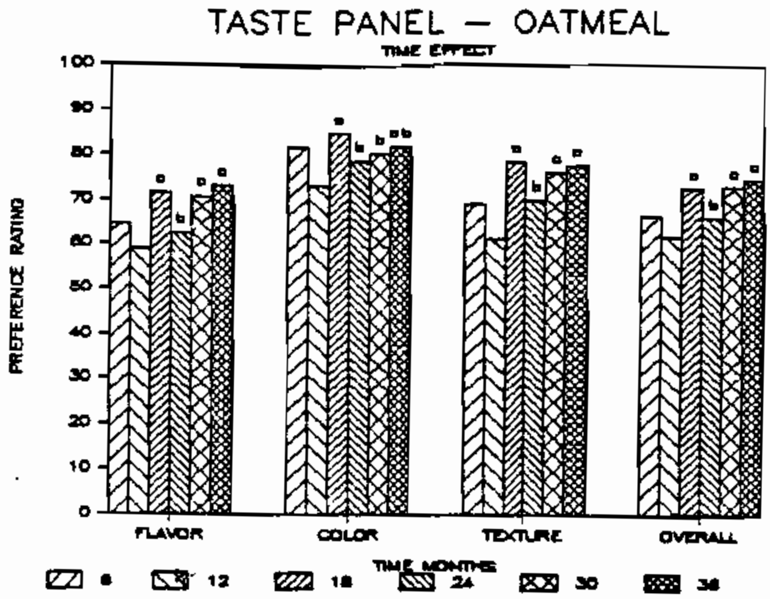

Figure 151 - Effect of storage time on dry oatmeal acceptability. Significant differences, p = .05 indicated by different letters above treatment.

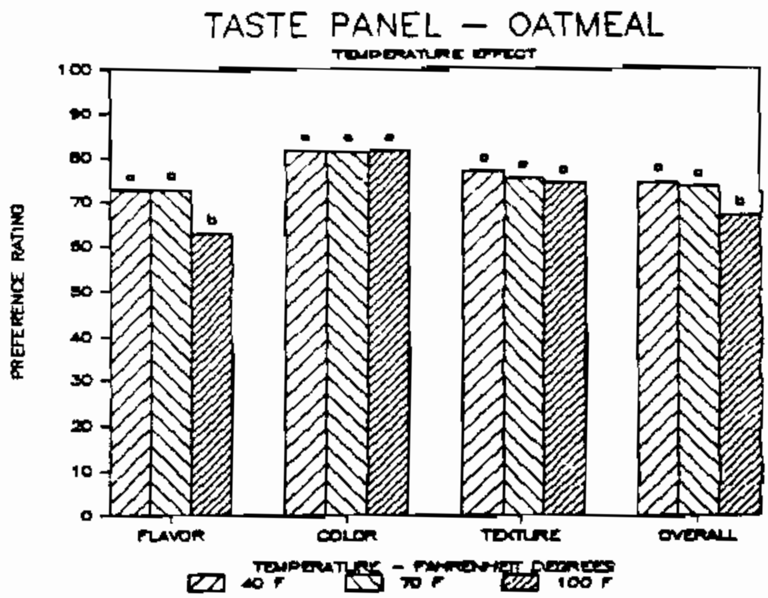

Figure 152 - Effect of storage temperature on dry oatmel acceptability. Significant differences, p = .05 indicated by different letters above treatment.

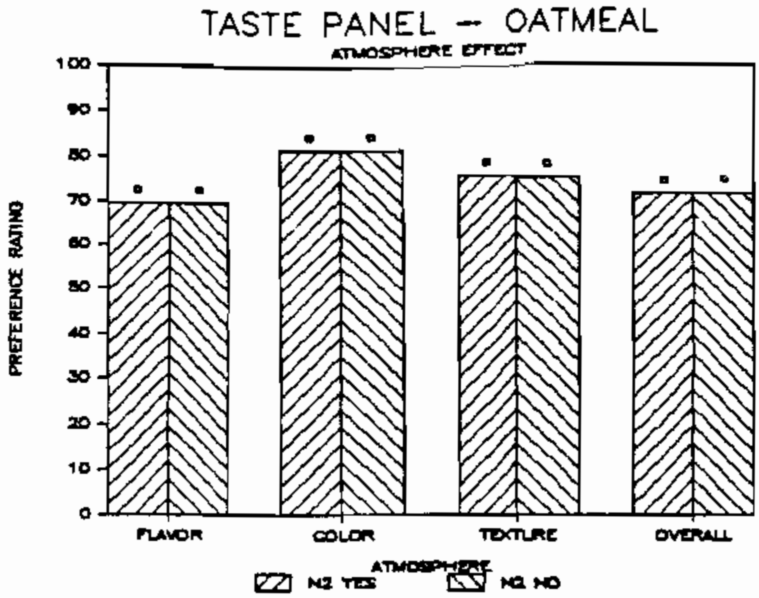

Figure 153 - Effect of interior can oxygen on dry oatmeal acceptability. Significant differences, p = .05 indicated by different letters above treatment.

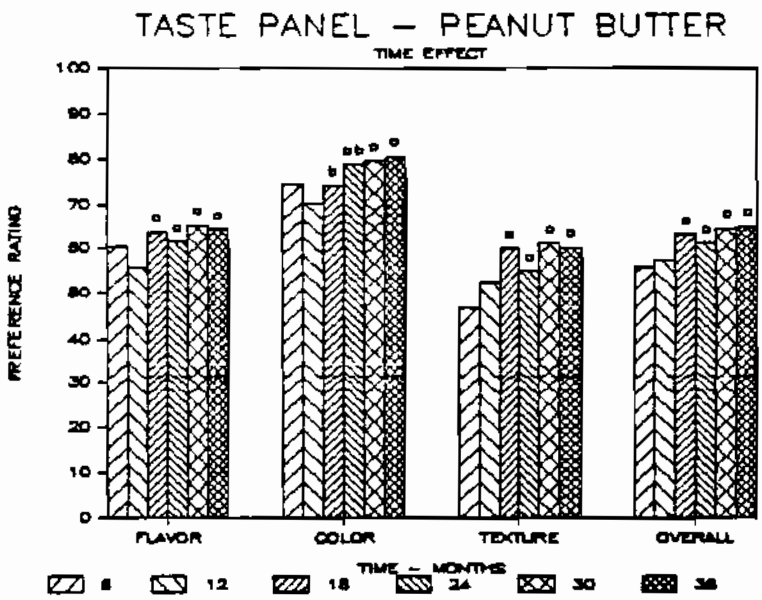

Figure 154 - Effect of storage time on dehydrated peanut butter acceptability. Significant differences, p = .05 indicated by different letters above treatment.

TABLE 21 - PEANUT BUTTER TASTE PANEL, TREATMENT MEANS.

	TIME	TASTE PANEL RESPONSE**					
		40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
FLAVOR	INITIAL	70.00					
	6 MONTH	67.11	59.74	62.89	63.42	59.21	49.74
	12 MONTH	55.00	58.33	57.86	54.76	56.67	52.14
	18 MONTH	65.66	62.51	66.27	56.66	72.62	57.47
	24 MONTH	72.45	57.39	71.94	53.35	69.85	45.00
	30 MONTH	72.76	65.06	69.35	60.30	72.44	51.96
	36 MONTH	75.67	66.78	66.59	61.86	65.83	49.33
COLOR	INITIAL	72.00					
	6 MONTH	75.53	73.68	73.16	73.42	76.05	75.00
	12 MONTH	70.24	71.90	71.90	69.05	70.71	68.57
	18 MONTH	75.07	75.44	73.29	70.26	77.79	72.09
	24 MONTH	77.87	79.62	77.81	78.60	78.63	79.15
	30 MONTH	79.76	77.02	80.14	79.48	80.84	80.22
	36 MONTH	81.86	77.95	82.34	80.53	80.41	79.71
TEXTURE	INITIAL	48.00					
	6 MONTH	48.42	46.32	48.16	46.58	47.37	43.95
	12 MONTH	54.29	46.67	54.29	53.33	53.81	50.95
	18 MONTH	63.35	59.90	59.45	56.90	62.15	58.33
	24 MONTH	56.77	52.54	58.93	50.04	61.30	49.97
	30 MONTH	60.82	62.99	61.12	59.74	66.38	55.86
	36 MONTH	63.73	56.85	68.24	59.90	56.88	55.70
OVERALL	INITIAL	60.00					
	6 MONTH	58.42	56.05	57.11	58.42	55.79	49.74
	12 MONTH	57.38	57.38	58.81	56.90	59.05	54.76
	18 MONTH	65.30	64.06	64.20	57.13	68.32	59.09
	24 MONTH	67.97	57.28	67.27	54.72	67.84	51.86
	30 MONTH	68.77	65.74	69.51	60.00	71.87	51.31
	36 MONTH	74.04	64.27	69.05	63.48	65.68	53.06

** 100 = very good, 0 = very poor.

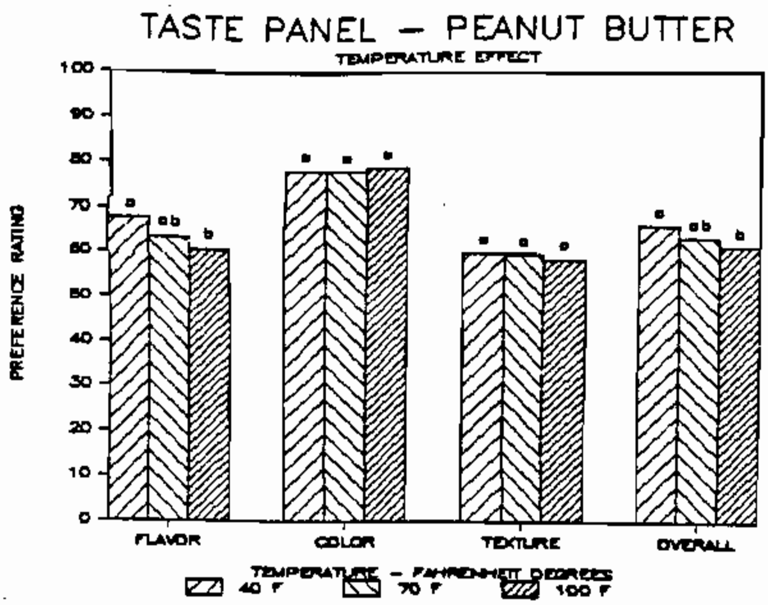

Figure 155 - Effect of storage temperature on dehydrated peanut butter acceptability. Significant differences, p = .05 indicated by different letters above treatment.

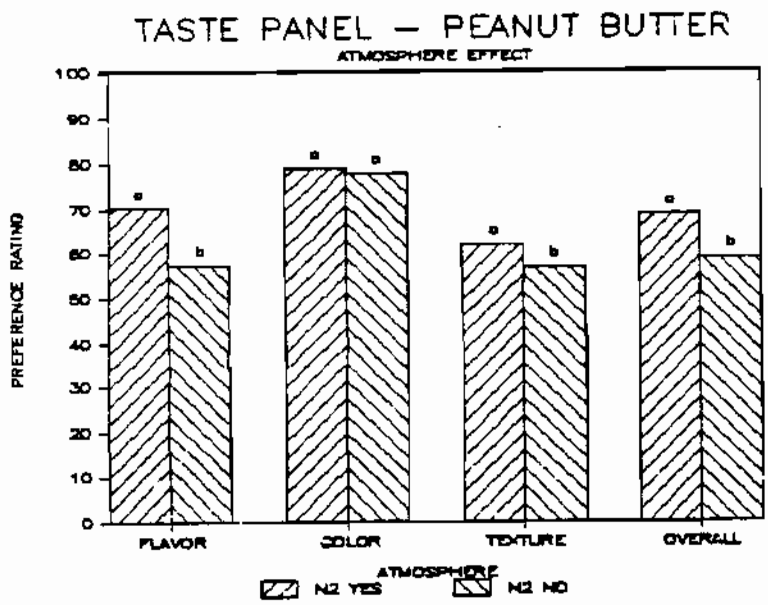

Figure 156 - Effect of interior can oxygen on dehydrated peanut butter acceptability. Significant differences, p = .05 indicated by different letters above treatment.

flavor and overall acceptability was detected (Figure 155). The atmosphere effect was far greater (Figure 156). Nitrogen-packed samples were rated significantly higher in flavor, texture and overall acceptability.

Peaches: Table 22 lists the taste panel treatment means for peaches. Samples stored at 100°F became dark rapidly and were judged unacceptable after 6 months. Samples stored at 40°F were rated significantly higher than those stored at 70°F in flavor, color, texture and overall acceptability (Figure 158). Greatest differences were in color; more darkening was seen with time at 70°F. The effect of atmosphere was not significant (Figure 159).

Potatoes: The treatment means for the potato taste panels are listed in Table 23. Considerable browning was evident in samples stored at 100°F which were unacceptable after 6 months storage. No significant differences were found between samples stored at 40 and 70°F (Figure 161). Nitrogen-packed samples were rated significantly higher than air-packed samples in flavor and overall acceptability (Figure 162).

Salad blend: Table 24 lists the treatment means from the salad blend taste panels. Samples stored at 100°F were quite brown and judged unacceptable after 6 months. Samples stored at 40°F were rated significantly higher than 70°F samples in flavor, color and overall acceptability (Figure 164), while atmosphere had no significant effect (Figure 165). Salad blend samples stored for 30 months are pictured in Figure 166. Browning was very evident in the 100°F sample.

TABLE 22 - PEACH TASTE PANEL, TREATMENT MEANS.

		TASTE PANEL RESPONSE**					
	TIME	40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
FLAVOR	INITIAL	60.00					
	6 MONTH	75.00	74.17	73.06	74.72	34.17	28.61
	12 MONTH	65.71	66.90	64.05	64.52	*	*
	18 MONTH	68.92	67.13	65.06	56.81	*	*
	24 MONTH	72.00	70.90	60.39	64.66	*	*
	30 MONTH	69.33	68.51	61.88	62.53	*	*
	36 MONTH	66.60	66.12	58.99	52.36	*	*
COLOR	INITIAL	52.00					
	6 MONTH	71.94	66.94	72.22	72.50	15.28	14.44
	12 MONTH	58.57	66.90	57.14	54.76	*	*
	18 MONTH	67.82	67.69	57.98	40.78	*	*
	24 MONTH	73.56	70.68	43.83	45.75	*	*
	30 MONTH	69.69	67.76	48.52	41.70	*	*
	36 MONTH	70.22	65.51	42.61	37.95	*	*
TEXTURE	INITIAL	50.00					
	6 MONTH	66.39	70.83	68.33	69.72	49.17	35.28
	12 MONTH	69.53	62.14	58.57	59.05	*	*
	18 MONTH	69.53	65.46	67.37	59.63	*	*
	24 MONTH	70.08	62.66	58.01	55.58	*	*
	30 MONTH	67.75	66.20	58.92	60.24	*	*
	36 MONTH	66.15	57.80	58.04	55.05	*	*
OVERALL	INITIAL	54.00					
	6 MONTH	71.11	70.56	69.72	72.22	29.72	26.94
	12 MONTH	60.71	65.48	61.90	59.76	*	*
	18 MONTH	66.62	66.05	61.61	50.15	*	*
	24 MONTH	73.55	69.31	58.64	58.73	*	*
	30 MONTH	68.27	66.86	57.72	54.78	*	*
	36 MONTH	65.72	60.11	54.32	46.59	*	*

* not tested due to low scores on previous tests.
** 100 = very good, 0 = very poor.

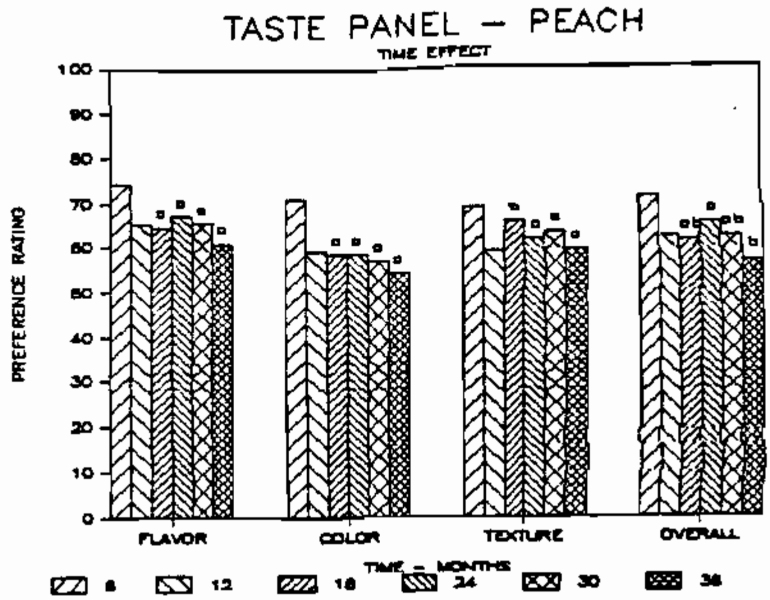

Figure 157 - Effect of storage time on dehydrated peach acceptability. Significant differences, p = .05 indicated by different letters above treatment.

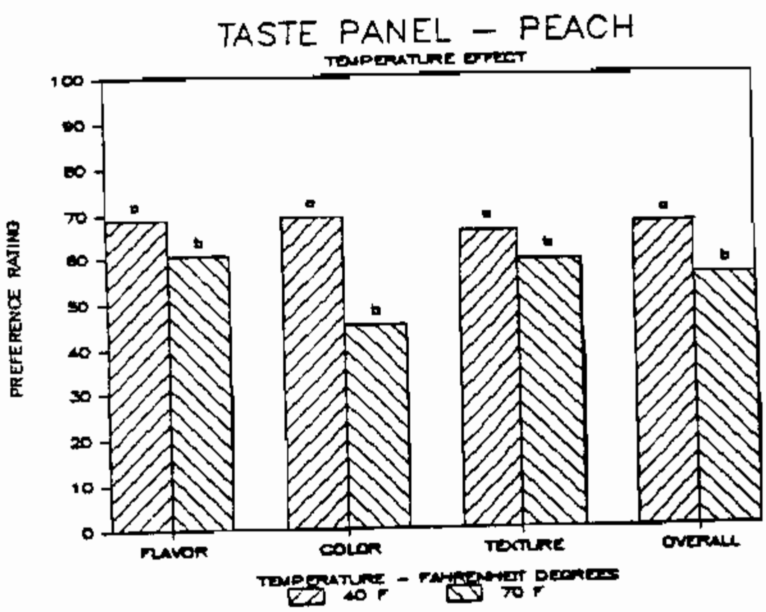

Figure 158 - Effect of storage temperature on dehydrated peach acceptability. Significant differences, p = .05 indicated by different letters above treatment.

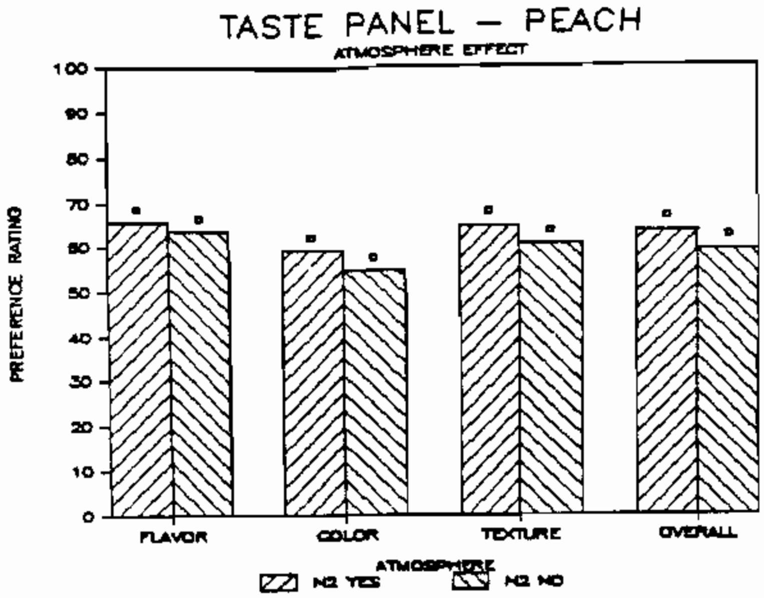

Figure 159 - Effect of interior can oxygen on dehydrated peach acceptability. Significant differences, p = .05 indicated by different letters above treatment.

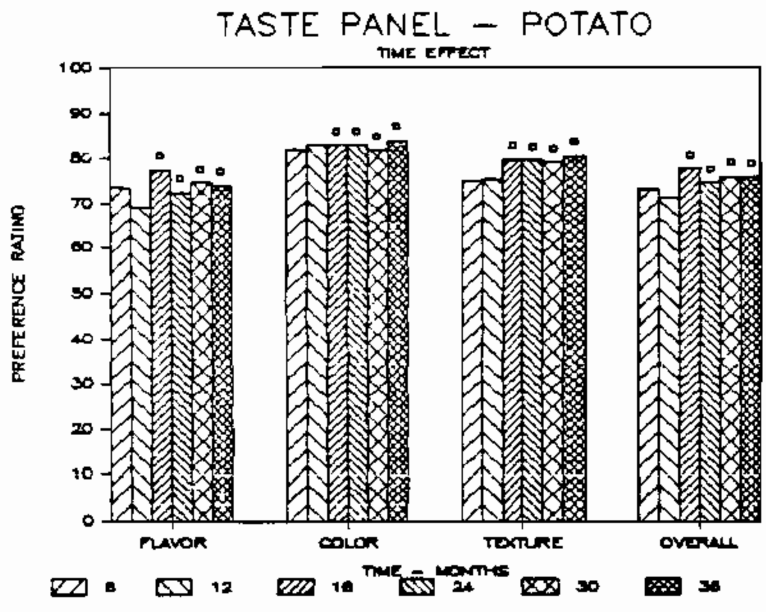

Figure 160 - Effect of storage time on dehydrated potato acceptability. Significant differences, p = .05 indicated by different letters above treatment.

TABLE 23 - POTATO TASTE PANEL, TREATMENT MEANS.

	TIME	40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
		TASTE PANEL RESPONSE**					
FLAVOR	INITIAL	80.00					
	6 MONTH	72.37	75.00	69.74	75.53	22.37	25.53
	12 MONTH	66.67	69.05	70.48	70.24	*	*
	18 MONTH	81.03	74.93	80.62	72.81	*	*
	24 MONTH	82.36	63.06	70.63	73.13	*	*
	30 MONTH	78.72	71.71	73.14	73.66	*	*
	36 MONTH	83.03	72.73	73.35	66.37	*	*
COLOR	INITIAL	92.00					
	6 MONTH	82.63	82.37	79.21	82.89	18.42	16.32
	12 MONTH	82.86	82.38	84.29	81.90	*	*
	18 MONTH	82.65	83.94	82.84	82.39	*	*
	24 MONTH	84.13	81.64	83.43	82.15	*	*
	30 MONTH	82.63	81.35	82.06	80.88	*	*
	36 MONTH	85.87	84.79	81.89	83.19	*	*
TEXTURE	INITIAL	88.00					
	6 MONTH	75.00	75.26	70.26	78.68	65.53	63.95
	12 MONTH	75.00	75.24	76.19	74.29	*	*
	18 MONTH	75.03	81.33	82.04	80.25	*	*
	24 MONTH	83.00	80.84	76.40	77.62	*	*
	30 MONTH	81.04	77.27	77.17	80.55	*	*
	36 MONTH	82.34	80.74	80.29	78.67	*	*
OVERALL	INITIAL	84.00					
	6 MONTH	72.63	73.95	69.47	75.79	25.00	25.26
	12 MONTH	69.76	71.43	71.19	72.14	*	*
	18 MONTH	78.94	76.98	80.28	74.13	*	*
	24 MONTH	82.39	67.93	73.40	74.57	*	*
	30 MONTH	79.87	72.71	75.35	75.06	*	*
	36 MONTH	81.17	74.67	75.58	71.27	*	*

* not tested due to low scores on previous tests.
** 100 = very good, 0 = very poor.

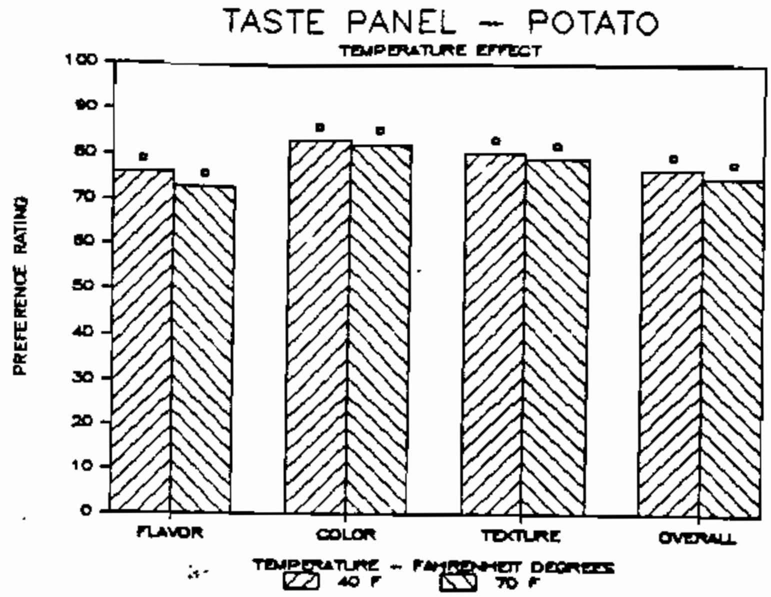

Figure 161 - Effect of storage temperature on dehydrated potato acceptability. Significant differences, p = .05 indicated by different letters above treatment.

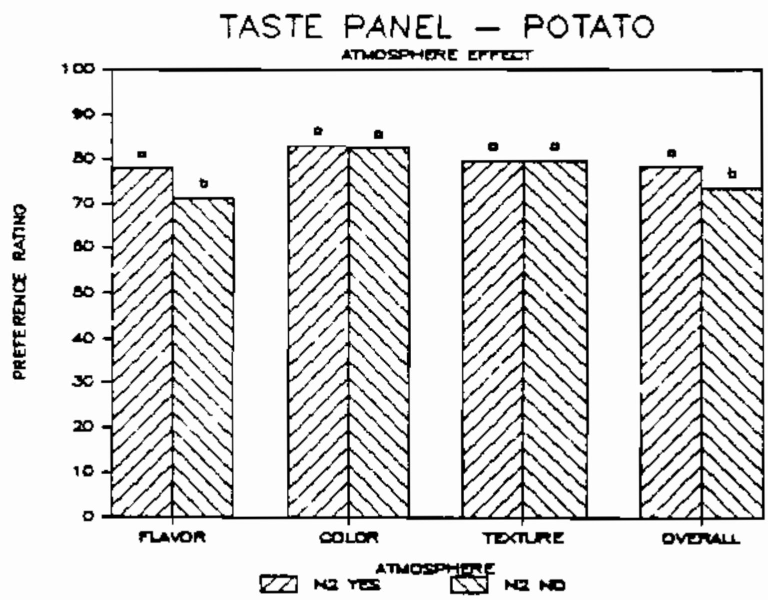

Figure 162 - Effect of interior can oxygen on dehydrated potato acceptability. Significant differences, p = .05 indicated by different letters above treatment.

TABLE 24 - SALAD BLEND TASTE PANEL, TREATMENT MEANS

	TIME	TASTE PANEL RESPONSE** 40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
FLAVOR	INITIAL	44.00					
	6 MONTH	66.05	66.32	64.47	62.11	29.47	23.95
	12 MONTH	58.06	61.11	57.78	56.39	*	*
	18 MONTH	71.81	59.12	63.95	56.76	*	*
	24 MONTH	71.29	66.48	60.06	60.86	*	*
	30 MONTH	59.51	55.28	57.26	53.13	*	*
	36 MONTH	60.80	63.15	51.85	48.74	*	*
COLOR	INITIAL	72.00					
	6 MONTH	73.16	75.79	74.74	76.05	18.42	17.11
	12 MONTH	71.67	73.33	70.28	68.06	*	*
	18 MONTH	73.14	74.97	66.71	68.04	*	*
	24 MONTH	71.70	75.27	60.92	60.19	*	*
	30 MONTH	66.21	67.06	58.68	60.09	*	*
	36 MONTH	64.44	73.07	48.31	54.96	*	*
TEXTURE	INITIAL	58.00					
	6 MONTH	60.00	60.52	62.37	65.00	37.37	32.37
	12 MONTH	55.83	58.06	56.39	57.22	*	*
	18 MONTH	64.41	60.37	58.91	56.38	*	*
	24 MONTH	65.15	61.12	58.64	62.32	*	*
	30 MONTH	59.80	58.98	61.13	55.96	*	*
	36 MONTH	59.59	65.23	53.35	56.56	*	*
OVERALL	INITIAL	46.00					
	6 MONTH	64.47	63.68	60.79	64.21	25.53	21.58
	12 MONTH	59.72	60.83	57.78	57.78	*	*
	18 MONTH	67.76	61.42	62.96	57.86	*	*
	24 MONTH	68.24	62.88	57.73	59.39	*	*
	30 MONTH	59.31	56.88	57.35	52.91	*	*
	36 MONTH	61.34	64.17	49.91	51.37	*	*

* not tested due to low scores on previous tests.
** 100 = very good, 0 = very poor.

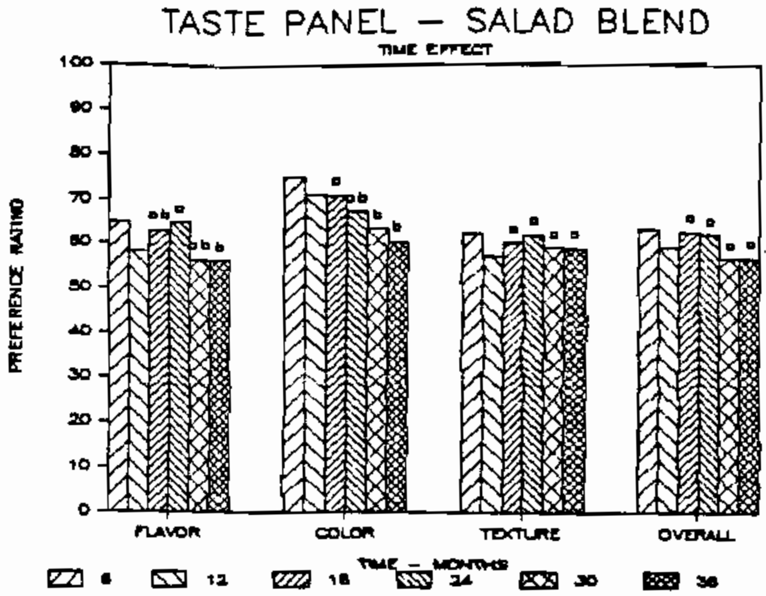

Figure 163 - Effect of storage time on dehydrated salad blend acceptability. Significant differences, p = .05 indicated by different letters above treatment.

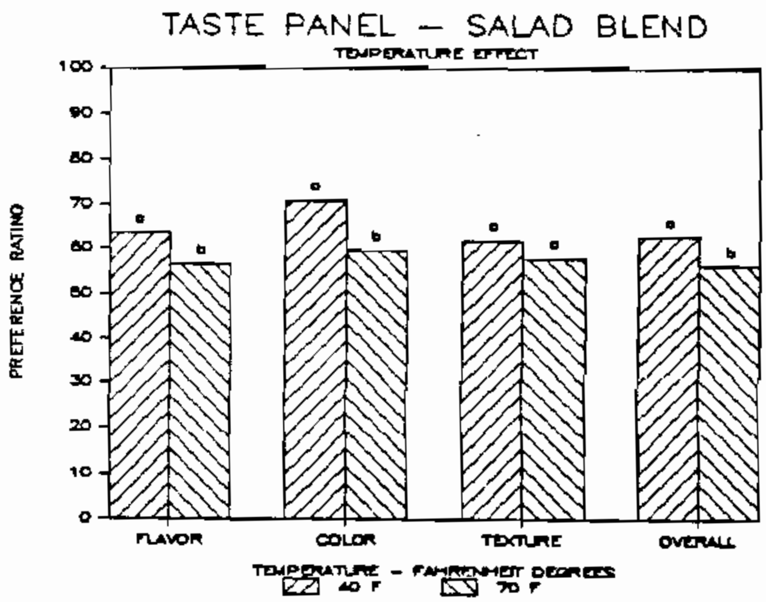

Figure 164 - Effect of storage temperature on dehydrated salad blend acceptability. Significant differences, p = .05 indicated by different letters above treatment.

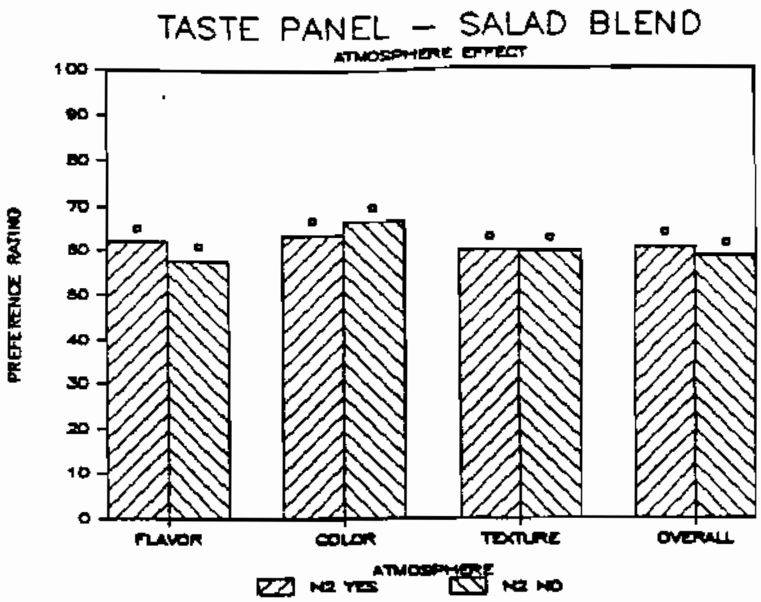

Figure 165 - **Effect of interior can oxygen on dehydrated salad blend acceptability.** Significant differences, p = .05 indicated by different letters above treatment.

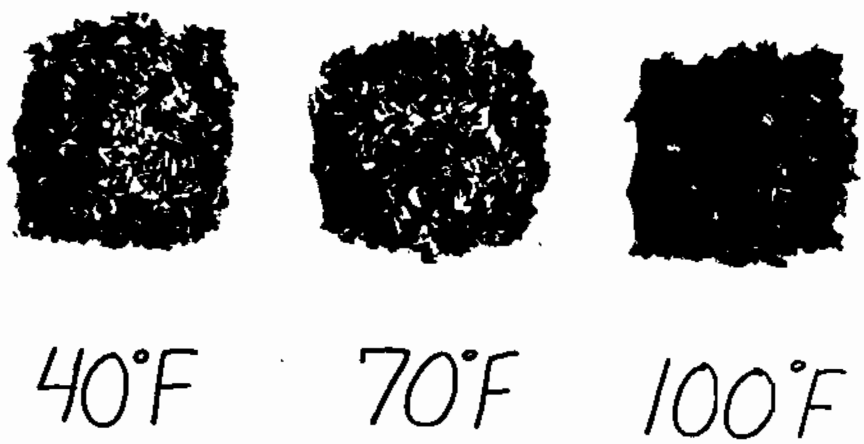

Figure 166 - Dehydrated nitrogen-packed salad blend samples after 30 months storage at 40°F, 70°F and 100°F.

Stroganoff: Table 25 lists the treatment means from the stroganoff taste panels. Samples stored at 100°F browned considerably and were unacceptable after 6 months. Samples stored at 70°F were rated significantly lower than 40°F samples in flavor, color, texture and overall acceptability (Figure 168). There were no differences due to atmosphere (Figure 169).

Tomatoes: Treatment means from the tomato taste panels are listed in Table 26. Samples stored at 100°F were brown and unacceptable after 6 months. There was no significant temperature difference between samples stored at 40 and 70°F (Figure 171). Atmosphere effects were significant only for flavor (Figure 172). Clumping and extreme darkening were evident in tomato samples stored at 100°F for 30 months (Figure 173).

TVP: Table 27 lists the treatment means from the TVP taste panels. All samples were tested at all time periods. Samples stored at 100°F were rated significantly lower than 40 and 70°F samples in flavor, texture and overall acceptability (Figure 175). There were no significant differences between 40 and 70°F samples. Nitrogen-packed samples were rated higher than air-packed samples in flavor and overall acceptability.

Vegetable noodle soup: As shown in Table 28, vegetable soup samples stored at 100°F were not tested after 6 months because of extreme browning and low acceptability. Samples stored at 40°F were rated significantly higher than 70°F samples in flavor, color, texture and overall acceptability (Figure 178). Nitrogen-packed

TABLE 25 - STROGANOFF TASTE PANEL, TREATMENT MEANS.

	TIME	TASTE PANEL RESPONSE**					
		40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
F	INITIAL	84.00					
L	6 MONTH	73.42	72.37	72.37	67.89	26.32	25.26
A	12 MONTH	76.43	74.29	70.95	60.95	*	*
V	18 MONTH	72.66	74.24	59.23	58.51	*	*
O	24 MONTH	75.64	76.77	65.20	59.40	*	*
R	30 MONTH	70.92	77.68	65.52	60.33	*	*
	36 MONTH	73.33	80.61	55.45	49.12	*	*
	INITIAL	78.00					
C	6 MONTH	77.63	79.21	76.32	73.68	25.79	27.37
O	12 MONTH	78.57	75.24	76.43	74.52	*	*
L	18 MONTH	78.35	76.88	76.56	75.60	*	*
O	24 MONTH	80.67	81.94	80.45	79.74	*	*
R	30 MONTH	78.63	80.73	76.43	75.11	*	*
	36 MONTH	80.21	79.19	68.43	66.86	*	*
T	INITIAL	80.00					
E	6 MONTH	70.79	70.79	75.53	70.79	50.53	57.11
X	12 MONTH	77.14	76.43	74.52	71.19	*	*
T	18 MONTH	74.94	71.35	66.72	67.02	*	*
U	24 MONTH	80.78	79.05	82.55	78.73	*	*
R	30 MONTH	76.95	80.25	77.65	75.24	*	*
E	36 MONTH	78.48	79.32	69.70	62.42	*	*
O	INITIAL	80.00					
V	6 MONTH	73.42	73.42	73.42	68.16	25.79	27.63
E	12 MONTH	75.48	74.52	72.86	64.05	*	*
R	18 MONTH	74.71	73.34	62.16	63.88	*	*
A	24 MONTH	79.13	80.09	70.87	64.26	*	*
L	30 MONTH	70.39	77.96	67.94	63.68	*	*
L	36 MONTH	74.98	79.17	57.91	52.87	*	*

* not tested due to low scores on previous tests.
** 100 = very good, 0 = very poor.

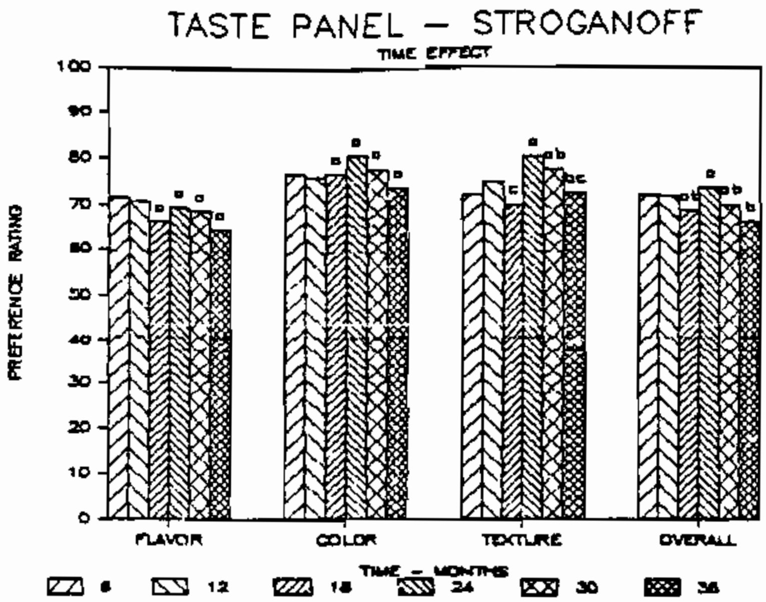

Figure 167 - Effect of storage time on dry stroganoff acceptability. Significant differences, p = .05 indicated by different letters above treatment.

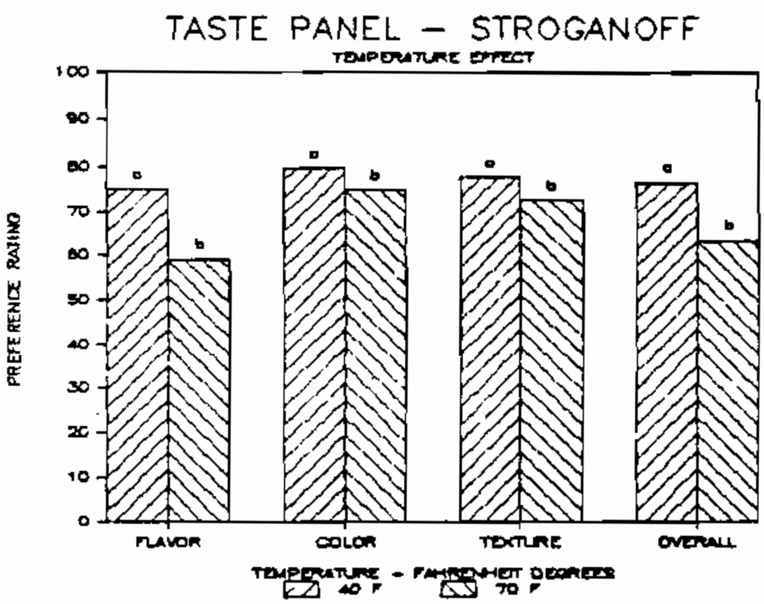

Figure 168 - Effect of storage temperature on dry stroganoff acceptability. Significant differences, p = .05 indicated by different letters above treatment.

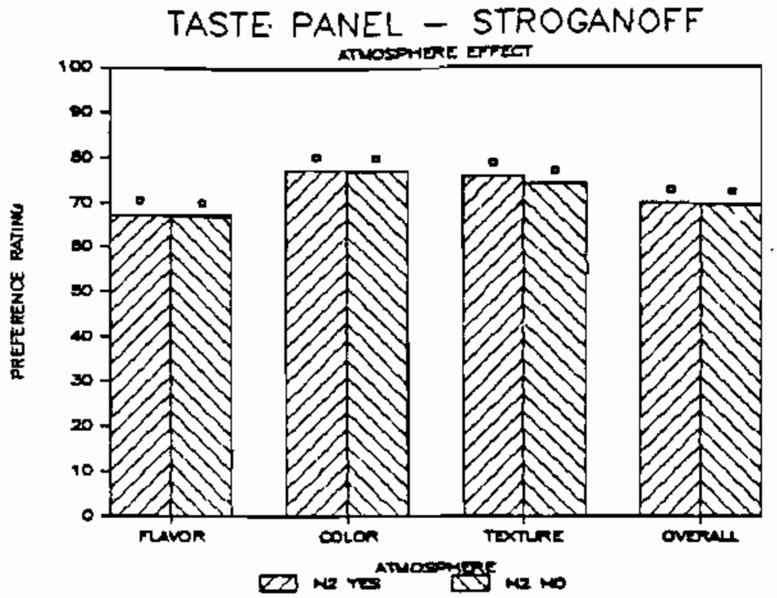

Figure 169 - Effect of interior can oxygen on dry stroganoff acceptability. Significant differences, p = .05 indicated by different letters above treatment.

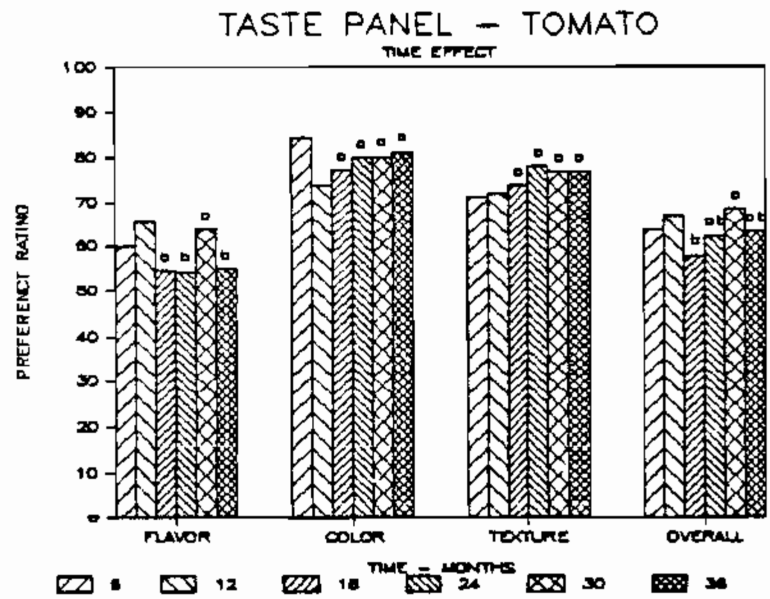

Figure 170 - Effect of storage time on dehydrated tomato acceptability. Significant differences, p = .05 indicated by different letters above treatment.

TABLE 26 - TOMATO TASTE PANEL, TREATMENT MEANS.

	TIME	TASTE PANEL RESPONSE**					
		40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
FLAVOR	INITIAL	66.00					
	6 MONTH	60.56	58.89	62.22	59.17	23.33	25.28
	12 MONTH	64.47	64.21	68.68	65.00	*	*
	18 MONTH	56.27	51.48	55.70	54.55	*	*
	24 MONTH	61.63	43.28	59.66	53.23	*	*
	30 MONTH	66.35	59.51	65.19	64.81	*	*
	36 MONTH	53.33	55.36	56.80	54.25	*	*
COLOR	INITIAL	88.00					
	6 MONTH	83.89	83.89	85.00	83.89	21.94	23.61
	12 MONTH	75.53	69.21	75.53	73.95	*	*
	18 MONTH	75.93	77.03	78.13	77.13	*	*
	24 MONTH	83.02	77.99	77.42	81.23	*	*
	30 MONTH	79.69	81.23	80.02	79.05	*	*
	36 MONTH	80.93	84.05	80.75	78.96	*	*
TEXTURE	INITIAL	84.00					
	6 MONTH	70.28	70.83	71.94	71.11	62.78	63.61
	12 MONTH	71.58	69.47	73.68	72.63	*	*
	18 MONTH	74.08	73.12	74.40	73.07	*	*
	24 MONTH	78.45	74.51	79.08	79.21	*	*
	30 MONTH	75.62	77.01	77.65	76.54	*	*
	36 MONTH	77.00	77.27	78.06	74.37	*	*
OVERALL	INITIAL	64.00					
	6 MONTH	63.06	63.33	65.00	62.50	24.44	25.00
	12 MONTH	67.89	64.21	68.95	66.32	*	*
	18 MONTH	62.36	53.74	56.80	58.46	*	*
	24 MONTH	65.69	55.71	64.84	62.53	*	*
	30 MONTH	68.84	65.72	69.32	68.85	*	*
	36 MONTH	62.14	62.77	64.50	62.81	*	*

* not tested due to low scores on previous tests.
** 100 = very good, 0 = very poor.

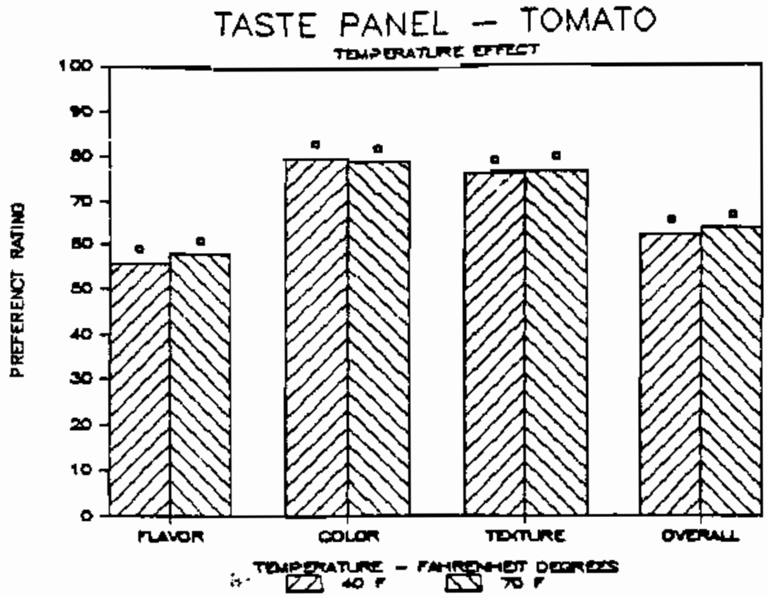

Figure 171 - Effect of storage temperature on dehydrated tomato acceptability. Significant differences, p = .05 indicated by different letters above treatment.

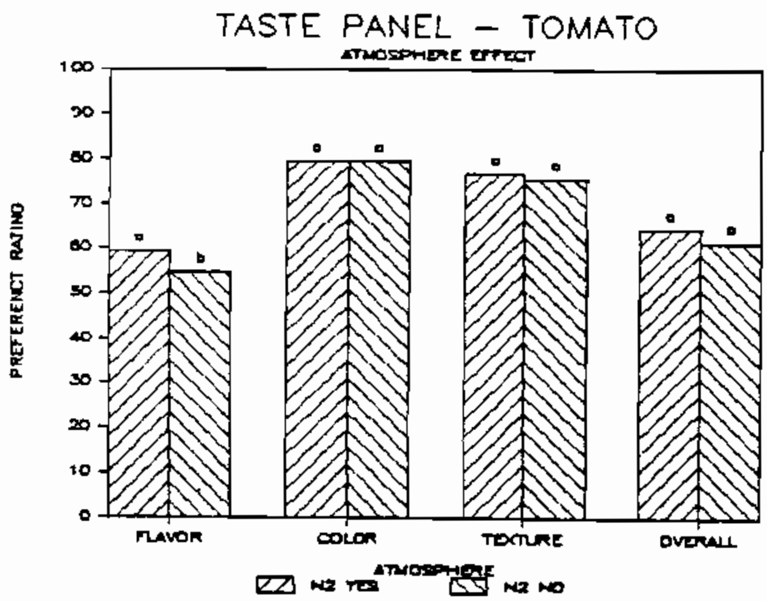

Figure 172 - Effect of interior can oxygen on dehydrated tomato acceptability. Significant differences, p = .05 indicated by different letters above treatment.

Figure 173 - Dehydrated nitrogen-packed tomato samples after 30 months storage at 40°F, 70°F, and 100°F.

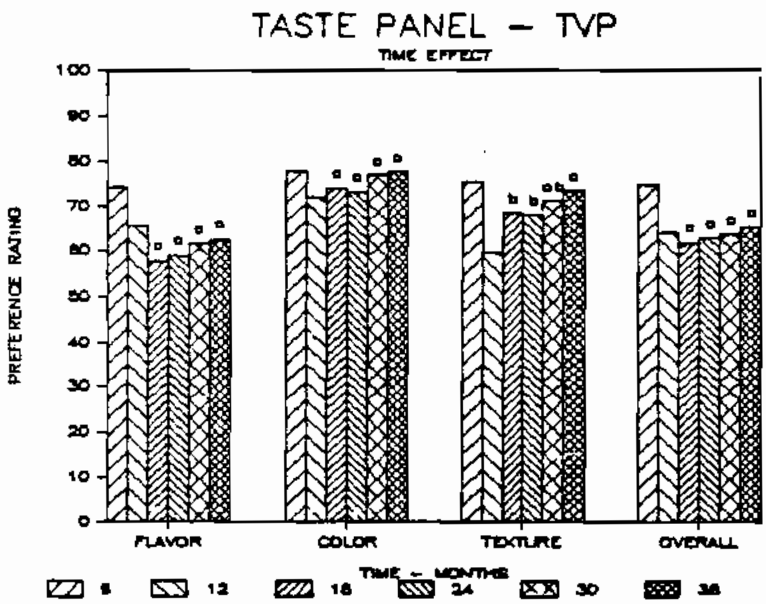

Figure 174 - Effect of storage time on dry TVP acceptability. Significant differences, p = .05 indicated by different letters above treatment.

TABLE 27 - TVP TASTE PANEL, TREATMENT MEANS.

	TIME	TASTE PANEL RESPONSE**					
		40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
FLAVOR	INITIAL	66.00					
	6 MONTH	62.89	63.42	62.89	67.11	58.42	55.79
	12 MONTH	65.24	61.90	66.67	62.86	65.95	59.52
	18 MONTH	64.63	53.63	66.38	56.02	51.70	55.24
	24 MONTH	70.51	66.57	66.21	58.22	50.49	42.50
	30 MONTH	67.43	61.18	66.76	65.84	55.89	51.85
	36 MONTH	70.40	58.57	71.98	68.21	53.04	52.95
COLOR	INITIAL	74.00					
	6 MONTH	75.26	73.95	71.84	74.74	72.89	75.79
	12 MONTH	79.29	78.10	79.29	79.05	77.14	76.43
	18 MONTH	75.49	74.89	76.88	72.26	70.18	73.50
	24 MONTH	73.61	75.25	75.42	75.49	70.32	68.29
	30 MONTH	76.19	75.00	77.14	77.95	76.32	77.57
	36 MONTH	76.33	77.27	79.19	77.64	77.44	77.45
TEXTURE	INITIAL	68.00					
	6 MONTH	67.11	65.26	66.05	70.26	66.05	64.21
	12 MONTH	69.76	69.52	68.81	70.00	69.76	65.71
	18 MONTH	71.12	63.99	70.39	70.01	67.44	65.89
	24 MONTH	71.90	75.04	69.92	67.28	60.78	62.46
	30 MONTH	73.05	71.80	71.16	74.00	69.50	68.01
	36 MONTH	76.79	72.25	76.59	75.86	69.50	69.06
OVERALL	INITIAL	64.00					
	6 MONTH	66.58	63.95	64.21	67.63	60.53	58.94
	12 MONTH	68.57	66.67	69.52	67.86	68.81	63.33
	18 MONTH	66.20	58.14	66.73	60.58	59.41	59.90
	24 MONTH	72.23	69.46	69.27	62.13	55.93	48.71
	30 MONTH	69.46	64.64	67.05	66.83	57.09	55.82
	36 MONTH	70.36	62.59	72.33	68.01	58.55	58.03

** 100 = very good, 0 = very poor.

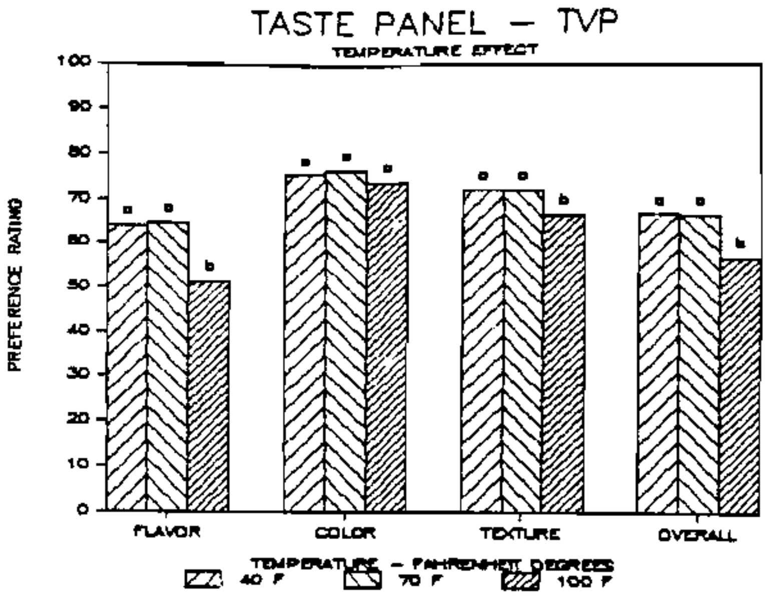

Figure 175 - Effect of storage temperature on dry TVP acceptability. Significant differences, p = .05 indicated by different letters above treatment.

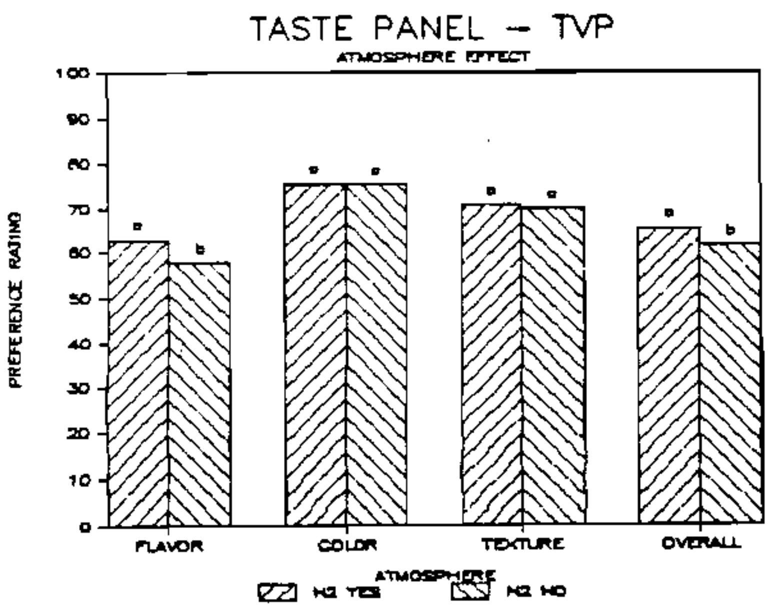

Figure 176 - Effect of interiot can oxygen on dry TVP acceptability. Significant differences, p = .05 indicated by different letters above treatment.

TABLE 28 - VEGETABLE SOUP TASTE PANEL, TREATMENT MEANS.

		TASTE PANEL RESPONSE**					
	TIME	40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
FLAVOR	INITIAL	58.00					
	6 MONTH	69.74	66.32	59.74	68.68	26.32	22.63
	12 MONTH	72.62	63.81	64.52	56.43	*	*
	18 MONTH	74.45	69.84	66.88	60.75	*	*
	24 MONTH	78.71	72.04	70.76	61.44	*	*
	30 MONTH	65.60	67.27	62.15	60.14	*	*
	36 MONTH	74.39	67.91	61.26	53.26	*	*
COLOR	INITIAL	70.00					
	6 MONTH	78.68	75.26	76.05	72.11	18.16	17.11
	12 MONTH	80.48	77.62	76.67	76.43	*	*
	18 MONTH	73.44	70.54	67.21	67.86	*	*
	24 MONTH	76.64	76.74	64.73	70.44	*	*
	30 MONTH	77.34	75.06	57.74	55.34	*	*
	36 MONTH	80.70	75.38	59.96	65.36	*	*
TEXTURE	INITIAL	58.00					
	6 MONTH	73.95	67.37	67.11	68.95	46.32	44.74
	12 MONTH	71.67	67.86	65.48	64.29	*	*
	18 MONTH	75.49	75.39	72.95	70.71	*	*
	24 MONTH	74.84	69.52	71.34	62.99	*	*
	30 MONTH	73.02	73.95	69.73	67.65	*	*
	36 MONTH	77.97	73.01	66.37	66.08	*	*
OVERALL	INITIAL	54.00					
	6 MONTH	68.68	66.05	61.58	66.84	21.32	22.11
	12 MONTH	74.52	66.90	65.71	62.86	*	*
	18 MONTH	73.26	68.11	67.45	65.35	*	*
	24 MONTH	76.91	73.97	69.07	60.67	*	*
	30 MONTH	67.83	69.18	60.70	58.07	*	*
	36 MONTH	75.10	68.44	61.79	56.22	*	*

* not tested due to low scores on previous tests.
** 100 = very good, 0 = very poor.

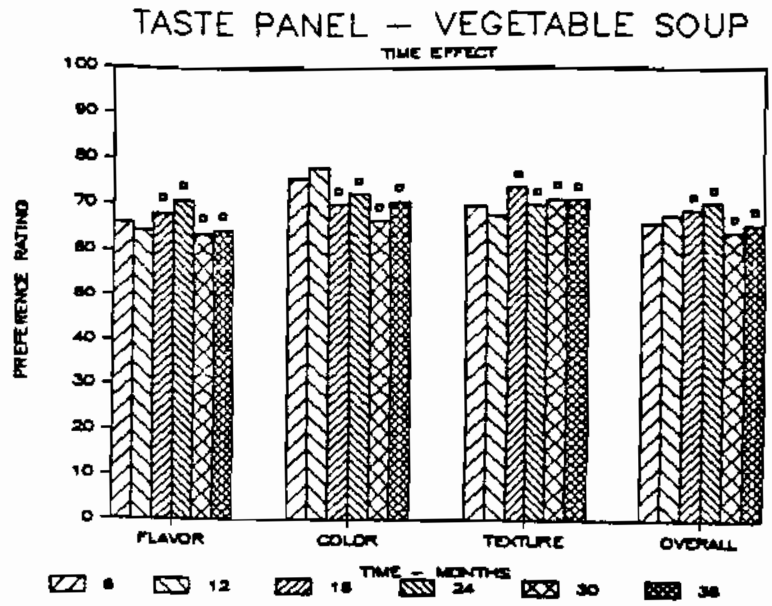

Figure 177 - Effect of storage time on dehydrated vegetable soup acceptability. Significant differences, p = .05 indicated by different letters above treatment.

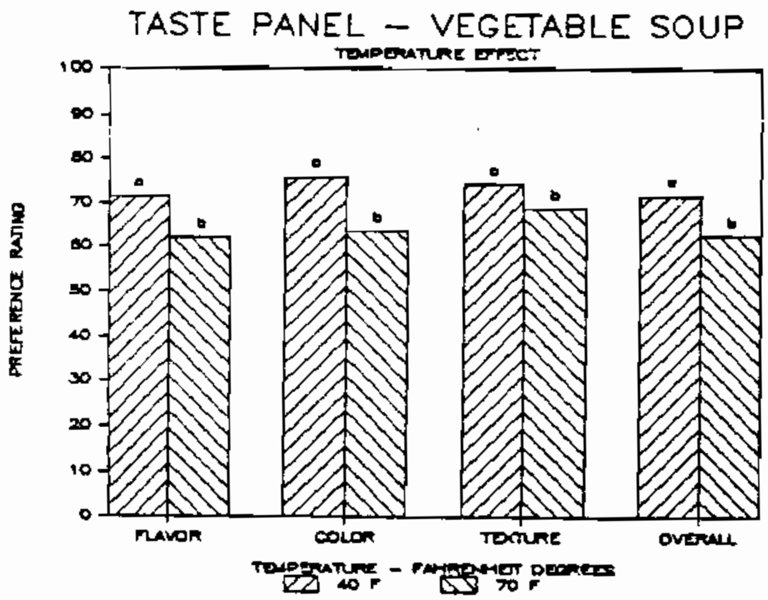

Figure 178 - Effect of storage temperature on dehydrated vegetable soup acceptability. Significant differences, p = .05 indicated by different letters above treatment.

samples received scores significantly higher than air-packed samples in flavor and overall acceptability (Figure 179).

Wheat: Table 29 lists the treatment means for the wheat taste panels. All samples were tested at all time periods. Flavor and overall acceptability were rated significantly lower in 100°F samples than 40 and 70°F samples (Figure 181). The effect of atmosphere on stored wheat samples was not significant (Figure 182).

The effect of temperature on color was generally due to non-enzymatic browning. Legault et al. (1951) found a decreased rate of browning with decreased moisture. Tuomy and Walker (1970) recommended a maximum moisture of 2% in dried eggs. Of the products in this study having an initial moisture below 2% (Table 1) apples was the only one where browning was significant. Browning in

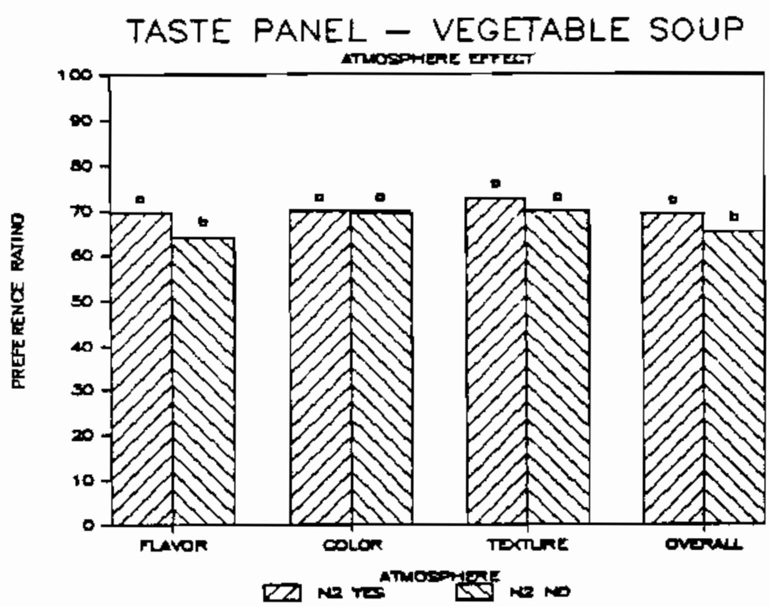

Figure 179 - Effect of interior can oxygen on dehydrated vegetable soup acceptability. Significant differences, p = .05 indicated by different letters above treatment.

TABLE 29 - WHEAT TASTE PANEL, TREATMENT MEANS.

	TIME	TASTE PANEL RESPONSE**					
		40 DEGREE N2 YES	40 DEGREE N2 NO	70 DEGREE N2 YES	70 DEGREE N2 NO	100 DEGREE N2 YES	100 DEGREE N2 NO
FLAVOR	INITIAL	88.00					
	6 MONTH	74.21	79.47	74.47	75.53	73.95	74.47
	12 MONTH	69.76	69.76	69.52	69.52	68.81	68.57
	18 MONTH	75.63	73.69	78.14	76.42	71.97	66.56
	24 MONTH	74.35	69.03	72.37	75.26	63.48	60.76
	30 MONTH	68.75	70.94	73.70	66.19	65.84	64.32
	36 MONTH	81.81	77.55	74.71	80.35	72.27	71.99
COLOR	INITIAL	88.00					
	6 MONTH	77.63	81.84	81.05	82.89	80.53	77.63
	12 MONTH	77.38	78.33	77.86	77.38	77.86	80.00
	18 MONTH	82.39	82.46	84.06	83.82	85.27	81.75
	24 MONTH	80.49	81.26	77.35	78.03	79.87	76.76
	30 MONTH	77.80	78.61	79.81	80.05	76.19	77.53
	36 MONTH	84.73	83.12	83.31	85.16	83.00	84.75
TEXTURE	INITIAL	86.00					
	6 MONTH	75.79	78.68	76.58	78.16	76.05	77.37
	12 MONTH	70.24	70.71	68.10	70.24	73.10	70.24
	18 MONTH	75.11	74.91	76.33	74.94	75.04	72.86
	24 MONTH	74.20	73.01	75.07	71.72	66.99	65.66
	30 MONTH	63.13	67.28	75.43	72.72	70.24	70.32
	36 MONTH	79.01	76.37	79.67	79.86	78.71	77.05
OVERALL	INITIAL	86.00					
	6 MONTH	74.21	79.21	75.79	77.37	73.95	75.00
	12 MONTH	68.57	69.05	70.24	70.00	71.43	70.24
	18 MONTH	77.45	76.72	78.57	76.64	75.83	72.11
	24 MONTH	75.08	70.43	72.44	74.92	65.44	64.10
	30 MONTH	66.89	70.92	74.20	70.76	70.15	68.01
	36 MONTH	80.86	77.27	76.91	79.60	73.56	74.65

** 100 = very good, 0 = very poor.

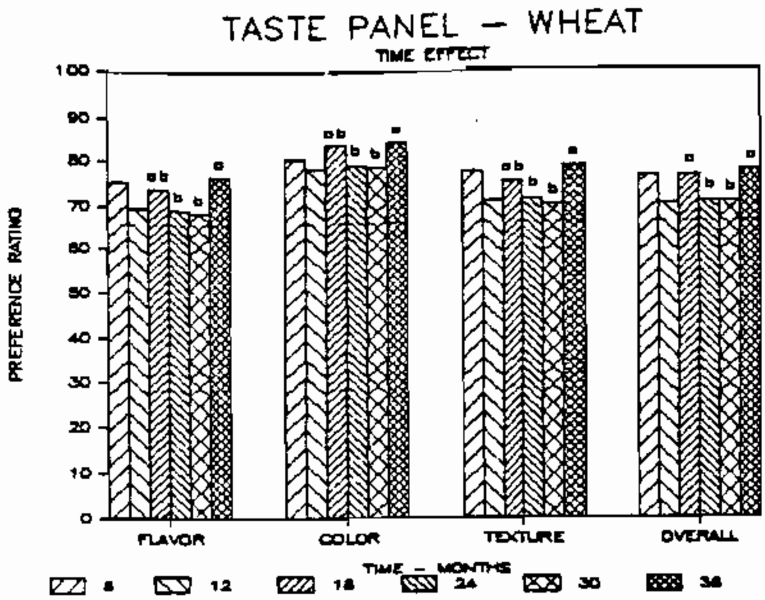

Figure 180 - Effect of storage time on dry wheat acceptability. Significant differences, p = .05 indicated by different letters above treatment.

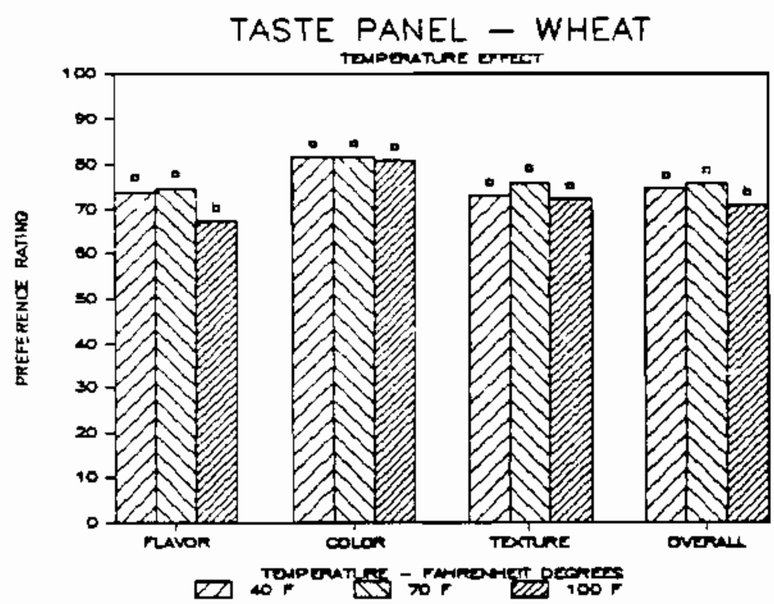

Figure 181 - Effect of storage temperature on dry wheat acceptability. Significant differences, p = .05 indicated by different letters above treatment.

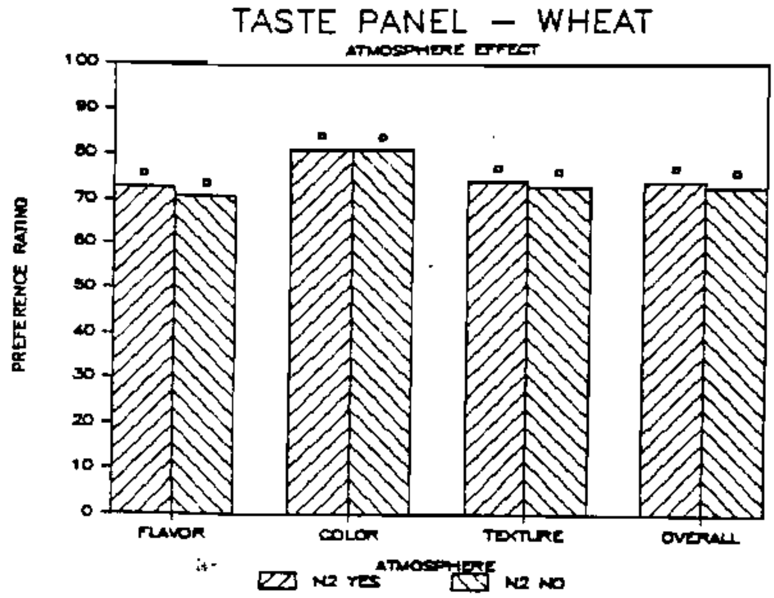

Figure 182 - Effect of interior can oxygen on dry wheat acceptability. Significant differences, p = .05 indicated by different letters above treatment.

apples at 1.7% H_2O was significantly less than browning in peaches at 5.2% H_2O (compare 6 month color values from Tables 11 and 22). Nonenzymatic browning is independent of oxygen content (Legault et al., 1951).

In addition to adverse color, the Maillard reaction (nonenzymatic browning) is one of the major causes of the degeneration of flavor in dehydrated products. In dehydrated potatoes this reaction results in the formation of 2-methylpropanal and 2- and 3-methylbutanal, the Strecker degradation aldehydes, as well as many other volatile compounds (Sullivan et al., 1974). In all products in this study except carrots where there was a significant temperature effect on color there was an accompanying temperature effect on flavor.

The effect of atmosphere on color was due to oxidative bleaching of pigments. This effect was positive in macaroni but negative in carrots. Products which showed an atmosphere effect on flavor were generally high in fat and oxygen increased rancidity. Rancidity was accelerated at higher temperatures. Not all fat containing products demonstrated rancidity nor was the rate the same in those which did. Antioxidants, naturally present or added decrease rancidity.

In a few products water reabsorption was adversely affected by high temperature storage. There was no atmosphere effect on texture.

SUMMARY

Twenty low-moisture (1-10% H_2O) products: apples, bananas, green beans, navy beans, butter product, carrots, egg mix, nonfat-dry milk, oatmeal, peaches, peanut butter powder, potatoes granules, salad blend, macaroni, stroganoff-style casserole, tomato crystals, vegetable noodle soup, TVP, whole wheat and Baker's yeast were sealed in metal containers with nitrogen or air and stored for three years at 40, 70 and 100°F. They were evaluated for consumer acceptability and nutritional content at 6 month intervals.

All products stored at 40 or 70°F were acceptable to consumers (receiving an overalll taste panel score greater than 40) at 36 months. Seven products stored at 100°F: bananas, macaroni, navy beans, oatmeal, peanut butter, TVP and wheat were acceptable at 36 months. Apples stored at 100°F were acceptable until 24 months. The other products stored at 100°F were not acceptable after 6 months.

In many products, nonenzymatic browning was responsible for the poor color and flavor which developed during storage. Nonenzymatic browning was accelerated at high temperatures but not affected by oxygen content. Oxidation caused fading of pigments and development of rancid off-flavors. Oxidative reactions were accelerated by increased temperature and oxygen. Texture was adversely affected by high temperature but not interior can atmosphere.

Nutrients retained in the products up to 6 months were relatively stable in storage thereafter. Effects of temperature and atmosphere were generally seen at 6 months and continued throughout the study.

Temperature adversely affected the retention of all three nutrients; beta-carotene, thiamin and ascorbic acid. Thiamin was quite stable at 40 and 70°F but destroyed rapidly at 100°F. Its chief pathway of destruction was believed to have been nonenzymatic browning.

The effect of atmosphere was greatest in the degradation of beta-carotene. Nitrogen-packed samples contained significantly more beta-carotene in all six products tested.

At low pH (< 4.2) ascorbic acid degradation seemed to be independent of oxygen concentration. Oxygen had little or no effect in apples, tomatoes and peaches. The effect of oxygen was significantly greater in green beans, salad blend, bananas (pH 5.9) and carrots.

Increased oxygen adversely affected thiamin retention in most products stored at 40 and 70°F but not at 100°F. Nonenzymatic browning which was common at 100^{o}F was independent of oxygen concentration.

Nutrient retention and consumer acceptability of dehydrated products was retained best in products that were nitrogen-packed and stored at 40^{o}F.

REFERENCES

AOAC. 1980. "Official Methods of Analysis," 12 ed. Association of Official Analytical Chemists, Washington, DC.

Ayra, S.S., Natesan, V., Parihar, D.B. and Vijayaraghavan, P.K. 1979a. Stability of carotenoids in dehydrated carrots. J. Food Technol. 14: 579.

Ayra, S.S., Natesan, V., Parihar, D.B. and Vijayaraghavan, P.K. 1979b. Stability of beta-carotene in isolated systems. J. Food Technol. 14: 571.

Bishov, S.J., Henick, A.S., Giffee, J.W., Nii, I.T., Prell, P.A., and Wolf, M. 1971. Quality and stability of some freeze-dried foods in "zero" oxygen headspace. J. Food Sci. 36: 532.

Boskovic, M.A. 1979. Fate of lycopene in dehydrated tomato products: carotenoid isomerization in food system. J. Food Sci. 44: 84.

Forenstein, B. 1975. Stability of nutrients in foods. In "Nutritional Evaluation of Food Processing," (Ed.) R.S. Harris and E. Karmas. 2nd ed, p. 16. AVI Publishing Co., Westport, CT.

Brekke, J.E. and Allen, L. 1967. Dehydrated bananas. Food Technol. 21: 101.

Chou, H. and Breene, W.M. 1972. Oxidative decoloration of beta-carotene in low-moisture model systems. J. Food Sci. 37: 66.

Christensen, C.M. 1983. Effects of color on aroma, flavor and texture judgments of foods. J. Food Sci. 48: 787.

Dennison, D.B. and Kirk, J.R. 1978. Oxygen effect on the degradation of ascorbic acid in a dehydrated food system. J. Food Sci. 43: 609.

Dennison, D., Kirk, J., Bach, J., Kokoczka, P. and Heldman, D. 1977. Storage stability of thiamin and riboflavin in a dehydrated food system. J. Food Proc. and Preserv. 1: 43.

Draudt, H.N. and Huang, I. 1966. Effect of moisture content of freeze-dried peaches and bananas on changes during storage related to oxidative and carbonyl-amine browning. J. Agr. Food Chem. 14: 170.

Dwivedi, B.K. and Arnold, R.G. 1973. Chemistry of thiamine degradation in food products and model systems: a review. J. Agr. Food Chem. 21: 54.

Eison-Perchonok, M.H. and Downes, T.W. 1982. Kinetics of ascorbic acid autoxidation as a function of dissolved oxygen concentration and temperature. J. Food Sci. 47: 765.

Falconer, M.E., Fishwick, M.J., Land, D.G. and Sayer, E.R. 1964. Carotene oxidation and off-flavour development in dehydrated carrot. J. Sci. Food Agric. 15: 897.

Fevold, H.L., Edwards, B.G., Dimick, A.L. and Boggs, M.M. 1946. Sources of off-flavors developed during storage; dehydrated egg powders. Ind. Eng. Chem. 38: 1079.

Goldman, M., Horev, B. and Saguy, I. 1983. Decolorization of beta-carotene in model systems simulating dehydrated foods. Mechanism and kinetic principles. J. Food Sci. 48: 751.

Gooding, E.G.B. and Duckworth, R.B. 1957. An accelerated storage test for dehydrated vegetables. J. Sci. Food Agric. 8: 498.

Haralampu, S.G. and Karel, M. 1983. Kinetic models for moisture dependence of ascorbic acid and beta-carotene degradation in dehydrated sweet potato. J Food Sci. 48: 1872.

Heberlein, D.G. and Clifcorn, L.E. 1944. Vitamin content of dehydrated foods effect of packaging and storage. Ind. Eng. Chem. 36: 912.

Kamman, J.F., Labuza, T.P. and Warthesen, J.J. 1981. Kinetics of thiamin and riboflavin loss in pasta as a function of constant and variable storage conditions. J. Food Sci. 46: 1457.

Karel, M. and Nickerson, J.T.R. 1964. Effects of relative humidity, air, and vacuum on browning of dehydrated orange juice. Food Technol. 18: 1214.

Kirk, J.R. 1981. Influence of water activity of stability of vitamins in dehydrated foods. In "Water Activity: Influences on Food Quality," (Ed.) L.B. Rockland and G.F. Stewart. Academic Press Inc., New York.

Kirk, J., Dennison, P., Kokoczka, P. and Heldman, D. 1977. Degradation of ascorbic acid in a dehydrated food system. J. Food Sci. 42: 1274.

Kramer, A. 1977. Effect of storage on nutritive value of food. J. Food Quality. 1: 23.

Labuza, T.P. and Riboh, D. 1982. Theory and application of Arrhenius kinetics to the prediction of nutrient losses in foods. Food Technol. 36(10): 66.

Labuza, T.P. and Tannenbaum, S.R. 1972. Nutrient losses during drying and storage of dehydrated foods. CRC Food Technol. 3(2): 217.

Lee, Y.C., Kirk, J.R., Bedford, C.L. and Heldman, D.R. 1977. Kinetics and computer simulation of ascorbic acid stability of tomato juice as functions of temperature, pH and metal catalyst. J. Food Sci. 42: 640.

Legault, R.R., Hendel, C.E., Talburt, W.F. and Pool, M.F. 1951. Browning of dehydrated sulfited vegetables during storage. Food Technol. 5: 417.

Lovric, T., Sablek, Z. and Boskovic, M. 1970. Cis-trans isomerisation and colour stability of foam-mat dried tomato powder during storage. J. Sci. Food Agric. 21: 641.

MacBride, D.E. and Wyatt, C.J. 1983. Evaluation of a modified AOAC determination for thiamin and riboflavin in foods. 1983. J. Food Sci. 48: 748.

Mallette, M.F. and Dawson, C.R. 1946. Commercially dehydrated vegetables: oxidative enzymes, vitamin content, and other factors. Ind. Eng. Chem. 38: 437.

Mizrahi, S., Labuza, T.P. and Karel, M. 1970. Feasibility of accelerated tests for browning in dehydrated cabbage. J. Food Sci. 35: 804.

Morgan, A.F., Mackinney, G. and Cailleau, R. 1945. Losses of ascorbic acid and four B vitamins in vegetables as a result of dehydration, storage, and cooking. Food Research 10: 5.

Ramakrishnan, T.V. and Francis, F.J. 1979. Stability of carotenoids in model aqueous systems. J. Food Qual. 2: 177.

Resnik, S. and Chirife, J. 1979. Effect of moisture content and temperature on some aspects of nonenzymatic browning in dehydrated apples. J. Food Sci. 44: 601.

Rettenmaier, R., Vuilleumier, J.P. and Mueller-Mulot, W. 1979. Assay of vitamin B-1 in food and biological material. Zeitschrift fur Lebensmittel - Untersuchung und - Forschung. 168(2): 120.

Rice, E.E., Beuk, J.F., Kauffman, F.L., Schultz, H.W. and Robinson, H.E. 1944. Preliminary studies on stabilization of thiamin in dehydrated foods. Food Research. 9: 491.

Riemer, J. and Karel, M. 1978a. Shelf-life studies of vitamin C during food storage: prediction of L-ascorbic acid retention in dehydrated tomato juice. J. Food Proc. Preserv. 1: 293.

Riemer. J. and Karel, M. 1978b. On the anaerobic degradation of ascorbic acid in dehydrated tomato juice. J. Agric. Food Chem. 26: 350.

Roe, J.H. and Kuether, C.A. 1943. The determination of ascorbic acid in whole blood and urine through the 2,4-dinitrophenylhydrazine derivative of dehydroascorbic acid. J. Biol. Chem. 147: 399.

Saguy, I., Goldman, M. and Karel, M. 1985. Prediction of beta-carotene decolorization in model system under static and dynamic conditions of reduced oxygen environment. J. Food Sci. 50: 526.

Salunkhe, D.K., Wu, M.T. and Do, J.Y. 1979. Effects of long-term storage of foods on quality of processed foods II. Freeze-dehydrated ration items in vacuum-packed flexible pouches. J. Food Qual. 2: 157.

Scott, D.T., Carter, M.W. and Bryce, G.R. 1984. Rummage II. Brigham Young University Statistics Department. Provo, Ut.

Stephens, T.S. and McLemore, T.A. 1969. Preparation and storage of dehydrated carrot flakes. Food Technol. 23: 104.

Sullivan, J.F., Konstance, R.P., Calhoun, M.J., Talley, F.B., Cording, J. and Panasiuk, O. 1974. Flavor and storage stability of explosion-puffed potatoes: nonenzymatic browning. J. Food Sci. 39: 58.

Teixeira Neto, R.O., Karel, M., Saguy, I. and Mizrahi, S. 1981. Oxygen uptake and beta-carotene decoloration in a dehydrated food model. J. Food Sci. 46: 665.

Tressler, D.K., Moyer, J.C. and Wheeler, K.A. 1943. Losses of vitamins which may occur during the storage of dehydrated vegetables. Am. J. Pub. Health. 33: 975.

Tuomy, J.M. and Walker, G.C. 1970. Effect of storage time, moisture level and headspace oxygen on the quality of dehydrated egg mix. Food Technol. 24: 1287.

Villota, R., Saguy, I. and Karel, M. 1980a. Storage stability of dehydrated food evaluation of literature data. J. Food Qual. 3: 123.

Villota, R, Saguy, I. and Karel, M. 1980b. An equation correlating shelf life of dehydrated vegetable products with storage conditions. J. Food Sci. 45: 398.

Walter, W.M., Purcell, A.E. and Cobb W.Y. 1970. Fragmentation of beta-carotene in autoxidizing dehydrated sweet potato flakes, J. Agr. Food Chem. 18: 881.

Watt, B.K. and Merrill, A.L. 1963. "Composition of Foods," Agriculture Handbook No. 8. ARS, USDA; USGPO.

Wong, F.F., Dietrich, W.C., Harris, J.G. and Lindquist, F.E. 1956. Effect of temperature and moisture on storage stability of vacuum-dried tomato juice powder. Food Technol. 10: 96.

Wuhrmann, J.J., Simone, M. and Chichester, C.O. 1959. The storage stability of freeze-dried soup mixes. Food Technol. 13: 36.

Appendix A

Beta-carotene - Analytical Method

Apparatus

a) Chromatographic tube - 12.5 mm id x 30 cm reduced to 10 mm od tube at bottom, pyrex.

b) Vacuum filtration device - for collection of eluate.

c) Spectrophotometer - Bausch and Lomb Spectronic 20.

Reagents

a) Acetone - reagent grade, BYU chem stores; various chem supply sources.

b) Hexane - reagent grade, BYU chem stores.

c) Extractant - Acetone-hexane (1:1).

d) Filter aid - Celite 545, JT Baker.

e) Potassium hydroxide solution - saturated reagent KOH pellets, (BYU chem stores), in methanol.

f) Magnesium oxide - Heavy powder, lab grade, Fisher.

g) Elutant - Acetone-hexane (1:19).

h) Absorbent - MgO-filter aid (1:1) heated overnight in drying oven 260^{o}F.

i) Sodium sulfate - Anhydrous granular reagent, BYU chem stores.

Extraction

Rehydrate 2-5g (weighed to the nearest mg) dry sample in 100 ml H_2O for 30-60 minutes. Add 140 ml methanol and 4 grams filter aid, stir and let set 5-10 minutes. Filter with suction through a filter aid mat (0.5 cm thick) until dry enough to be powdered. Discard the filtrate. Scrape off sample layer and combine with 100 ml extractant, stir and let set 10-20 minutes. Again filter with suction through a filter aid mat; wash the beaker with 50 ml extractant. This time save the filtrate. Extract the sample a second time and combine filtrate with that from first extraction in a 500-ml separatory funnel. Wash filter flask with 50 ml extractant and add to the separatory funnel. Add 50 ml H_2O to the separatory funnel and gently swirl. Drain the hypophase and discard. Wash extract with three 100-ml portions of H_2O. Add 20 ml KOH-saturated methanol to the funnel. Shake for 2 minutes; let stand for 5 minutes. Drain and discard the hypophase and wash three times with 100 ml portions of H_2O. Transfer the washed filtrate to a 250 ml beaker and dry with 20 grams anhydrous Na_2SO_4.

Separation of pigment

To prepare column, place a small glass wool plug inside the chromatographic tube and fill with hexane. Attach to suction apparatus and gradually add adsorbent until column is about 19 cm in length. Top off with 5 grams anhydrous Na_2SO_4.

With vacuum continuously applied to flask, add sample to top of column. Allow the filtrate to collect on the column. Wash column with elutant, collecting the beta-carotene band. Transfer to a 100 ml volumetric flask and make to volume with elutant.

Determination

Read the absorbance at 450 nm. Calculate carotene

$$(A \times V)/(0.25 \times W) = \text{mg carotene/g sample}$$

where A = absorbance at 450 nm; V = volume, liters; W = sample weight, grams; 0.25 is a factor for the extinction coefficient of beta-carotene $E^{1\%}_{cm} = 2500$.

Appendix B

Vitamin A - Analytical Method

Reagents and apparatus

a) Methanolic KOH - add 20 g of reagent KOH pellets, (BYU chem stores), to 100 ml of reagent methanol. Stir carefully and periodically, do not cause overheating. Allow to set overnight.

b) Ethyl ether - reagent grade, BYU chem stores.

c) Chloroform, $CHCl_3$ - reagent grade, BYU chem stores.

d) Sodium sulfate - reagent, anhydrous, BYU chem stores.

e) Acetic anhydride, $(CH_3CO)_2O$ - reagent grade, BYU chem stores.

f) Carr/Price reagent - add 100 g dry practical grade antimony chloride crystals, (BYU chem stores), to 500 ml $CHCl_3$. Warm, stir to obtain complete solution. Cool and add 15 ml $(CH_3CO)_2O$. Filter with caution. Keep in a dark bottle.

f) Vitamin A reference solution - USP reference standard solution containing all-*trans* retinyl acetate in cottonseed oil.

g) Spectrophotometer - Bausch and Lomb Spectronic 20.

Procedure

a) Add 50 ml methanolic KOH to 1 g (weighed to the nearest mg) sample in a 250 ml round bottom flask. Swirl to disperse homogeneously.

b) Reflux 10 minutes at 110°C.

c) Cool under cold tap water and pour into a 500 ml separatory funnel. Wash the flask with two 50 ml portions ethyl ether which are added to the funnel. Then rinse flask with two 50 ml portions of H_2O which are also added to the funnel.

d) Agitate the funnel gently, releasing pressure.

e) Discard the hypophase; then wash with two 50 ml portions of H_2O. Discard the aqueous phase each time.

f) Transfer the ether phase to a beaker and add 20 grams of anhydrous Na_2SO_4 (to remove moisture). Swirl and allow to stand for 1-2 minutes.

g) Transfer the ether solution to a 250 ml round bottom flask. Rinse the Na_2SO_4 in the beaker with two consecutive 15 ml portions of ethyl ether which are poured into the flask.

h) Evaporate the ether to dryness at a moderate rate in a heating mantle with N_2 gas gently blowing into the flask; cool.

i) Add 2 ml $CHCl_3$ and swirl to completely dissolve the residue in the flask.

j) Prepare a blank using 1 ml $CHCl_3$ and 5 ml Carr/Price reagent. Zero the Spectronic 20 at 620 nm.

k) Place 1 ml sample $CHCl_3$ solution into cuvette with 5 ml Carr/Price reagent. Shake briefly and immediately read (within 30 seconds of adding the reagent) at 620 nm.

l) Prepare standard curve using several known dilutions of vitamin A standard solution. Dilute with $CHCL_3$.

Appendix C

Thiamin - Analytical Method

Reagents and apparatus

a) 2.5 normal sodium acetate - dissolve 205 g reagent NaOAc anhydrous powder, (BYU chem stores), in enough H_2O to make 1 liter.

b) Ethanol 25% - dilute 250 ml absolute EtOH, (BYU chem stores), to one liter with distilled water. Used to make thiamin stock solutions.

c) Hydrochloric acid 1.0 normal - dilute 85 ml of concentrated reagent HCl, (BYU chem stores), to 1 liter with H_2O.

d) Hydrochloric acid 0.1 normal - dilute 100 ml of 1.0 N HCl to 1 liter with H_2O.

e) Buffer - mix together 450 ml 0.1 N HCl, 30 ml 2.5 N NaOAc and 120 ml H_2O. Used to make thiamin working solution.

f) Acid potassium chloride solution - dissolve 250 g reagent KCl crystals, (BYU chem stores), in 800 ml of distilled water. Add 100 ml of 1.0 N HCl and make to 1 liter volume.

g) Potassium ferricyanide solution, 1% - dissolve 1 g $K_3Fe(CN)_6$ reagent crystals, (BYU chem stores), in H_2O to make 100 ml. Refrigerate in brown bottle until use.

h) Sodium hydroxide solution, 15% - dissolve 150 g of reagent NaOH pellets, (BYU chem stores), in refrigerated H_2O to make 1 liter.

i) Thiamin stock solution, 100 mcg/ml - Accurately weigh 100 mg USP thiamin hydrochloride reference standard, (Sigma Chem.) that has been dried to constant weight over P_2O_5 in desiccator. Dissolve in 1 liter 25% ethanol.

j) Thiamin intermediate solution, 5 mcg/ml - dilute 5 ml of stock solution to 100 ml with H_2O.

k) Thiamin working solution, 0.2 mcg/ml - dilute 8 ml intermediate solution to 200 ml with buffer.

l) Isopropanol, redistilled - reagent grade isopropanol, (BYU chem stores) is added to 100 ml 40% KOH in H_2O. Reflux 2-3 hours then distill at rate of 2-3 drops per second in all-glass apparatus.

m) Sodium sulfate, reagent, anhydrous, fine granular, (BYU chem stores), - should be kept in tightly closed container.

n) Alkaline potassium ferricyanide solution - dilute 3 ml 1% $K_3Fe(CN)_6$ to 100 ml volume with 15% NaOH. Make fresh daily.

o) Enzyme solution - Dissolve 0.3 g Mylase 100 (US Biochem. Corp. #19299) in 50 ml 2.5 N NaOAc. Prepare daily.

p) Resin - Mix Amberlite CG-50 100-200 mesh (Sigma Chem.) with H_2O. Let settle and decant the cloudy supernatant. Repeat H_2O washing until clear (2-3 times).

q) Chromatographic columns - pour CG-50 slurry to a settled height of 5 cm into a 12.5 x 300 mm column containing a glass wool plug. Drain the excess water to the top of the resin but do not allow resin to dry out.

r) Fluorometer - Turner Fluorometer model III.

s) Centrifuge - Adams Physicians Compact Centrifuge.

Extraction

Add 50 ml 0.1 N HCl to 2-5 g (weighed to the nearest mg), sample and stir until evenly dispersed. Heat in boiling water bath for 30 minutes, stirring occasionally. Cool to below 50°C.

Add 10 ml enzyme solution, mix, and incubate 3 hours in water bath at 47°C. Suction filter while still warm through Whatman #42 filter paper. (Samples with high viscosity or gelatinous sediment which slow filtration may be centrifuged prior to filtration. Centrifuge for 20 minutes at 2000-2500 rpm. Decant the supernatant through the filter, wash the centrifuge pellet with 10 ml H_2O. Centrifuge again for 10-15 minutes, filter the supernatant. Repeat again, then filter supernatant and also the pellet. Wash well with H_2O). Pour filtrate into 100 ml volumetric flask and make to volume with H_2O. Mix thoroughly.

Purification

Pass 25 ml of filtered solution thru prepared chromatographic column. Wash with three 10-ml portions of almost boiling H_2O. Do not permit surface of liquid to fall below surface of resin.

Elute the thiamin by passing two 10-ml portions of near boiling acid KCl solution thru column. Do not permit surface of liquid to fall below surface of resin until final portion of acid-KCl solution has been added. Collect eluate in 25 ml volumetric flask. Cool and dilute to volume with acid-KCl solution.

Oxidation of thiamin to thiochrome

Place 2 ml sample solution into each of two 12-ml ground glass stopper centrifuge tubes. Add 1.5 ml alkaline $K_3Fe(CN)_6$ solution to one tube and 1.5 ml 15% NaOH solution to the remaining tube (sample blank). Shake tubes for 10 seconds. Add 7.5 ml isopropanol to both tubes and shake 20 seconds. Centrifuge at 2500-3000 rpm until clear supernate can be obtained (5 minutes). Suction off aqueous (lower) phase. Add 3 g anhydrous Na_2SO_4 and shake for 20 seconds. Centrifuge an additional 2 minutes. Pour into cuvette for fluorescence measurement. Measure fluorescence of both sample and blank solutions. Make several dilutions of thiamin working solution and oxidize by same treatment as sample. Calculate thiamin concentration from standard curve.

Appendix D

Ascorbic Acid - Analytical Method

Reagents and apparatus

a) 9 N Sulfuric acid - cautiously add 250 ml of reagent concentrated H_2SO_4, (BYU chem stores), to 700 ml H_2O; cool and dilute to 1 liter with H_2O.

b) 2% 2,4-Dinitrophenylhydrazine, (DNPH) - dissolve 2 g 2,4-DNPH, J.T. Baker ('Baker'™ Grade) in 100 ml of 9 N H_2SO_4 and filter. Keep refrigerated when not in use; make new each week.

c) 10% Metaphosphoric acid - dissolve 100 g of reagent grade HPO_3 pellets, (BYU chem stores), in 900 ml H_2O and dilute to 1 liter with H_2O.

d) 5% Metaphosphoric acid - dilute 500 ml 10% HPO_3 to 1 liter with H_2O.

e) 1% Thiourea solution - dissolve 5 g reagent thiourea crystals, (BYU chem stores), in 500 ml 5% HPO_3.

f) 2% Thiourea solution - dissolve 10 g thiourea in 500 ml 5% HPO_3.

g) 85% Sulfuric acid - cautiously add 900 ml concentrated H_2SO_4 to 100 ml H_2O.

h) Ascorbic acid standard, 1 mg/ml - dissolve 100 mg L-ascorbic acid USP reference standard, (Sigma Chem.) in 90 ml 5% HPO_3 and 10 ml glacial acetic acid.

i) Activated charcoal - (Sigma Chemical C-4386) or equivalent.

j) Waring Blendor with microblender cup.

k) Spectrophotometer -Bausch and Lomb Spectronic 20.

Extraction

a) Rehydrate 2-5 g (weighed to the nearest mg) sample in 90 ml 5% HPO_3 and 10 ml glacial acetic acid; stir and let sit for 5-10 minutes.

b) Blend in Waring microblender cup at high speed for two minutes.

c) Vacuum filter first thru fast filter paper (Whatman #4) and then thru medium filter paper (Whatman #2).

Oxidation

a) Add 5 grams acid washed charcoal to the filtered sample; mix thoroughly. Vacuum filter thru Whatman #42 fine, ashless filter paper.

b) To a 10-ml aliquot of oxidized extract, add 10 ml 2% thiourea solution. Mix thoroughly yielding a diluted sample of 20 ml.

c) To a 5-ml aliquot of oxidized extract, add 10 ml 2% thiourea solution and 5 ml 5% HPO_3. Mix thoroughly, yielding a diluted sample of 20 ml.

Formation of osazone

a) Pipet 4-ml aliquots of each sample dilution into each of 2 matched colorimetric tubes.

b) Set one tube of each dilution aside to serve as a blank.

c) To the 2 remaining tubes add 1.0 ml 2% 2,4-DNPH.

d) Place all the tubes in a water bath at 37°C for exactly 3 hours.

e) At the end of 3 hours, remove the tubes from the water bath and place in a ice bath.

f) While the tubes are in the ice bath, add slowly, drop by drop, 5 ml 85% H_2SO_4. Mix completely, then allow to remain in the ice bath 1 minute.

g) Remove the tubes from the ice bath and allow to stand 30 minutes at room temperature.

h) Add 1 ml 2,4-DNPH to each of the blank tubes.

Measurement of color

a) Set spectrophotometer to 540 nm.

b) With blank in place, set the instrument to read 100 % transmittance.

c) Read and record the per cent absorbance for the samples.

Standards

a) Suction filter standard AA solution (1 mg/ml) first thru fast filter paper (Whatman #4) and then thru medium filter paper (Whatman #2).

b) Oxidize standard AA solution by mixing with 5 grams charcoal and then suction filter with fine ashless paper (Whatman #42).

c) Pipet 10 ml oxidized solution into a 500-ml volumetric flask. Add 5.0 g thiourea. Dilute to volume with 5% HPO_3.

d) Prepare final diluted dehydroascorbic acid solutions containing 1, 2, 4, 5, 8, 10, and 12 mcg per ml by pipeting 4, 10, 20, 25, 40, 50, and 60 ml of the diluted solution into seven 100-ml volumetric flasks and diluting each to the mark with 1% thiourea in 5% HPO_3.

e) Treat each of the seven standard AA solutions in the same manner as samples starting from formation of the osazone.

f) Prepare a standard curve by plotting absorbance vs AA concentration.

Calculations

a) Calculate the total AA content of each aliquot according to the formula:

$$\frac{(R)\ (0.1)}{W} = \text{mg total AA per 100 g sample}$$

where

R = mcg total AA per ml diluted sample obtained from standard curve.

W = weight of sample in grams in one ml of diluted sample.

0.1 = factor to convert mcg/g to mg/100 g.

Appendix E

Sample Preparation

Apple slices - Place 3 cups of hot water, (160-180°F) in a suitable container. Stir in 4 oz., (approximately 2 cups) Low Moisture Apple Slices. Allow apple slices to stand with hot water for 30 minutes. Stir occasionally. Serve at room temperature.

Banana slices - Serve as is from the can. Serve at room temperature.

Green beans - Combine 1 cup Low Moisture Green Beans with 3 cups boiling water. Bring to a boil, cover and simmer for 30 minutes. (Add more water, if necessary). Drain. Serve warm.

Small white beans - Soak 1 cup Small White Beans overnight in 4 cups cool water. Add 1/2 teaspoon salt and boil until tender or 2 hours. Drain. Serve warm.

Butter product - Measure 1 cup Butter Product into suitable container. Slowly add 3 tablespoons water while mixing constantly. Mix until smooth. Chill before serving. Serve chilled butter on small slices, (about 0.25 oz) crustless white bread.

Carrots - Combine 1 cup Low Moisture Diced Carrots with 2 1/2 cups water. Bring to a boil, cover and simmer 15 minutes or until tender. Drain. Serve warm.

Egg mix - Blend 14 tablespoons Dried Egg Mix with 1 1/3 cup water in blender until smooth. Pour into greased skillet, stir and cook over low heat. Serve warm.

Nonfat-dry milk - Blend 1/2 can, (7.5 oz) Low Moisture Regular Nonfat Milk with 3 quarts of cold water in blender until well mixed. Refrigerate. Serve cold.

Rolled oats - Combine 2 cups boiling water with 1 cup Instant Rolled Oats and 1/4 teaspoon salt while stirring constantly. Reduce heat and simmer 1 minute. Stir occasionally. Serve warm; milk optional.

Peach slices - Combine 1 cup Low Moisture Peach Slices with 3 cups cold water and 1/4 cup sugar. Mix thoroughly and bring to a boil. Cover and simmer 10 minutes. Serve room temperature.

Peanut butter powder - Stir 1 teaspoon vegetable oil into 5 teaspoons Peanut Butter Powder. Add a dash of salt. Serve at room temperature on small slices, (about 0.25 oz) crustless white bread.

Potato granules - Combine 1 1/2 cups water, 1/2 cup milk, 1/2 teaspoon salt, 1 tablespoon butter. Heat to a boil. Remove from heat and mix in 1/2 cup of Potato Granules. Beat until fluffy. Serve warm.

Salad blend - Place 1/3 of can of Salad Blend, (2 oz) into a bowl. Stir in 2 cups of cold water. Soak for 2 hours or longer in refrigerator. Serve cold.

Elbow spaghetti - Add 1 teaspoon salt and 3/4 cup, (3 oz) Elbow Spaghetti to 4 cups rapidly boiling water. Boil 10 minutes. Drain. Serve warm.

Stroganoff-style casserole - Place 1 can, (10 oz) Low Moisture Stroganoff-style Casserole into a large pan. Add 5 cups of boiling hot water. Bring to a boil while stirring constantly. Cover and simmer 15 minutes. Stir occasionally to keep food from sticking to the pan. Remove from heat, leave lid on pan and allow to stand at least 10 minutes. Serve warm.

Tomato crystals - Combine 1/2 cup Tomato Crystals with 1/2 cup water. Stir into paste over low heat. Serve at room temperature.

Vegetable noodle soup mix - Combine the contents of 1 can, (9 oz) Low Moisture Vegetable Noodle Soup Mix with one gallon of water.

Bring to a boil, cover, and simmer for at least 14 minutes. Serve warm.

Textured vegetable protein - Combine Textured Vegetable Protein with an equal volume of water. Soak for 15 minutes. Heat. Serve warm.

Whole Wheat - Coarsely grind wheat. Add 1/2 cup cracked wheat and 1/2 teaspoon salt to 1 1/2 cups rapidly boiling water. Cover and simmer 8-10 minutes. Serve warm, milk optional.

Appendix F

Taste Panel Evaluation

Product ______________________ Number*__________

QUESTIONNAIRE

Please mark on the scales below your own personal preference after you examine this food. Any comments you may have relative to good or undesireable qualities of this food will be appreciated.

Code No. ______
APPEARANCE:
Very Poor ______________|______________ Very Good
FLAVOR:
Very Poor ______________|______________ Very Good
TEXTURE:
Very Poor ______________|______________ Very Good
OVERALL:
Very Poor ______________|______________ Very Good
Comments, if any ______________________________

Code No. ______
APPEARANCE:
Very Poor ______________|______________ Very Good
FLAVOR:
Very Poor ______________|______________ Very Good
TEXTURE:
Very Poor ______________|______________ Very Good
OVERALL:
Very Poor ______________|______________ Very Good
Comments, if any ______________________________

Code No. ______
APPEARANCE:
Very Poor ______________|______________ Very Good
FLAVOR:
Very Poor ______________|______________ Very Good
TEXTURE:
Very Poor ______________|______________ Very Good
OVERALL:
Very Poor ______________|______________ Very Good
Comments, if any ______________________________

Code No. ______
APPEARANCE:
Very Poor ______________|______________ Very Good
FLAVOR:
Very Poor ______________|______________ Very Good
TEXTURE:
Very Poor ______________|______________ Very Good
OVERALL:
Very Poor ______________|______________ Very Good
Comments, if any ______________________________

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*Don't forget to put your number on this form.

Appendix G

Yeast Activity

Procedure: Mixtures of 1 tablespoon yeast sample (rehydrated in 300 ml distilled water), 2 tablespoons sugar and 1 tablespoon flour were poured into calibrated fermentation tubes which were partially immersed in warm (30-35^{o} C) water. The volume of the gas evolved in four minutes was measured. Results are listed in the table below.

Time	40^{o} F N_2 yes	40^{o} F N_2 no	70^{o} F N_2 yes	70^{o} F N_2 no	100^{o} F N_2 yes	100^{o} F N_2 no
6 months	5.0 ml	5.0 ml	2.0 ml	2.0 ml	0.3 ml	0.2 ml
12 months*	3.0 ml	1.8 ml	2.1 ml	0.9 ml	trace	trace
18 months*	0.6 ml	0.6 ml	trace	0.2 ml	trace	trace
24 months	2.5 ml	1.5 ml	1.6 ml	0.7 ml	trace	trace
30 months	2.0 ml	1.2 ml	0.3 ml	0.2 ml	trace	none
36 months	3.1 ml	2.8 ml	0.8 ml	0.3 ml	trace	trace

* these samples remained opened a couple of months prior to analysis.

STORAGE OF LOW-MOISTURE FOODS: EFFECT OF STORAGE

TEMPERATURE, TIME AND OXYGEN LEVEL ON

CONSUMER ACCEPTABILITY AND NUTRIENT CONTENT

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M.S. Degree, April 1986

ABSTRACT

Twenty low-moisture products: apple slices, banana slices, green beans, small white (navy) beans, butter product, carrots, egg mix nonfat-dry milk, rolled oats, peach slices, peanut butter powder, potato granules, salad blend, elbow spaghetti (macaroni), stroganoff-style casserole, tomato crystals, vegetable noodle soup, texturized vegetable protein (TVP), whole wheat and baker's yeast were studied to determine the effects of storage time, temperature and oxygen concentration on quality retention. Samples were sealed in metal cans, with air or nitrogen (18-21% or less than 2% respectively), and stored at 40, 70 and 100^{O}F for up to three years. At 6 month intervals, evaluations included 1) subjective observation of clumping and odor, 2) taste panels for acceptability, 3) moisture and oxygen determinations and 4) nutrient analysis of <u>beta</u>-carotene, ascorbic acid and/or thiamin when levels were sufficient.

All products stored at 40 or 70^{O}F were acceptable at 36 months. Seven products: bananas, navy beans, oatmeal, peanut butter, macaroni, TVP and wheat were acceptable at 36 months storage at 100^{O}F. Storage temperature, time and available oxygen significantly affected the deterioration of ascorbic acid, thiamin and <u>beta</u>-carotene in low-moisture foods. Organoleptic and nutrient quality were retained best in nitrogen-packed products stored at 40^{O}F.

COMMITTEE APPROVAL:

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