# Nutrient Retention and Sensory Quality in Low-Moisture Foods Stored 42 to 60 months: Effect of Storage Temperature, Time and Oxygen Level.

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# INTRODUCTION AND LITERATURE REVIEW

The promotion and use of low-moisture foods has greatly increased in the past decade for such applications as dehydrated soups and soup mixes, baby foods, dry cereals and snacks (e.g. trail mixes) and may be a good way of utilizing more vegetables and fruits. The loss of nutritional quality and palatability in these foods is often the limiting factor in their shelf life. An accurate model for the prediction of quality loss during storage of low-moisture foods is necessary for the processor to make accurate label claims.

Factors which generally contribute to loss of nutritional and sensory quality of low-moisture foods include oxygen, moisture content or water activity ($a_w$), in situ reactivity, temperature and time of storage, and exposure to light. It is necessary to control these factors to provide optimal retention of vitamins, color, flavor, and texture in low moisture foods.

## Nutrient Stability

The deterioration of nutrients in food during storage not only indicates nutritional loss but also flavor, color and textural deterioration as well. Any of these factors can limit the shelf life of a low-moisture or dehydrated food product.

Villota et al. (1980) reported that the storage stability of a product usually has an inverse relationship with the storage temperature. Temperature affects the rate and kind of spoilage mechanism predominating in the food product.

The loss of nutrients during processing before the food product is packaged and stored often can lead to a major loss of nutrients. Tressler et al. (1943) reported in a study with dehydrated vegetables, that very little carotene is lost during dehydration but the loss was rapid at storage temperatures above -40°C. Storage under $CO_2$ seemed to prevent this rapid loss. Thiamin was found to be relatively stable in storage, but thiamin leaches out during hot water blanching.

Ascorbic acid significantly decreased during blanching and dehydration, but was retained fairly well during storage. Potatoes lost large amounts of ascorbic acid during blanching and dehydration. Cabbage retained a high level of ascorbic acid during dehydration and storage.

Nutrient loss and flavor changes in dehydrated foods are not due only to evaporation and leaching, but oxidation and non-enzymatic browning (NEB) contribute also. Draudt and Huang (1966) studied oxidative and carbonyl-amine browning in freeze dried bananas and peaches. The application of sulfur dioxide was found to greatly inhibit peroxidase activity, but not completely. In bananas, sulfur dioxide provided considerable protection to the ascorbic acid present. Bananas had a slow rate of browning when stored at low moisture levels. In peaches, ascorbic acid destruction was moisture dependent and was associated with NEB. Dehydroascorbic acid was reported to react with beta-amino acids to produce darkly colored complexes. Only peaches containing 8% or more moisture darkened after 100 and 242 days storage at 28° C. The peaches developed the dark color even with sulfur dioxide treatment at moisture levels of 8% or higher during long term storage. They concluded that the only effective way to lower the possibility of browning was a moisture level below 8% and treatment with sulfur dioxide.

Another important consideration for consumer acceptability of dehydrated food products is their ability to be rehydrated and produce a good texture. Dried vegetables have a dense structure with collapsed or shrunken interior capillaries which often cause the vegetable to not rehydrate well and thus have a poor texture. Most dried fruits become mushy when they are rehydrated. Villota et al. (1979) have found an improvement in texture of fruits (apples) by pretreatment with calcium chloride. Freeze drying is preferable for textural quality and ease of rehydration; however, the process is very costly, highly sensitive to oxidation and demands special packaging requirements.

## THIAMIN

The destruction of thiamin may be related to heat, pH, storage temperature, trace metals and the form of thiamin present in the food system. The destruction of thiamin is primarily a first order thermal reaction, not oxidative; this is predicted by the Arrhenius equation. Dwivedi and Arnold (1973) reported that the destruction of thiamin can occur by way of two reactions: (1) the breaking of the methylene bridge leaving pyrimidine and thiazole groups or (2) the breaking of the thiazole ring, producing hydrogen sulfide. The breakage of the thiazole ring requires less energy than cleavage of the methylene bridge. The loss of thiamin is rapid when heating is prolonged at temperatures above 27°C. They demonstrated that thiamin heated in neutral solution was easily cleaved at the methylene bridge to produce the pyrimidine ring and thiazole fragments. The major sulfur product, 4-methyl-5-(beta-hydroxyethyl) thiazole, is produced when thiamin is heated in an acidic solution, whereas hydrogen sulfide is the major product when heated in alkaline solutions.

Thiamin is more stable to heat when complexed in a food system in comparison with the free form. Thiamin destruction in a model system is more rapid in basic solutions. Watanbe (1944) reported that most acids (i.e. hydrochloric, citric, tartaric, oleic, malic) increase the stability of thiamin; however, acetic and boric acids are less effective.

When foods are pasteurized or sterilized, the retention of thiamin is favored by use of a high-temperature short-time process.

Thiamin loss during storage of ready-to-eat breakfast cereal appears to be negligible at a storage temperature of $\leq$ 37°C (Dennison et al., 1977). Cereal stored at 45°C had a significantly greater loss of thiamin at an $a_w$ of 0.24; NEB of the product was very pronounced at these conditions.

Thiamin reacts rapidly in Maillard-type reactions, which can be a major cause of losses in low-moisture foods during processing or storage at high temperatures. Thiamin hydrochloride will react with glucose at a $pH > 4$ to yield 2-glucothiamines. Von der Poil (1956) reported thiamin participation in NEB, as demonstrated by brown discoloring of pasta at 55° C. This browning is not observed at lower temperatures of storage for up to 1 year.

Farrer (1955) and Dwivedi and Arnold (1973) reported that sucrose, lactose, and glucose have a slightly accelerating effect on the destruction of thiamin at 110° C. However, fructose, mannitol, invertose and inositol have been shown to retard the destruction of thiamin.

Heavy metals influence the destruction of thiamin when they form complex ions with it. Copper ($Cu^{2+}$) ions in particular accelerate thiamin destruction. Mulley et al. (1975) reported that food contaminated with $Cu^{2+}$ often has alternate formation of thiamin-Cu complexes resulting in loss of thiamin value in the product. The addition of metal chelating agents, such as EDTA, ascorbic acid and sulfites, retard the decomposition of thiamin by copper. Thiamin itself, however, is sensitive to the preservative and possible chelator, sulfite. In a model system, Dwivedi and Arnold (1973) found thiamin was cleaved to the free thiazole base and a pyrimidyl-methane sulfurous acid in a (up to 0.1%) sodium sulfite solution at a pH of 5 to 6.

Thiamin occurs in three forms: free, as a pyrophosphate ester (cocarboxylase), or bound to protein (in milk and cheese). The cocarboxylase form is less stable than free thiamin, especially when exposed to heat. Thiamin bound to protein has a protective effect not completely understood. Atkin et al. (1943) reported a protective effect of gelatin, albumin, gums, dextrin and soluble starch on thiamin in various food model systems. McIntire and Frost (1944) demonstrated that alpha and beta amino acids can also decrease the rate of thiamin destruction in foods. Wada and Suzuki (1973) proposed that disulfide complexes of thiamin interchanged with the SH groups of protein on egg albumin. They found the SH groups of egg albumin protective on thiamin. Leichter and Joslyn (1969) reported a protective effect of casein and starch on thiamin but found casein does not combine with thiamin. He also reported soluble starch has a protective effect on thiamin. The absorption of thiamin to starch in foods is important in the retention of thiamin during heating and processing. It has also been proposed that starch protects the vitamin through an interfacial surface effect. Skim milk powder, wheat, soya flour, dehydrated vegetables and rolled oats have been shown to have a more stable form of thiamin. Wheat contains little protein-bound thiamin or cocarboxylase but it does contain a stable form of thiamin. Yeast, however, contains the phosphorylated form of thiamin which is less stable.

Thiamin retention is significantly improved when a moderate amount of cereal is present. For example, Rice et al. (1944) reported thiamin retention to be improved when a 33% cereal mixture was added to pork when dehydrated. Macromolecular compounds such as carbohydrates and proteins which are present in cereals and dried milk apparently have chemical or physical properties that allow them to prevent the detrimental action of water on thiamin. The loss of thiamin is increased by increasing moisture content, as with anhydrous pork, until a maximum effect is reached at 6%. The effect of moisture is not the sole cause of thiamin destruction but complete dehydration is one way of minimizing thiamin loss. Kamman et al. (1981) reported that loss of thiamin can be predicted by a linear model and that as $a_w$ increased the rate of thiamin destruction also increased. At 45° C, the half life of thiamin at 0.44 $a_w$ was 313 days in comparison to 111 days at 0.65 $a_w$. Thiamin loss was insignificant at temperatures below 30°C and 50% RH.

Klose et al. (1943) studied thiamin loss in spray-dried whole egg. At 32°C, 14% of the thiamin was lost in 3 months and 48% after 9 months. When the egg was stored at 37°C' thiamin losses were 25, 32, and 50% at 3, 6, and 9 months respectively. Olson (1948) reported that thiamin retention in spray dried whole egg after 20 and 57 weeks of storage at 37°C was inversely dependent with the moisture content in the egg.

Tressler et al.(1943) studied the destruction of thiamin in dehydrated vegetables: beets, cabbage, potatoes and rutabagas. The vegetables were stored under air or $CO_2$ at temperatures ranging from-4.4°C to 24°C in cellophane bags. They reported no loss of thiamin under these conditions in 3-4 months; however, 76% was lost in 3 months at 54.4°C.

Compounds produced from thiamin destruction can become an important contributor to food flavors, both positive and negative. For example, hydrogen sulfide, a major product from thiamin degradation, is associated with the flavor of several foods with a pronounced effect when heated. Dwivedi and Arnold (1973) demonstrated that thiamin is a relatively insignificant source of hydrogen sulfide in most food systems. Several volatile compounds have been isolated from the degradation of thiamin and identified in heated foods, such as 2-methyl furan which is present in coffee.

# ASCORBIC ACID

Ascorbic acid, a water soluble vitamin, is one of the most unstable nutrients present in foods. The ascorbic acid content of fresh vegetables decreases rather rapidly after harvesting, especially in leafy vegetables. The degradation of ascorbic acid in food systems is primarily an oxidative process, and is affected by $a_w$, metal catalysts, temperature, and non-enzymatic browning.

Platenius and Jones (1944) reported that reduction of oxygen in the storage atmosphere will slow the rate of ascorbic acid loss. They studied asparagus, broccoli, snap beans, kale, brussel sprouts, peas and spinach sealed in glass jars in the dark at 10°C and 21°C. The storage temperature had little effect on the destruction caused by oxygen content of the jars. Oxygen had a greater effect on ascorbic acid loss at lower temperatures than at higher ones. Storing peas in an atmosphere of $CO_2$ accelerated ascorbic acid losses by 19%.

Eison-Perchonok and Downes (1982) demonstrated that only the divalent ion of ascorbic acid absorbed oxygen at an alkaline pH; however, at pH 7 the monovalent ion was also involved. Oxygen absorption in an ascorbic acid solution is dependent upon temperature and the oxygen present (i.e. headspace $O_2$).

The solubility of oxygen decreases as the temperature increases to 100°C where the solubility approaches zero. Laing et al. (1978) demonstrated that the oxygen content in a model system may be a limiting factor as the temperature of the system approached 100°C. They reported a shift in the degradation of ascorbic acid from an oxidative to a non-oxidative reaction at these high temperatures. They concluded that the Arrhenius equation using linear regression can only be used on models that are stored at temperatures between 61-92°C.

Kirk et al. (1977) reported that the dissolved oxygen in a food system is a function of the $a_w$. Their system was a ready-to-eat cereal stored in 303 x 411 or thermal death time (TDT) 208 x 006 cans. The loss of ascorbic acid in TDT cans was shown to follow a first order reaction at 30°C. The stability of ascorbic acid was reported to decrease as the air and temperature of storage were increased. Cereal stored in 303 cans had an increased rate of ascorbic acid loss, thought due to the reacted oxygen being replaced by oxygen present in the cans. Dissolved oxygen was a function of $a_w$ in the system because as the moisture content was increased, the viscosity was reduced resulting in more mobility of the reactants, hydration of catalysts and swelling of solid matrices exposing new catalytic sites. They proposed that the destruction of ascorbic acid is an anaerobic process in low $a_w$ foods.

Lee and Labuza (1975) studied water activity as related to the stability of ascorbic acid in both desorption and adsorption in food systems. During desorption the system had a higher moisture content and a more rapid rate of oxidation of unsaturated lipids. There was an increased rate of ascorbic acid loss in a model system with a high $a_w$ during desorption. Water dilutes ascorbic acid causing an apparent greater loss; if the aqueous phase becomes less viscous by increased $a_w$ then the absorption of oxygen is enhanced.

Transition metals, especially copper and iron, have been demonstrated in numerous studies to have catalytic action in autoxidation of ascorbic acid. Dennison and Kirk (1982) reviewed the literature on this topic where several models have been proposed. One theory is that an ascorbate-metal oxygen complex is formed involving the transfer of a single electron to oxygen. Another theory is the formation of a metal-metal dinuclear ascorbate-oxygen intermediate involving a two electron transfer to oxygen. The stability of ascorbic acid in a system with an $a_w$ below 0.65 is not significantly affected by metal ions. This may be due to the need for complete hydration of the metal for its mobility. Therefore trace mineral fortification in a low moisture food will have little effect on the stability of ascorbic acid if the $a_w$ is below 0.65 in the capillary region.

An additional factor involved in ascorbic acid loss in a dehydrated food is non-enzymatic browning (NEB). The NEB reaction is due to amino-carbonyl and carbonyl-carbonyl interactions. NEB is a major deteriorative mechanism in dehydrated foods and is sensitive to changes in moisture. This reaction is generally controlled by regulating $a_w$ and by addition of sulfite to the food. The rate of NEB is accelerated by high storage temperatures and by a high moisture content. Legault et al. (1951) reported that the rate of browning of white potato is proportional to its reducing sugar content and the effect of temperature is approximately linear with the rate. Browning was shown to decrease markedly with reduction in moisture such that for every 2% increase in moisture, the rate of browning was increased two fold up to 9% in this study. The atmosphere in the package was shown to have little effect on the rate of browning. Sulfite in dehydrated vegetables retarded browning, but once the reaction is well underway sulfite had little effect on the rate. For every 18$^{o}$F increase in temperature the rate of browning increased 6-8 fold; this effect was even greater with a low moisture content (5% versus 9%).

Resnik and Chirife (1979) studied NEB in dehydrated apples. Since apples are a sugar-acid containing food, the browning mechanism is probably due to the degradation of the sugars to produce furfurals which condense with nitrogenous compounds, polymerize, and produce the brown resinous material. The presence of fructose and glucose in apples with organic acids, such as malic acid, produces a favorable condition for the development of 5-hydroxy-methyl-furfural (5-HMF) during thermal processing including air dehydration. Furfural and 5-HMF accumulation developed during the heat induced browning of apples and it followed a zero order of reaction.

Riemer and Karel (1978) reported that $a_w$ of freeze-dried tomato juice had a major effect on retention of ascorbic acid.

Heberlein and Clifcorn (1944) studied the retention of ascorbic acid in dehydrated foods packaged in metal cans under air or inert gas, or in paper cartons and stored at 21.1$^{o}$C, 36.7$^{o}$C, or 54$^{o}$C for one year. The protective effect of the inert gas on ascorbic acid retention was reduced significantly as the temperature increased.

## BETA-CAROTENE

*Beta*-carotene, a fat soluble vitamin, is in the class of carotenoids of the tetraterpene $C_{40}$ compounds, with a symmetrical skeleton built up of eight $C_5$ isoprene units including the ring structures at each end. Carotenoids are fat soluble and are generally extracted from tissues by use of nonpolar solvents like acetone, alcohols and petroleum ethers.

Isolated carotenoids can easily undergo cis-trans isomerization when in the presence of light, heat or acid and in some cases are also sensitive to alkali-catalyzed autoxidation. The conjugated double-bond structure of beta-carotene makes it especially susceptible to oxidative bleaching by oxygen and to thermal degradation. The chromophoric groups are gradually lost during the oxidation of beta-carotene, causing a change in color, mostly at the blue end of the visible spectrum. Cis isomers have a maximum absorption at a lower intensity and at shorter wavelengths than all-trans beta-carotene, due to the distortion of rotation near the cis bond.

Carotenoids are located exclusively in the chloroplast grana as chromoproteins in photosynthetic tissues. In non-photosynthetic tissues, like apricots and tomatoes, the carotenoids are usually located in the chromoplasts.

Beta-carotene is often used as an index of deterioration in storage studies. The maintenance of natural pigments in a food is important for the final product to be accepted by and attractive to the consumer. The stability of beta-carotene is dependent upon the presence and action of acids, alkali, catalysts, light, oxygen and $a_w$.

Stefanovich and Karel (1981) demonstrated that the rate of degradation of beta-carotene is dependent on the initial concentration and the thickness of the carotene layer, where oxygen diffusion would become a limiting factor.

Kalac and Kyzlink (1980) reported that thermostable lipoxygenases can form reactive radicals which destroy carotene in vegetables. These enzymes can be greatly reduced with blanching.

Stephens and McLemore (1969) studied dehydrated carrot flakes packaged in air or flushed with nitrogen and reported a loss of beta-carotene from 1200 ppm to 1050 ppm after one month under nitrogen after which the carotene remained constant for 23 months. Carrots packaged in air decreased from 1200 ppm to 400 ppm after two months of storage, then also remained constant.

Goldman et al. (1983) found headspace oxygen important in the degradation of beta-carotene in a model system. They showed that even a low oxygen concentration of 1 to 2% leads to a significant loss of carotene. At 1, 2, 10, 15 and 20.9% oxygen the shelf life (loss of 50% carotene) was, 37, 25, 10, 7 and 5 days, respectively. When oxygen was totally removed, only 12% beta-carotene was lost in 60 days.

Lovric et al. (1970) reported that the main cause of color fading in tomato powder was the oxidation of lycopene. When the tomato powder was vacuum dried and flushed with an inert atmosphere, color retention was high.

The effect of oxygen in the package on autoxidation and isomerization of beta-carotene is one of the more extensively studied if not the most important reaction leading to the loss of this provitamin in stored foods. Freeze dried and spray dried foods are especially susceptible to oxidation of beta-carotene, due to the porous structure and highly exposed surfaces produced.

The oxidation of beta-carotene involves first, an induction *period, where an increase in free radicals are produced;* second, a propagation period when there is a rather constant rate of reaction and intermediate products are formed and consumed by additional reactions; and finally, a retardation period or termination. The presence of free radicals accelerates the reaction, while inhibitors of free radical formation, such as BHT, slow the rate of oxidation.

Bishov et al. (1971) reported that food products adsorb oxygen mainly as a function of their pigment content. Saguy et al. (1985) reported that the outer layers in a food system will oxidize at a maximum rate, whereas the inner layers are limited by the diffusion of oxygen and so have a slower rate of oxidation. Goldman et al. (1983) reported the rate of decolorization of beta-carotene to be affected more strongly by the oxygen content than the partial pressure and proposed this as a method whereby starch may exert it's protective action.

Chou and Breene (1972) reported that after a brief induction period, the oxidative deterioration of beta-carotene follows a first order reaction. Goldman et al. (1983) demonstrated that for every mole of beta-carotene oxidized, eight moles of oxygen are required. The high oxygen consumption is proposed to be a sequence of reactions and interactions of the intermediate products formed with oxygen. The products produced from the oxidative deterioration of beta-carotene include hydroperoxides, carbonyl compounds and other volatile compounds. Therefore, not only does the oxidation of beta-carotene lower the nutritional quality of the product and cause decolorization but it also involves the development of off-odors and flavors.

The free radical content of the system can be significantly reduced by the interaction of water with the radicals, depending on the composition of the food system. Chou and Breene (1972) reported that adsorbed moisture in a food system will extend the induction period and reduce the rate of oxidative decolorization. However, increasing the water content can also mobilize the pro-oxidant factors in the system and cause swelling, thereby exposing new sites within the matrix.

Ramakrishnan and Francis (1979) reported that for resistance to oxidation, optimal storage would be at moisture levels near or at the monolayer level of water molecules. They proposed that water molecules can form H bonds with the hydroperoxides produced and thus protect them from decomposing or binding to each other, thus slowing the rate of initiation through peroxide decomposition. The authors also demonstrated that increasing the relative humidity of a system results in protection of the carotenoid pigments. Most oxidized samples of beta-carotene decompose at a slower rate and thus are more stable than the parent molecule.

As the $a_w$ is lowered from rather high values, Labuza (1980) showed that the rate of oxidation will first decrease and then increase again as the $a_w$ goes below the monolayer. This is due to (1) changes in the hydration of trace metal catalysts, making them more active as they lose water, (2) changes in the mobility of the metal so it can now go to the lipid interface and increase the oxidation rate, and (3) H bonding of peroxide intermediates to the water interface.

Walter et al. (1970) reported that much beta-carotene in dehydrated sweet potato flakes is not available for oxidation. This was because of polymer formation of beta-carotene itself or from copolymerization of beta-carotene oxidative fragments with starches, pectins, cellulose and proteins present in the sweet potato. Most of the carotene in their study was involved in fragmentation. Temperature of storage or dehydration also plays a role in the rate of oxidative deterioration. Chou and Breene (1972) reported that higher temperatures of storage caused a decrease in the induction time of the oxidative reaction. Lovric et al. (1970) reported that dehydration causes trans-cis isomerization of beta-carotene. The cis-isomers are more susceptible to oxidation; some however are reisomerized to the all trans-form. Using tomato powder and lycopene as a model, they showed that as storage temperature increased, reversion of the cis isomers and a 'deepening' of the color was observed; however, oxidation was also accelerated. Boskovic (1979) reported that isomer reversion in dehydrated tomato products is a slower reaction than the autoxidation of cis isomers. The reversion of cis isomers was found to be favored by an increase in storage temperature (to 20°C) and favored in air packed samples stored at room temperature because the amount of reversion taking place was higher than the oxidation of lycopene. Tomato products under an inert atmosphere retained more cis isomers than air packed samples. As lycopene is oxidized, it is split into smaller fragments producing a hay- or grass-like odor due mostly to volatile aldehydes and ketones.

Lovric et al. (1970) reported that tomato powder stored at 37°C had a darkening of color due to NEB. They observed the formation of additional water, accompanied by caking of the powder and burnt and caramel-like odors after a few weeks.

During the oxidation of beta-carotene several odorous compounds are produced. Walter et al. (1970) reported acrolein production, so at least a small amount of carotene was oxidized to short chain carbonyls and alcohols. Falconer et al. (1964) reported a violet-like aroma in carrots due to alpha and beta-ionine from the oxidation of carotene. A bitter, soapy after taste also became noticeable. There was a slightly non-linear relationship between carotene loss and the development of off-flavors.

Purcell et al. (1969) demonstrated that color changes noticed in heating of vegetables is due to a change in the 'physical state' of the carotenes. In heated fresh carrot, the chromoplasts disintegrated and the carotenes dissolved in the cellular lipids.

Park (1987) reported a decreased carotene content in carrots, broccoli and spinach after vacuum drying. He also observed species differences in the retention of carotene in these dehydrated vegetables. By decreasing the carotene content the induction period will be longer, thus lowering the oxidation rate; this is called the 'dilution effect.'

## Non-Enzymatic Browning

There are three general types of non-enzymatic browning which produces unsaturated, colored polymers: (1) carbonyl-amino reactions, which includes the reactions of aldehydes, ketones and reducing sugars with amines, amino acids, peptides and proteins, (2) caramelization, which involves pyrolysis of sugars or polysaccharides at high temperatures without the presence of amino compounds, and (3) oxidative reactions, often involving reductones such as the dehydro form of ascorbic acid.

The Maillard reaction involves carbonyl and amino compounds, the rate of which depends on the alkaline strength of the amines and percentage of carbonyl compounds present. Hodge (1953) reported that as food is dehydrated the reversible sugar-amine condensation can go to completion.

Caramelization and non-amino reactions occur at high temperatures (above 100°C) and can occur in the presence of such accelerators as carboxylic acids and their salts, phosphates and metallic ions. This is also accelerated by an increased pH, inhibited by sulfur dioxide, and slightly enhanced by an oxygen atmosphere. Ascorbic acid and other reductones are also involved in non-amino browning in alkaline conditions on contact with air. The unstable dehydro-ascorbic form is involved in formation of dark-colored compounds oxidatively promoted by copper or tin.

Hodge (1953) reported that all stored dehydrated foods contain an increased amount of reductones other than ascorbic acid. This increase is greater as storage time and temperature are increased.

This study compares 20 different dehydrated foods under air or nitrogen flush, stored at 4.4, 21 or 37.8°C for 42 to 60 months. These foods were analyzed for thiamin, ascorbic acid, beta-carotene, residual oxygen, moisture content, Hunter color values and taste paneled for acceptability.

# MATERIALS AND METHODS

Twenty dried food products were prepared and packaged in No. 2 1/2 or No. 10 metal cans by the Vacu-Dry Company (Sebastopol, CA.). The products - apples, bananas, green beans, navy beans, butter powder, carrots, egg mix, milk, oats, peaches, salad blend, macaroni, stroganoff, tomato powder, vegetable noodle soup, texturized vegetable protein, wheat and yeast were analyzed for vitamin content and evaluated by taste panels. Potatoes and peanut butter were also tested in the taste panels. The canned samples were packaged in air (17-20% oxygen) or flushed with nitrogen (approximately 2% oxygen) and stored at Brigham Young University at 4.4, 21 and 37.8°C. At storage times of 42, 48, 54 and 60 months, the samples were taken from storage and tested for residual oxygen. The cans were opened and the replicates (usually 3 cans) were combined in a large bowl and mixed thoroughly. Samples for the taste panels were returned to a can and sealed with a plastic lid and stored at 4.4°C for no longer than one week. One cup of mixed sample was placed dry in a Waring blender, ground finely and stored in an air tight plastic bag at -20°C for vitamin analysis.

## Clumping and Odor Determination

At the time the cans were opened, two analysts were present to assess odors and clumping in each can. A scale was used to designate the extent of clumping as follows:

Light clumping - falls apart as poured from container

Medium clumping - requires moderate pressure to break the clumps apart

Heavy clumping - won't break apart until pried apart or immersed in water.

The odors were detected subjectively by two analysts present and noted.

Color Determination

Samples stored for 48, 54 and 60 months were analyzed for color by use of a Hunterlab Labscan II Colorimeter. Approximately 20 grams of sample were placed in a glass container, tapped down to obtain uniformity and L, a and b values were obtained.

Moisture Content

Five to 10 grams of ground sample in an aluminum weighing dish were placed in a vacuum oven for 24 hours at 80°C under vacuum which reduced atmospheric pressure by 25 inches mercury,then reweighed, and moisture content was determined by difference.

## Nutrient Analysis

Nutrient analysis was conducted with two replicates of each storage condition.

Thiamin

Thiamin content of the food samples was analyzed by the fluorometric thiochrome assay (AOAC, 1980) with modification in column exchange resin (Rettenmouer et al., 1979) and phosphatase enzyme and extraction solvent (MacBride and Wyatt, 1983) as detailed in Appendix A.

Ascorbic Acid

Total ascorbic acid was determined spectrophotometrically using the 2-4-dinitrophenyl hydrazone modified procedure of Roe and Kuether (1943) Appendix B.

Beta-Carotene

*Beta*-carotene was determined after extraction and purification in acetone-hexane and separation in a MgO column, from pigment adsorption at 450 nm (AOAC, 1980, modified; Appendix C).

Vitamin A

Vitamin A was determined by the Carr Price method in dried butter and quantitated by absorption at 620 nm (Appendix D).

Taste Panel

Within one week of the opening of each sample, a taste panel was conducted. Twenty to twenty-five panelists were used including eight faculty of the Food Science and Nutrition Department. The remaining panelists were university students which were newly recruited each storage test period. The panelists were instructed to rate the foods for quality based on normal quality of dehydrated foods. One food, identified by three-digit codes, was presented per day with the six treatments in random order. The foods were evaluated for appearance and color, flavor, texture, and overall acceptability (see Appendix K). The panelists responses, given on a linear scale of 0 (very poor) to 100 (very good), were considered as a percentage. Samples which received an average flavor score of 40 or less were removed from the next storage period taste evaluation.

Data Analysis

The general linear model for analysis of variance was run utilizing the computer program SAS, version 5. The data was then analyzed with Minitab using various plotting such as boxplots, contour plots, two dimensional plots and residual plots. For data presentation, boxplots and the two dimensional plots are used since they most clearly show relationships.

## RESULTS AND DISCUSSION

Many variables were tested and much data obtained during this study. In order to present and discuss the results in the simplest manner, only the significant effects are discussed; the complete raw data is in Appendices E thru M.

### Experimental Design

This study is a continuation of the study of Norseth (1986) wherein 3 years storage were covered. The design of the study was set, and time, budget and project restraints required that the previous design be followed. The study would have been improved by taking random samples from each can opened and analyzing each one instead of combining all cans and then taking a random sample. This could have determined if the variance was due to different factors in individual cans or the food _per se_.

### Odor and Clumping

By 42 months of storage, all of the samples stored at 37.8°C had off-odors to some degree. Many dried foods developed a burnt or caramelized odor. Bananas, peanut butter and TVP produced a rancid odor; navy beans exhibited an unpleasant fishy odor, possibly due in part to a reaction with the enameled can. Salad blend, with the cabbage, developed a rotten sulfurous, burnt odor; wheat smelled fruity; and yeast had a sickeningly sour odor.

After 54 months, all foods stored at 21°C also developed off-odors to varying degrees. TVP, bananas and peanut butter smelled rancid. Carrots and salad blend produced an oxidized, sweet odor and the remainder of the foods developed an old or unfresh odor. By 60 months of storage, the majority of the samples held at 4.4°C in nitrogen still smelled fresh, however some samples stored in air at 4.4°C produced slight off-odors.

Clumping was a problem in some foods: butter, eggs, peanut butter, stroganoff, vegetable noodle soup and tomato crystals. The clumping grew worse with increasing temperature and storage time. Tomato crystals, the worst sample, at 37.8°C was a single, hard, dark brown clump which could not be pried apart unless rehydrated with water. A homogeneous, dry sample was impossible since only the outer layers could be scraped off.

### Residual Oxygen

The average residual oxygen content of the food products is listed in Appendix E. The most dramatic uptake of oxygen was seen in the foods packaged under air and stored at 37.8°C. Oxygen uptake by the food is discussed below with the deterioration of ascorbic acid and *beta*-carotene.

### Moisture

The percentage moisture in the food samples is presented in Appendix F. The general trend was a decrease in moisture over time, until 60 months when the moisture was almost always above the initial value.

## Color

The colorimeter L and a values are listed in Appendix G. The L value describes the change in darkness of the sample, where L=100 is white and L=0 is black. The a value measures red to green hue of the sample, where +a is red and -a is green.

The changes noted in L and a values are discussed in relationship with the deterioration of thiamin, ascorbic acid and beta-carotene in the food. The L and a values appear to be related with non-enzymatic browning occurring within the food since increased browning causes a darker sample or a lower L value and a redder color affecting the a value. Non-enzymatic browning is especially active in low to intermediate moisture foods. It forms colored polymers which range from yellow to red to brown in color. However, if the food already has a red color present, such as in carrots or tomatoes, the presence of an additional dark brown shade would decrease the redness of the net color.

## Thiamin

The deterioration of thiamin in vacuum-dried foods was found to be primarily a reaction which is accelerated by heat. In all the foods analyzed for thiamin, the loss was highest at 37.8°C; in some foods, the thiamin was completely destroyed. The deterioration of thiamin across storage time was generally insignificant and the effect of atmosphere varied in significance among foods.

Egg, stroganoff, TVP, and vegetable soup displayed a statistically significant loss of thiamin at 37.8°C compared to only a slight

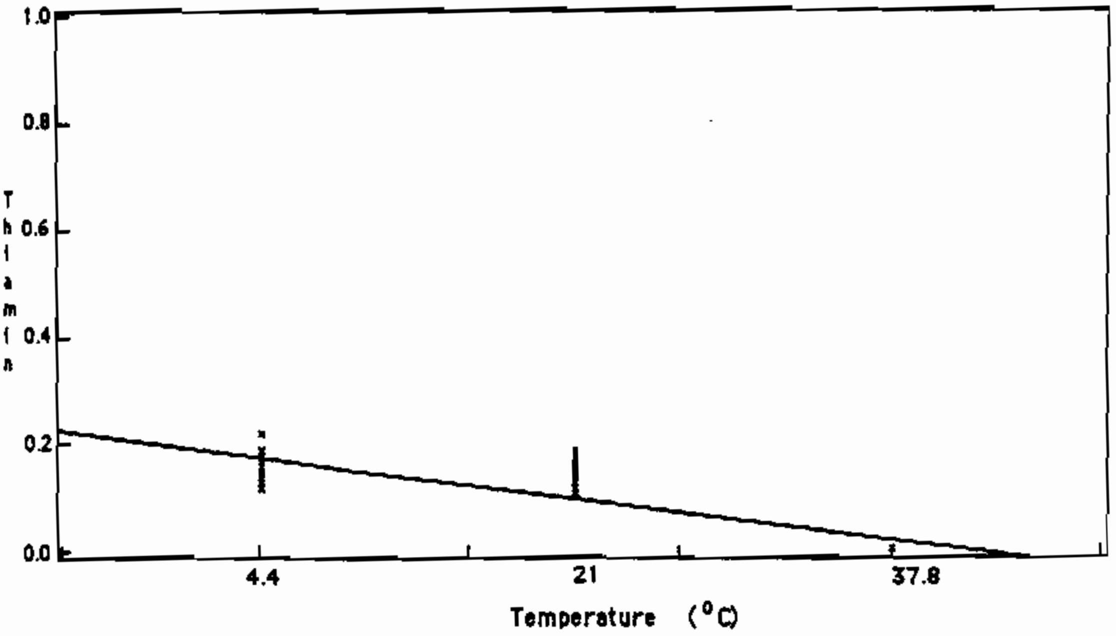

**Figure 1.1** Temperature versus thiamin retention (mg./100g.) in dried eggs.

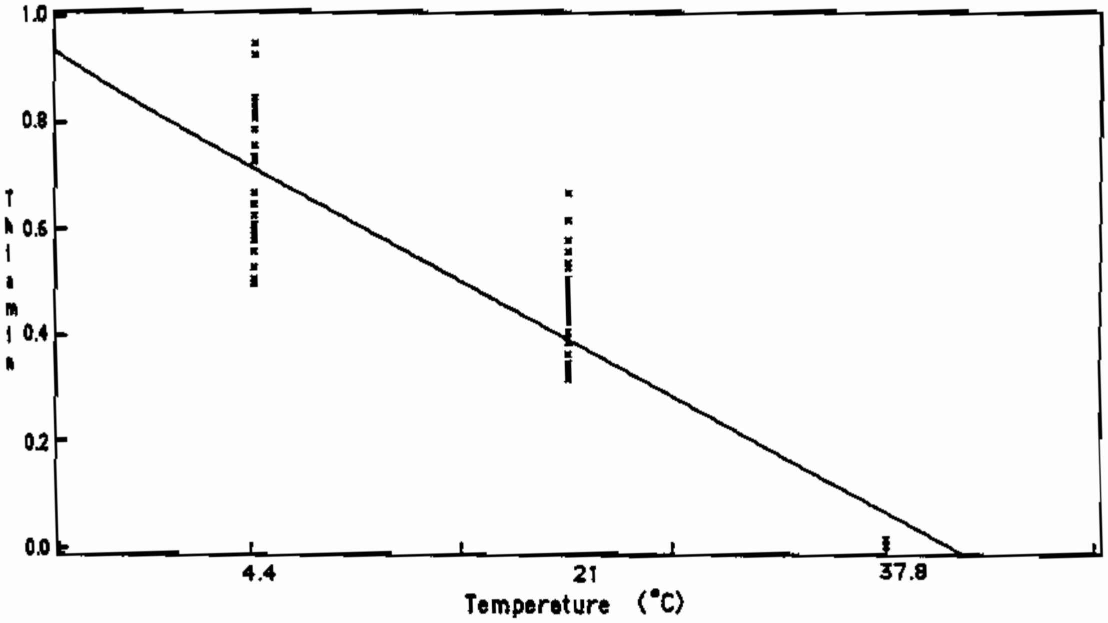

**Figure 1.2** Temperature versus thiamin retention (mg./100g.) in enriched macaroni.

decrease at 4.4 and 21°C. Figure 1.1 displays the temperature effect in eggs as shown by the means of 0.15, 0.14 and 0.00 mg./100g. at 4.4, 21 and 37.8°C, respectively, and is similiar to the other foods. Eggs, navy beans and macaroni exhibited a total thiamin loss at 37.8°C after 42 months. The increased loss is probably due to an accelerating effect occurring between 21 and 37.8°C. Dwivedi and Arnold (1973) reported that at 27°C, thiamin loss accelerated in dehydrated foods.

Oatmeal, macaroni, navy beans, wheat and yeast all displayed significant temperature effects at 21 and 37.8°C. Figure 1.2 illustrates the temperature sensitivity of thiamin in macaroni, the means being 0.68, 0.46 and 0.01 at 4.4, 21 and 37.8°C, respectively. Perhaps in these foods thiamin is in a less stable form such that its thermal destruction occurs at a lower temperature. Non-fat dry milk retained thiamin quite well, as can be seen in the boxplot in Figure 1.3, with the means of 0.15, 0.14 and 0.12 at 4.4, 21 and 37.8°C, respectively. The only difference of significance was the loss between 4.4 to 37.8°C. Leichter and Joslyn (1969) reported that thiamin bound to protein, as it exists in milk, has a protective effect on retention.

Dennison et al.(1977) reported accelerated thiamin loss in cereal stored at 45°C due to non-enzymatic browning. In observing the color changes, there appears to be a relationship between color change and thiamin loss at increased temperatures (100°F). Figure 1.4 and Table 1 portrays the relationship in macaroni. As the macaroni became darker with an L value less than 40, or as the red a value increased to above 10 the thiamin was lost. This shows a strong relationship between NEB at elevated temperatures, and accelerated thiamin destruction. Van der

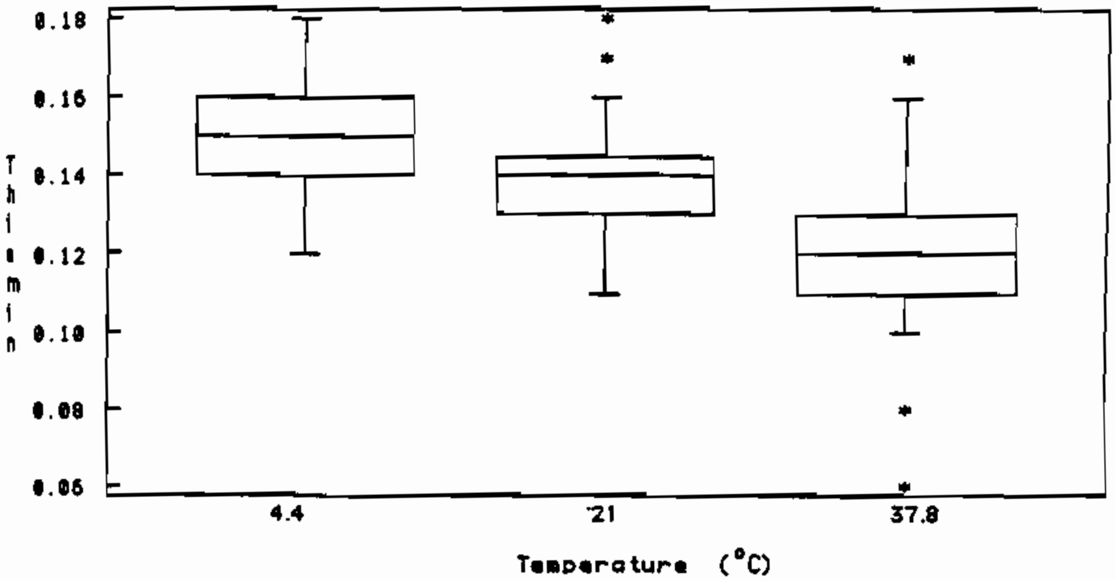

**Figure 1.3.** Boxplot of the effect of storage temperature on the retention of thiamin (mg./100 g.) in dried milk.

* Boxplots are read as: The whiskers are the range, the * are the outliers, the line inside the box is the median value and the upper box line is the 75 th percentile and the bottom line the 25th percentile values.

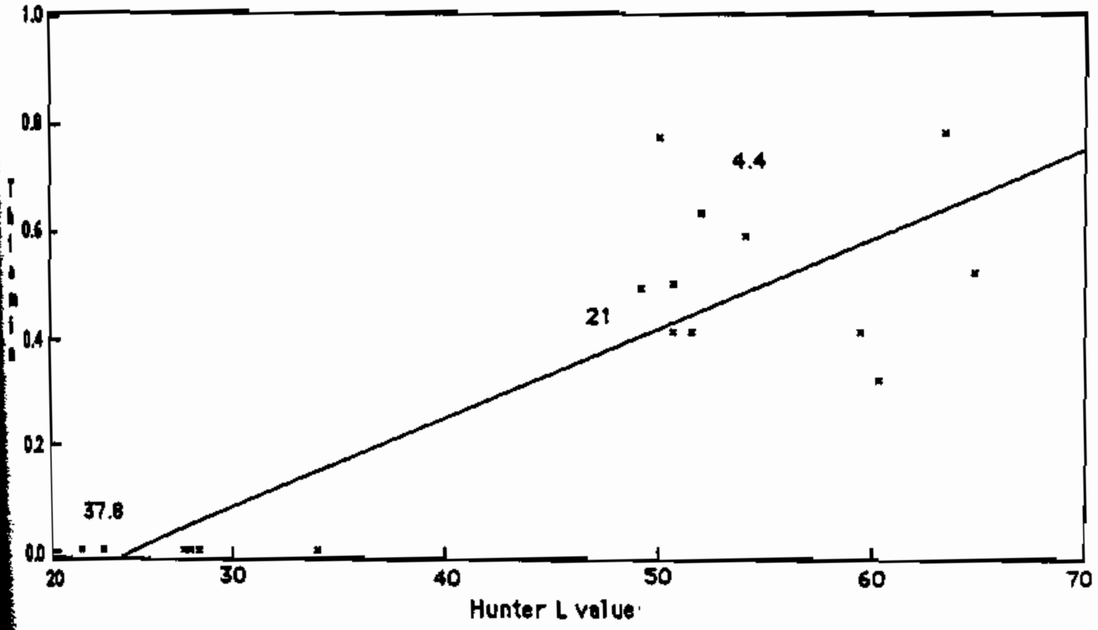

**Figure 1.4.** Thiamin retention (mg./100g.) and Hunter L value in macaroni stored at 4.4, 21 or 37.8 °C for 48 to 60 months.

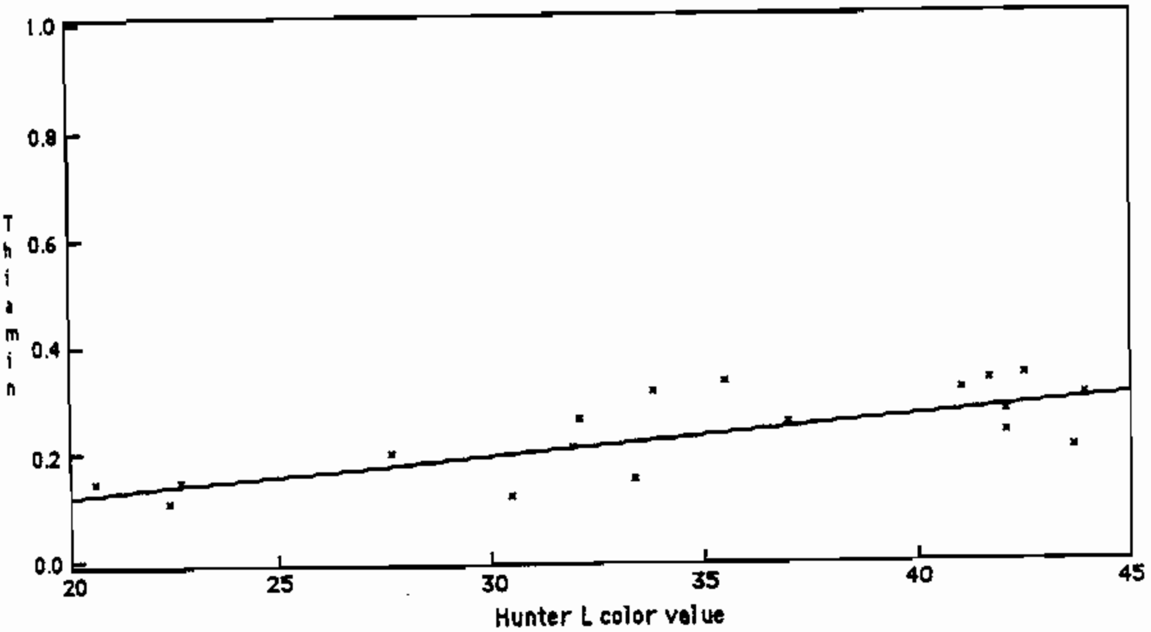

**Figure 1.5.** Thiamin retention (mg./100g.) versus Hunter L color values in dehydrated vegetable soup stored at 4.4, 21 or 37.8°C for 48, 54 or 60 months.

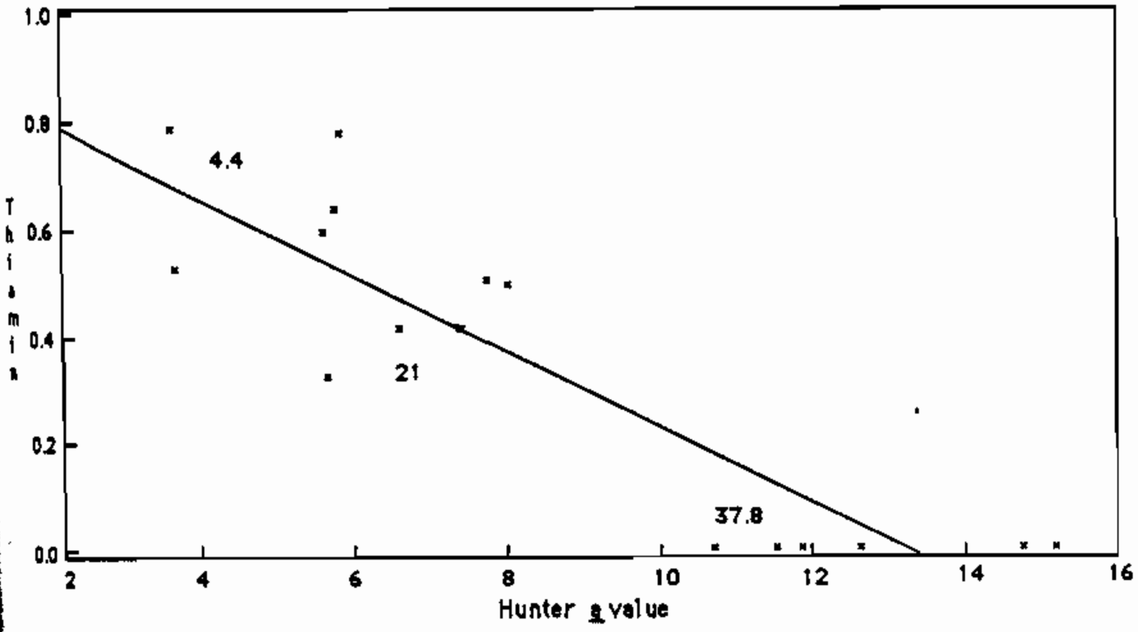

**Figure 1.4b.** Thiamin retention (mg./100g.) versus Hunter a color values in macaroni stored at 4.4, 21 and 37.8 °C for 48 to 60 months.

Poil (1956) reported that thiamin participates in NEB by donating it's amino group to sugars.

Table 1. **Effect of Temperature on Hunter Color Values and Thiamin Content of Macaroni**

| Temperature °C | Color L | Color +a | Thiamin mg./100g. |
|---|---|---|---|
| 4.4 | 56.82 | 4.83 | 0.68 |
| 21 | 53.60 | 7.10 | 0.46 |
| 37.8 | 27.18 | 12.76 | 0.01 |

* Means of measurement are taken over 48 to 60 months

The observed color change with thiamin loss is also apparent in egg, navybeans, vegetable soup, stroganoff, wheat and yeast. The relationship observed in eggs and navy beans between color and thiamin shows a similiar pattern as with macaroni. Vegetable soup and stroganoff, however, both displayed a decrease in both L and a values as, portrayed in Figure 1.5 and Table 2 for vegetable soup. There appears to be a parallel response between both L and a values, and thiamin content. When the thiamin falls, there is a drop in both L and a values, as the food darkened and also became less red.

Table 2. **Effect of Temperature on Hunter Color Values and Thiamin Content in Dried Vegetable Soup.**

| Temperature °C | Color L | Color + a | Thiamin mg./100g. |
|---|---|---|---|
| 4.4 | 42.64 | 9.76 | 0.28 |
| 21 | 35.19 | 7.26 | 0.27 |
| 37.8 | 26.19 | 5.15 | 0.13 |

* Means of measurements are taken over 48 to 60 months.

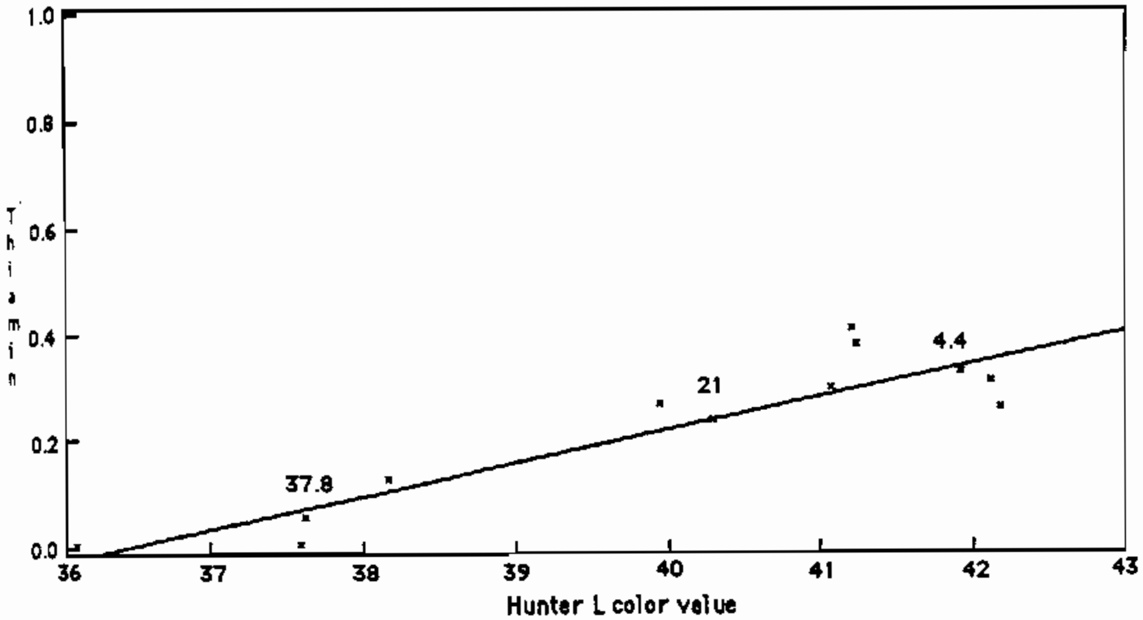

**Figure 1.6.** Thiamin retention (mg./100g.) versus Hunter L color values in dry wheat stored at 4.4, 21 or 37.8 C for 48, 54 o months.

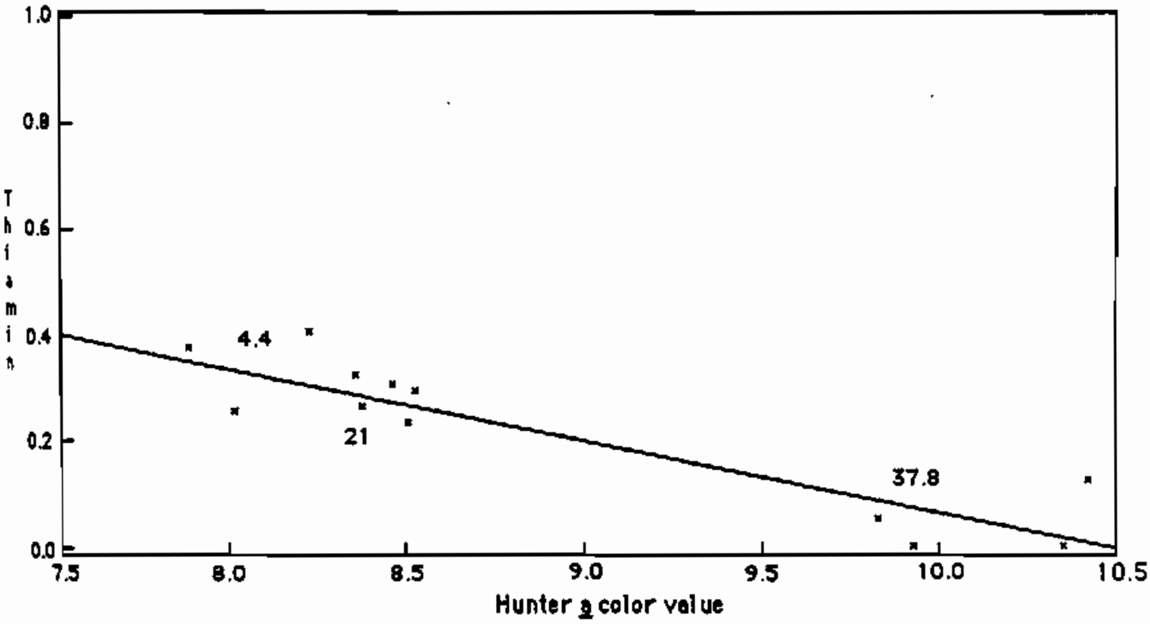

**Figure 1.6b.** Thiamin retention (mg./100 g.) versus Hunter a color values in dry wheat stored at 4.4, 21 or 37.8°C for 48, 54 or 60 months.

Wheat is similiar to macaroni, eggs and navy beans but with a more definite increase in a and decrease in L values when thiamin levels became low (Figure 1.6 and Table 3). Yeast, however, shows little relationship between thiamin and L values, but displays a gentle decreasing trend in the red a value and thiamin loss as temperature is increased (Figure 1.7).

Table 3. **Mean Values for Hunter Color Values and Thiamin in Wheat stored 48 to 60 months.**

| Temperature °C | Color L | Color +a | Thiamin mg./100g. |
|---|---|---|---|
| 4.4 | 41.63 | 8.11 | 0.35 |
| 21 | 40.85 | 8.46 | 0.28 |
| 37.8 | 37.35 | 10.13 | 0.09 |

Thiamin in several foods is not significantly lost up to 54 months but then values drop at 60 months. Macaroni, navy beans, vegetable soup and stroganoff exhibit this trend, as is illustrated with vegetable soup in Figure 1.8 and the means 0.22, 0.23, 0.24 and 0.19 at 42, 48, 54 and 60 months, respectively. Milk, oatmeal, TVP and wheat were fairly stable across time without any significant thiamin loss. The stability of thiamin in rolled oats across time is shown in Figure 1.9. Yeast showed no significant differences across time. Thiamin retention in egg showed a decrease at 48 months then an increase at 54 months. This increase may be due to errors associated with the analysis or perhaps the samples prepared for the 54 month analysis had a higher vitamin content to start with.

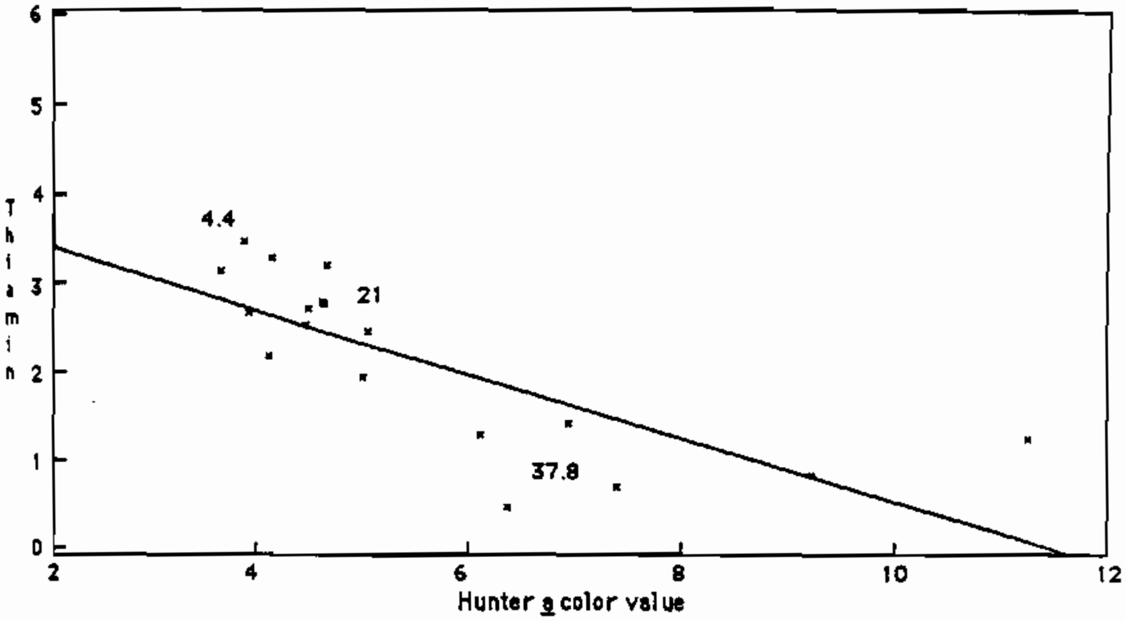

**Figure 1.7.** Thiamin retention (mg./100 g.) versus Hunter a values in dry yeast stored at 4.4, 21 or 37.8°C for 48, 54 or 60 months.

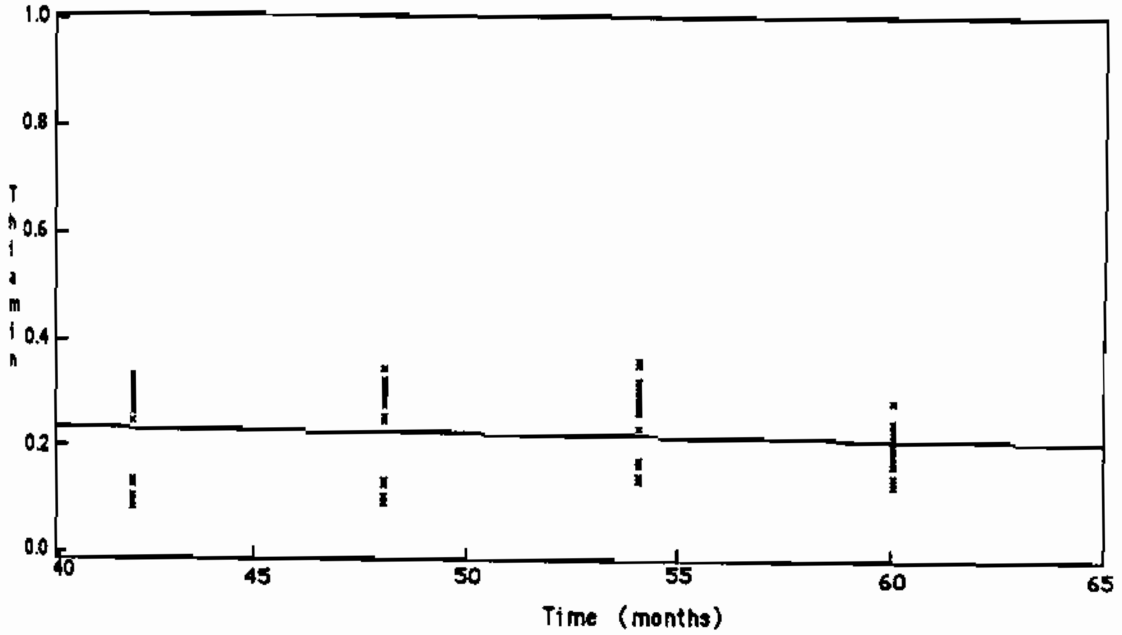

**Figure 1.8.** The effect of storage time on the retention of thiamin (mg./100 g.) in dried vegetable soup.

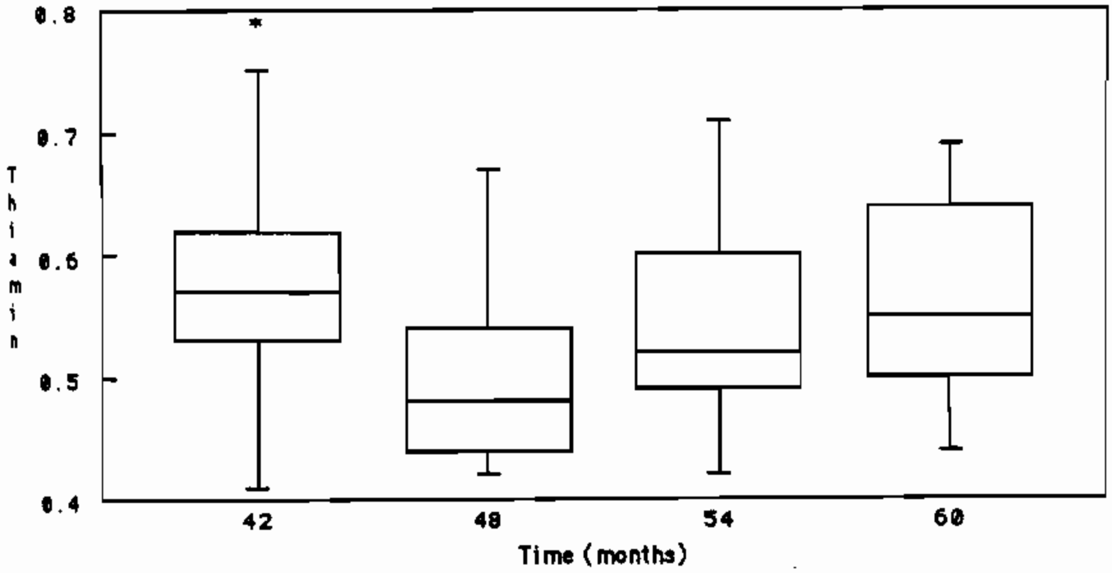

**Figure 1.9.** The effect of storage time on the retention of thiamin (mg./100 g.) in dry rolled oats.

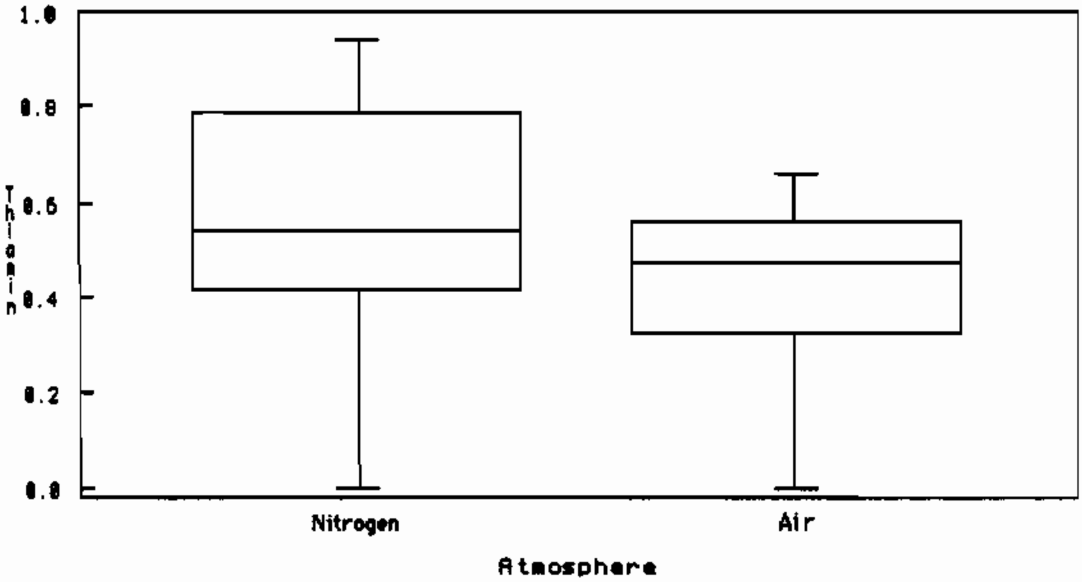

**Figure 1.10** The effect of package atmosphere on thiamin retention (mg./100 g.) in dry macaroni.

Although the deterioration of thiamin is mainly thermal, there seems to be an effect imposed by the can atmosphere. Wheat, vegetable soup, milk and egg displayed no significant differences in thiamin retention between the samples packed with air or flushed with nitrogen. Oatmeal and stroganoff exhibited a greater loss of thiamin as temperature increased in samples under nitrogen than those packed in air. The nitrogen flushed samples still retained a higher average thiamin content over all levels, but the drop in thiamin with increasing temperature was more dramatic.

Yeast, macaroni, navy beans and TVP all displayed significantly higher thiamin when packed under nitrogen (Figure 1.10). TVP had a greater difference in thiamin content at 4.4°C compared to 37.8°C in an inert atmosphere. In yeast, there was a larger amount of thiamin at 37.8°C under nitrogen than in the air packs.

The overall retention of thiamin after 60 months is presented in Table 4. The percent was calculated using 24 month data as the 100% base due to the use of different analytical column exchange resins and enzymes before the 24 month period.

At 4.4°C eggs, milk, oats, TVP and yeast retained more than 85% thiamin while vegetable soup and wheat lost 40% or more. At 21°C, eggs, milk, oats, stroganoff and TVP retained approximately 85% thiamin while macaroni and vegetable soup lost nearly 50%. At 37.8°C dry milk and oats retained a mean 68 and 83% thiamin, respectively, after 60 months but egg, macaroni, navy beans and wheat lost it all. Vegetable soup did not display much difference after 60 months between 4.4, 21 or 37.8°C.

Table 4 Percent Retention of Thiamin after 60 months

| | Temperature °C | | | | | |
|---|---|---|---|---|---|---|
| | 4.4 | 4.4 | 21 | 21 | 37.8 | 37.8 |
| | Atmosphere | | | | | |
| Food Product | $N_2$ | air | $N_2$ | air | $N_2$ | air |
| Egg | 80.0 | 94.0 | 94.0 | 75.0 | 0 | 0 |
| Macaroni | 87.6 | 74.3 | 53.9 | 52.4 | 0 | 0 |
| Milk | 100 | 100 | 100 | 93.0 | 75.0 | 61.6 |
| Navy Bean | 78.5 | 74.6 | 59.6 | 73.7 | 0 | 0 |
| Oats | 89.3 | 84.8 | 91.5 | 79.7 | 81.7 | 83.9 |
| Stroganoff | 85.4 | 47.7 | 91.4 | 78.8 | 32.2 | 48.3 |
| TVP | 100 | 100 | 89.8 | 83.0 | 54.6 | 41.5 |
| Veg.Soup | 52.4 | 47.5 | 62.5 | 51.3 | 76.0 | 50.0 |
| Wheat | 61.5 | 59.5 | 83.0 | 66.7 | 0 | 0 |
| Yeast | 87.2 | 93.8 | 76.2 | 74.3 | 48.7 | 22.3 |

## Ascorbic Acid

The deterioration of ascorbic acid in this study appeared to be largely due to oxidative and/or thermal processes. A nitrogen atmosphere always gave better retention of ascorbic acid. All foods analyzed for ascorbic acid (apple, banana, carrot, green beans, peaches, salad blend and tomatoes), had significant losses at 60 compared with 24 months of storage.

Only apples and peaches did not exhibit a significant loss of ascorbic acid with increasing temperatures. Losses were most dramatic with other foods at 37.8°C as illustrated with green beans in Figure 2.1 where the means were 33, 14 and 4 mg./100g. at 4.4, 21 and 37.8°C, respectively. This was also evident in salad blend, with means of 206, 108 and 9 mg./100g. at 4.4, 21 and 37.8°C, respectively.

Bananas lost more ascorbic acid from 48 to 54 months at 4.4°C than at 21 or 37.8°C, but from 54 to 60 months there was a greater loss at 21 and 37.8°C. This could be due to oxygen absorption being greater at lower temperatures but the rate of non-enzymatic browning is greater at 37.8°C and it may have destroyed ascorbic acid at a rate surpassing oxidative destruction during 54 to 60 months.

Bananas, carrots, peaches and tomato exhibited a significantly greater loss of ascorbic acid in air packed samples than those with nitrogen. Although the rate of ascorbic acid deterioration was approximately the same in both atmospheres, the nitrogen flushed samples started with higher amount at month 42. This is illustrated with carrots in Figure 2.2, the mean values being 8 and 6 for the nitrogen and air packs, respectively.

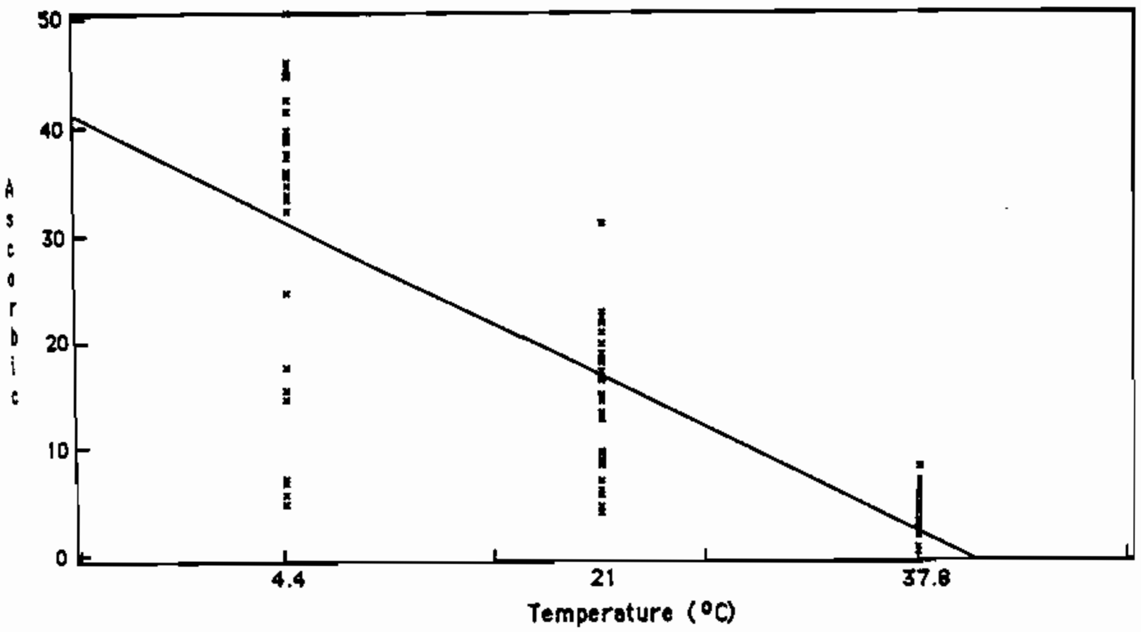

**Figure 2.1** The effect of storage temperature on the retention of ascorbic acid (mg./100 g.) in dried green beans.

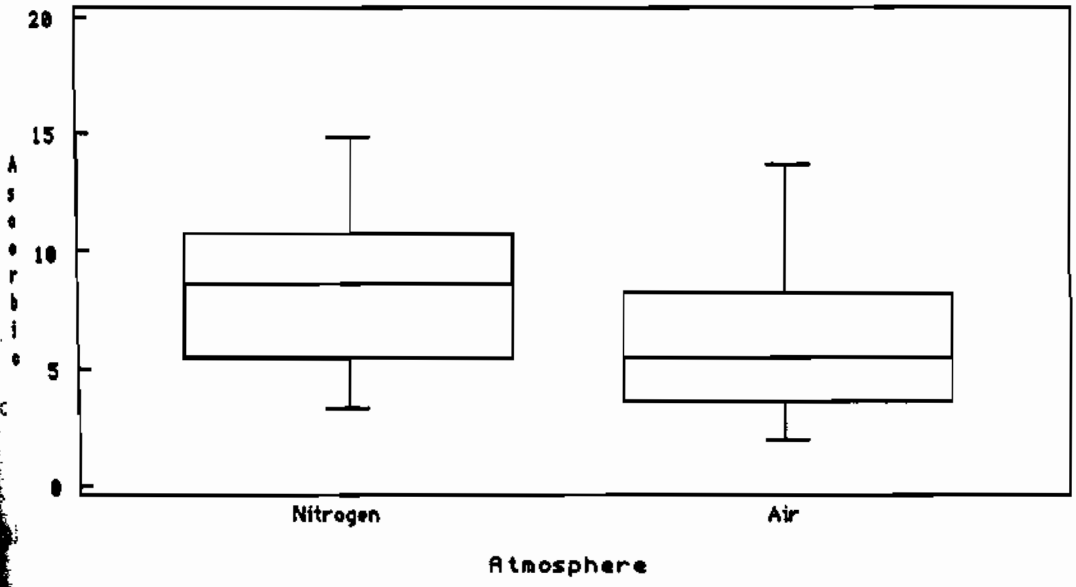

**Figure 2.2.** Boxplot of the retention of ascorbic acid (mg./100 g.) in the two package atmospheres in dried carrots.

Apples lost all ascorbic acid by 42 months in the air packed samples, therefore oxygen control is helpful in extending shelf life (Figure 2.3). The samples flushed with nitrogen showed a decrease in ascorbic acid content at 4.4 and 21°C, but at 37.8°C there was greater retention as shown by the means: 3.9, 3.6 and 5.5 mg./100g. for 4.4, 21 and 37.8°C in the nitrogen packs.

Salad blend (Figure 2.4) and green beans both displayed larger losses of ascorbic acid in air packs at 4.4 and 21°C than at 37.8°C, whereas in nitrogen packs, there was a larger loss at 37.8°C. The mean values for the atmospheric effect in salad blend are in Table 5. Platenius and Jones (1944) also observed a greater effect of oxygen on ascorbic acid loss at lower temperatures in dehydrated vegetables.

The uptake of headspace oxygen by some foods occurred with ascorbic acid loss. Tomato, green beans and salad blend decreased in ascorbic acid and headspace oxygen as the temperature increased. Figure 2.5 shows with tomatoes that there is a sharper drop from 4.4 to 21°C and a gentler slope between 21 and 37.8°C. This can also be seen by the means of the interaction in Table 5. Therefore it is possible that at 4.4 and 21°C a faster rate of oxidation of ascorbic acid is occurring than at 37.8°C. Previous studies (Laing et al., 1978) reported this is ue to decreased solubility of oxygen at higher temperatures.

In carrots and bananas, the oxygen uptake versus ascorbic acid lots show clustering of points by temperature with a general trend of creased oxygen uptake and a decrease in ascorbic acid. Carrots play two parallel trends in air packs (Figure 2.6). The upper three

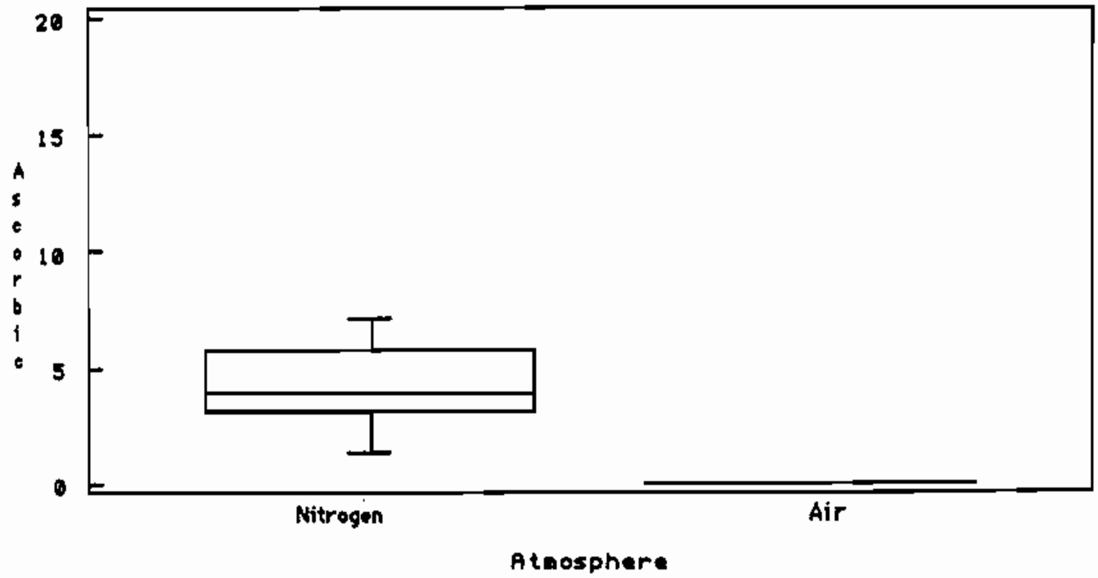

**Figure 2.3.** Boxplot of the effect of package atmosphere on the retention of ascorbic acid (mg./100g.) in dried apples.

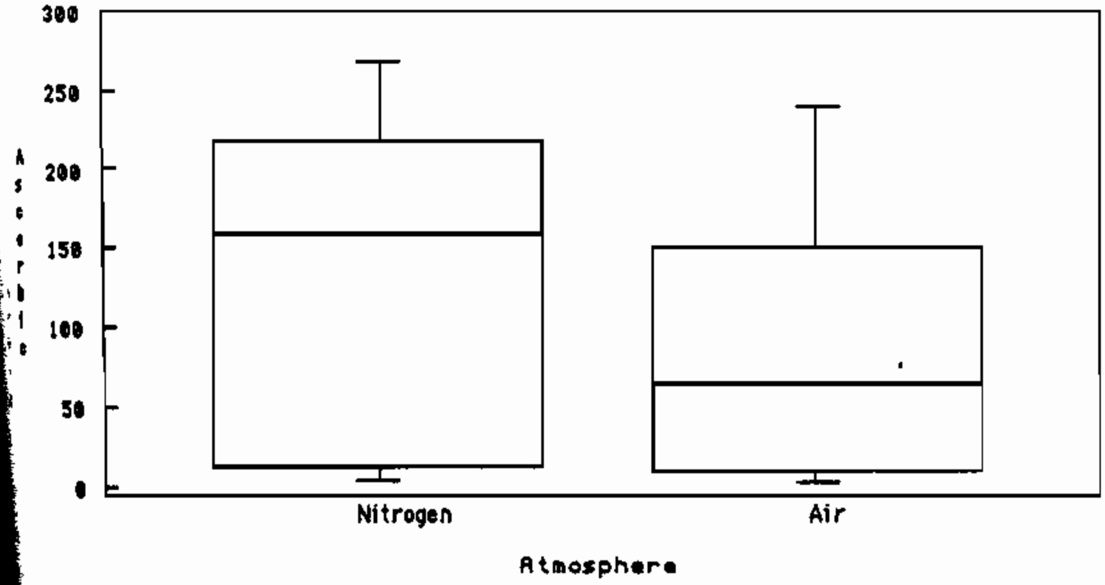

**Figure 2.4.** Boxplot of the effect of package atmosphere on the retention of ascorbic acid (mg./100 g.) in dried salad blend.

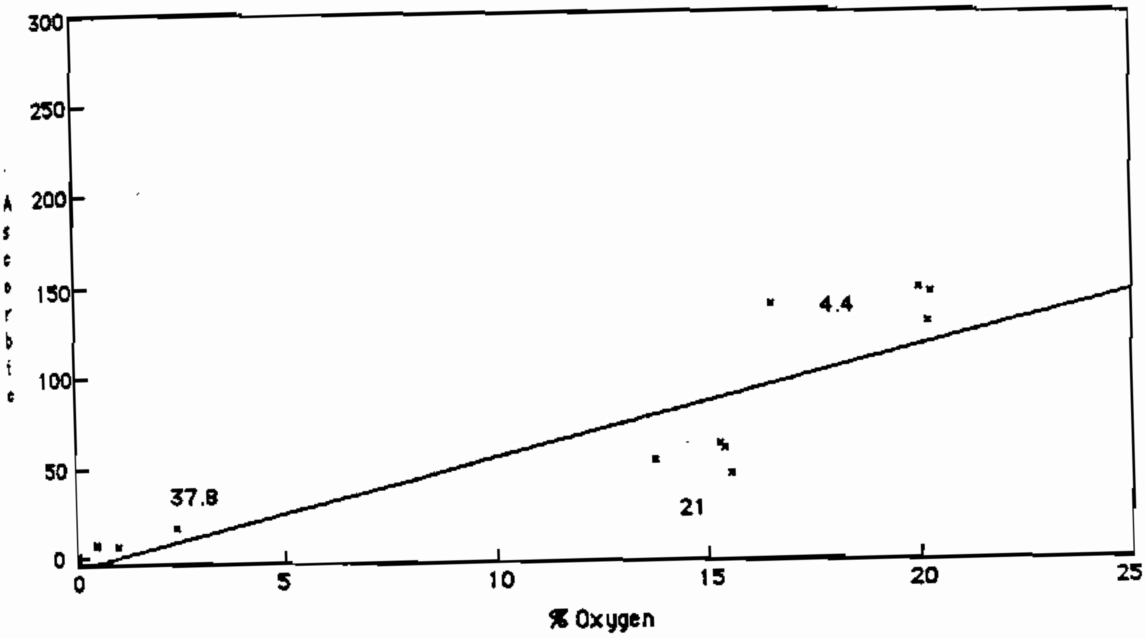

**Figure 2.5.** The relationship between residual oxygen and the retention of ascorbic acid (mg./100 g.) in dried tomato crystals in the oxygen packs.

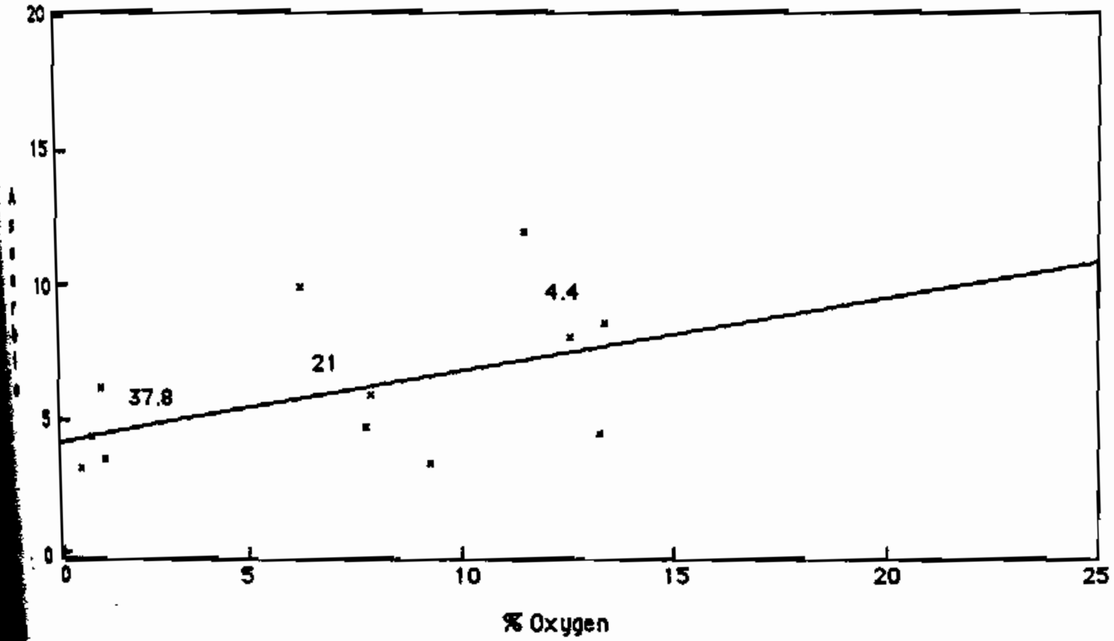

**Figure 2.6.** The relationship between residual oxygen and ascorbic acid retention (mg./100 g.) in dried carrot in the air packs.

points are high values observed for ascorbic acid at 48 months. The curve seen with bananas (Figure 2.7), shows a sloping decrease in

Table 5. **Effect of Atmosphere on Ascorbic Acid in Dried Salad Blend and Tomato stored 42 to 60 Months.**

| Temperature °C | Atmosphere | Ascorbic acid mg./100g. |
|---|---|---|
| Salad Blend | | |
| 4.4 | Nitrogen | 229.03 |
| 4.4 | Air | 182.70 |
| 21 | Nitrogen | 156.28 |
| 21 | Air | 58.96 |
| 37.8 | Nitrogen | 10.70 |
| 37.8 | Air | 7.89 |
| Tomato | | |
| 4.4 | Nitrogen | 149.63 |
| 4.4 | Air | 137.74 |
| 21 | Nitrogen | 58.99 |
| 21 | Air | 52.70 |
| 37.8 | Nitrogen | 10.30 |
| 37.8 | Air | 8.14 |

ascorbic acid as oxygen is taken up, but below an 10% oxygen, ascorbic acid appears to remain fairly constant. This was also observed in the temperature effect; the reason is not clear. The mean values for the ygen effect on ascorbic acid retention is presented in Table 6. The rge drop in oxygen cannot be contributed solely to ascorbic acid idation or there would be essentially no vitamin left, therefore some her reaction must also be occurring, such as oxidation of carotene in carrots.

There is not a significant difference between 4.4 and 21°C in orbic acid loss in relation to oxygen uptake in peaches, even though re is a drop in ascorbic acid at 21°C with 18% oxygen. However, at

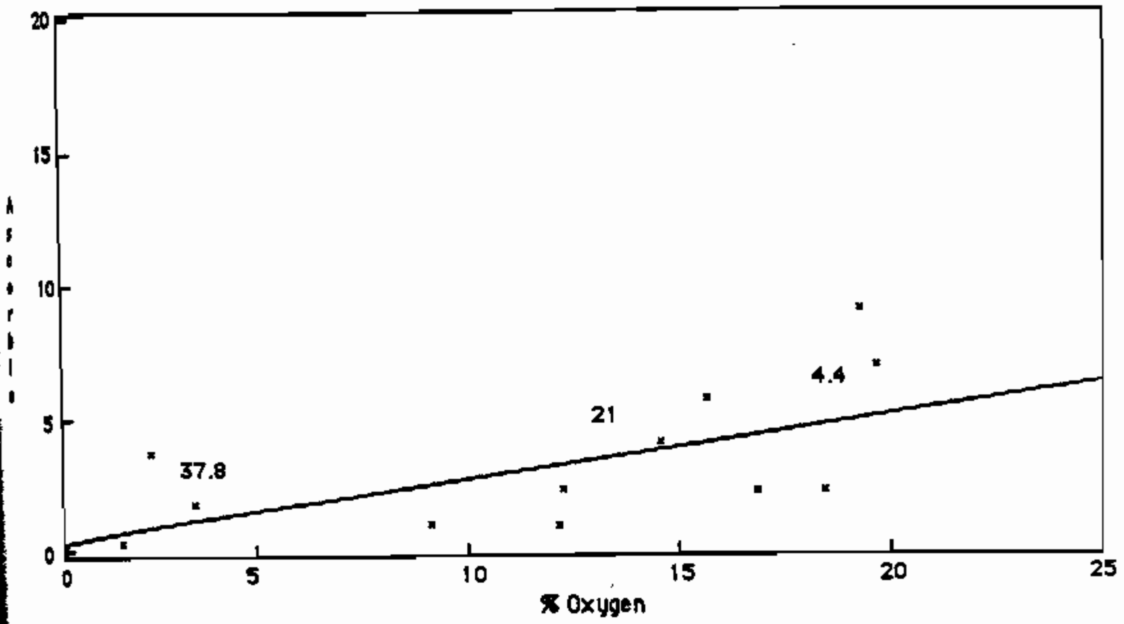

**Figure 2.7.** Residual oxygen versus ascorbic acid retention (mg./100 g.) in dried bananas packed in air.

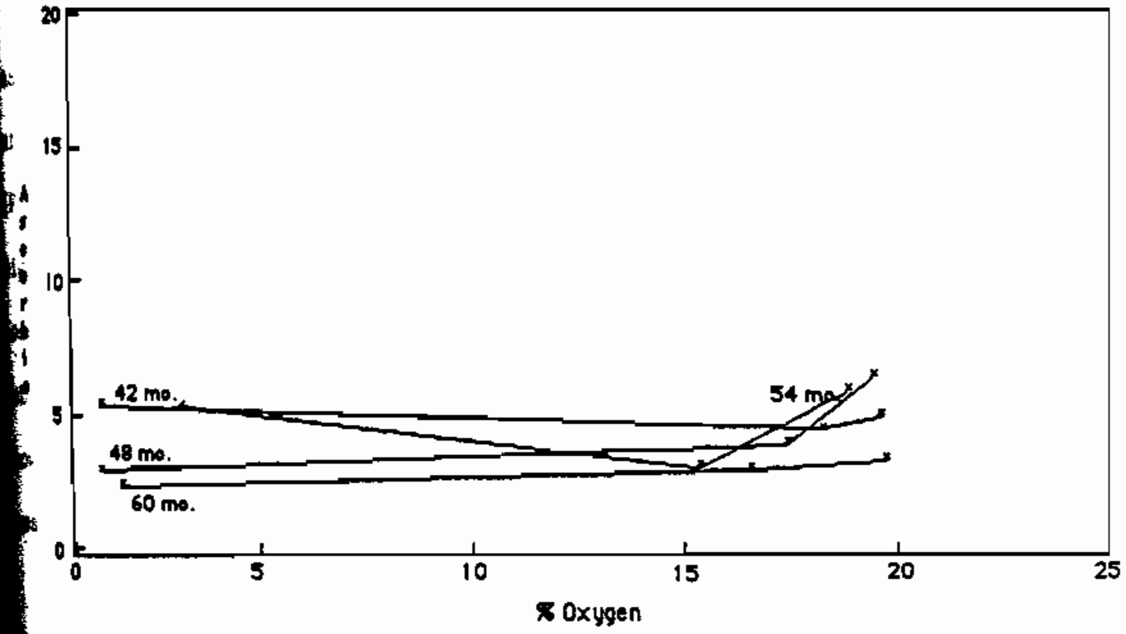

**Figure 2.8.** Residual oxygen versus ascorbic acid retention (mg./100 g.) in dried peaches. mg./100 g.).
* The 37.8°C data is on the far left, 21°C near the right and the 4.4°C on the far right.

37.8°C there is a significant drop in oxygen at 48 and 54 months where the ascorbic acid level remains fairly constant (Figure 2.8).

Table 6. **Mean Values of Residual Oxygen versus Ascorbic Acid in Dried Carrots and Bananas.**

| Temperature °C | % Oxygen | Ascorbic Acid mg./100 g. |
|---|---|---|
| CARROTS | | |
| 4.4 | 12.60 | 8.13 |
| 21 | 7.70 | 5.85 |
| 37.8 | 1.00 | 4.15 |
| BANANA | | |
| 4.4 | 18.50 | 4.91 |
| 21 | 13.60 | 3.07 |
| 37.8 | 4.15 | 1.53 |

Non-enzymatic browning (NEB) plays a role in deterioration of scorbic acid. By dramatic changes in Hunter L and a values, this effect was evident in tomatoes and salad blend stored at 37.8°C (Figures 2.9, 2.10). These plots reveal that NEB is not occurring gnificantly at 4.4 or 21°C, but is a major factor in ascorbic acid s at 37.8°C. This is illustrated by the mean values presented in le 8. The remaining foods, except apples, displayed a random plot wing no definite relationship between color or NEB and ascorbic acid s.

Apples showed an increased darkening as temperature increased and crease in a value at 21°C (Figure 2.11). Previous research (Resnik Chirife, 1979) reported NEB to occur in dried apples, producing compounds and a loss of ascorbic acid. However, from the values

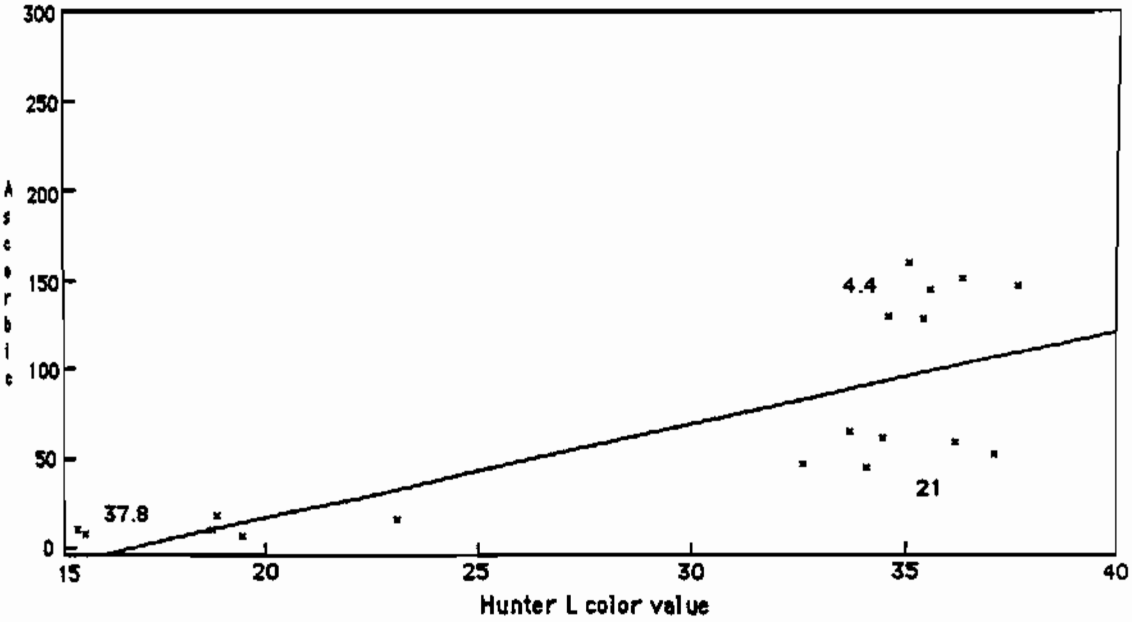

**Figure 2.9a.** Hunter L color values versus ascorbic acid retention (mg./100 g.) in dried tomato crystals stored at 4.4, 21 or 37,8°C for 48, 54 or 60 months.

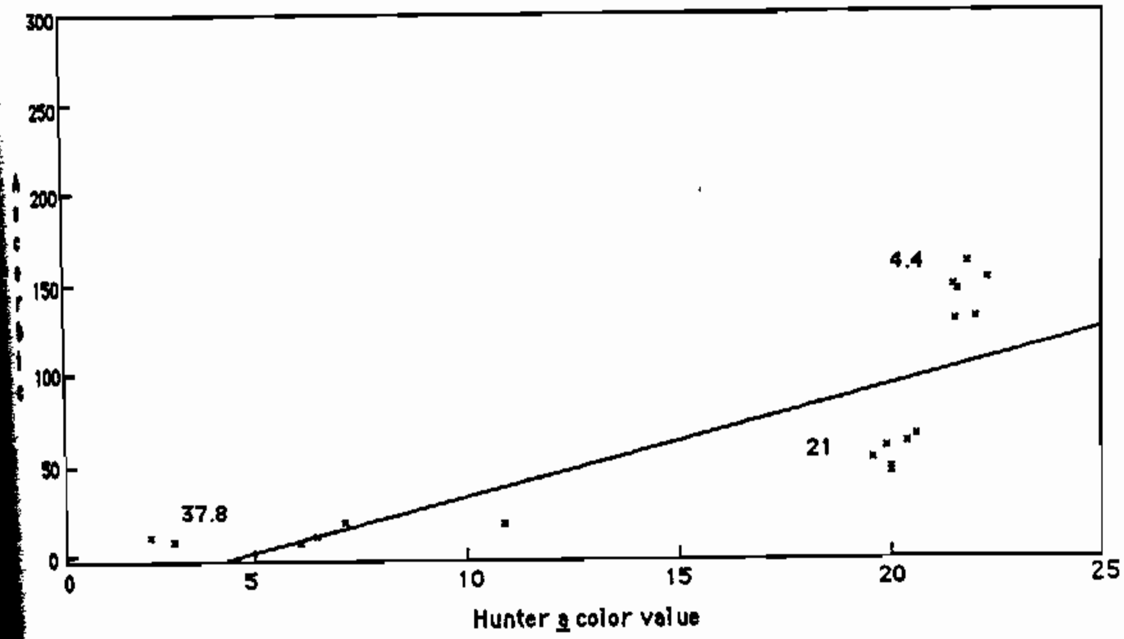

**Figure 2.9b.** Hunter a color values versus ascorbic acid retention (mg./100 g.) in dried tomato crystals stored at 4.4, 21 or 37.8°C for 48, 54 or 60 months.

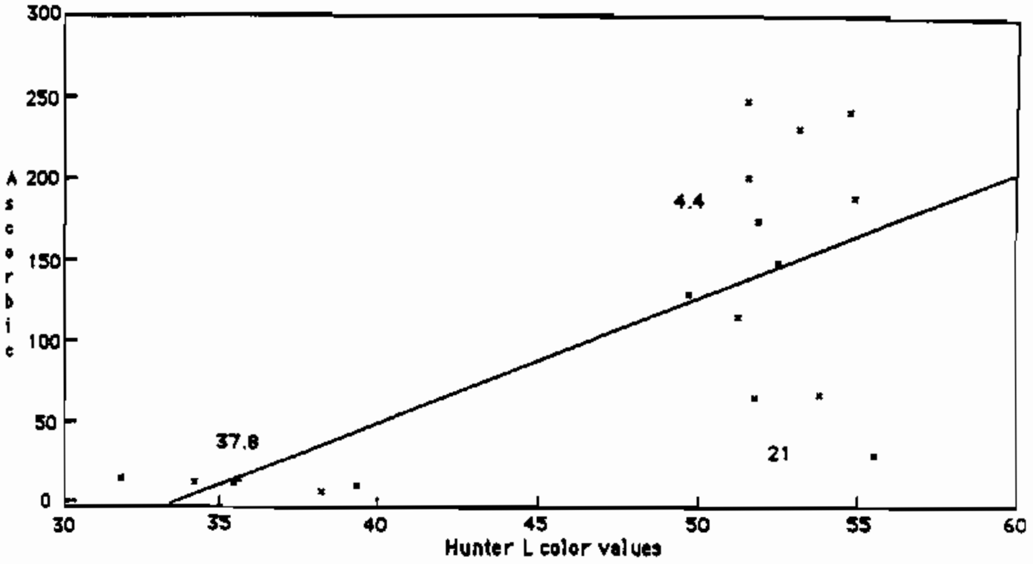

**Figure 2.10a.** Mean Hunter L color values versus ascorbic acid retention (mg./100g.) in dried salad blend stored at 4.4, 21 or 37.8 °C for 48 to 60 months.

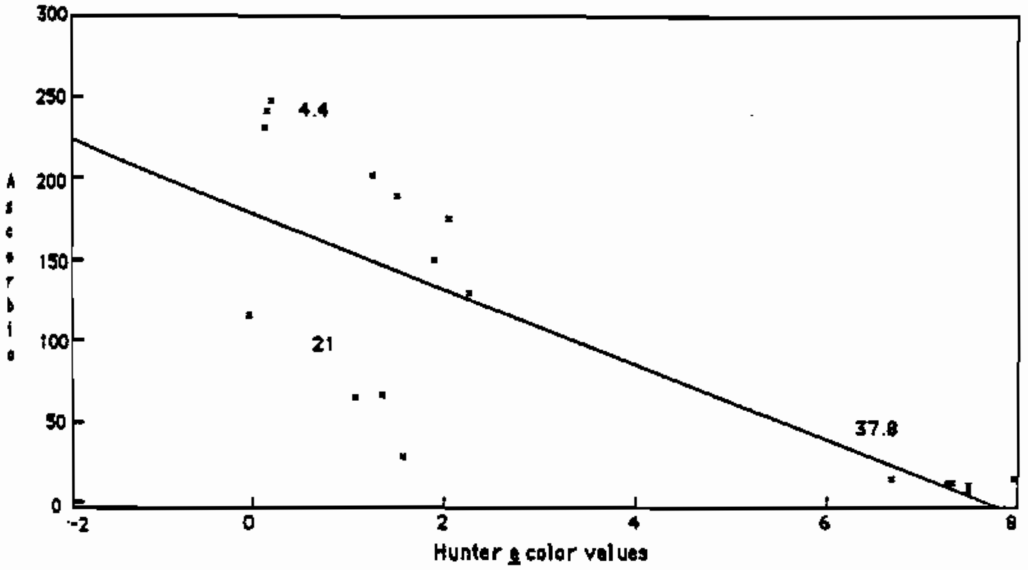

**Figure 2.10b.** Hunter a color values versus ascorbic acid retention (mg./100g.) in dried salad blend stored at 4.4, 21 or 37.8°C for 48, 54 or 60 months.

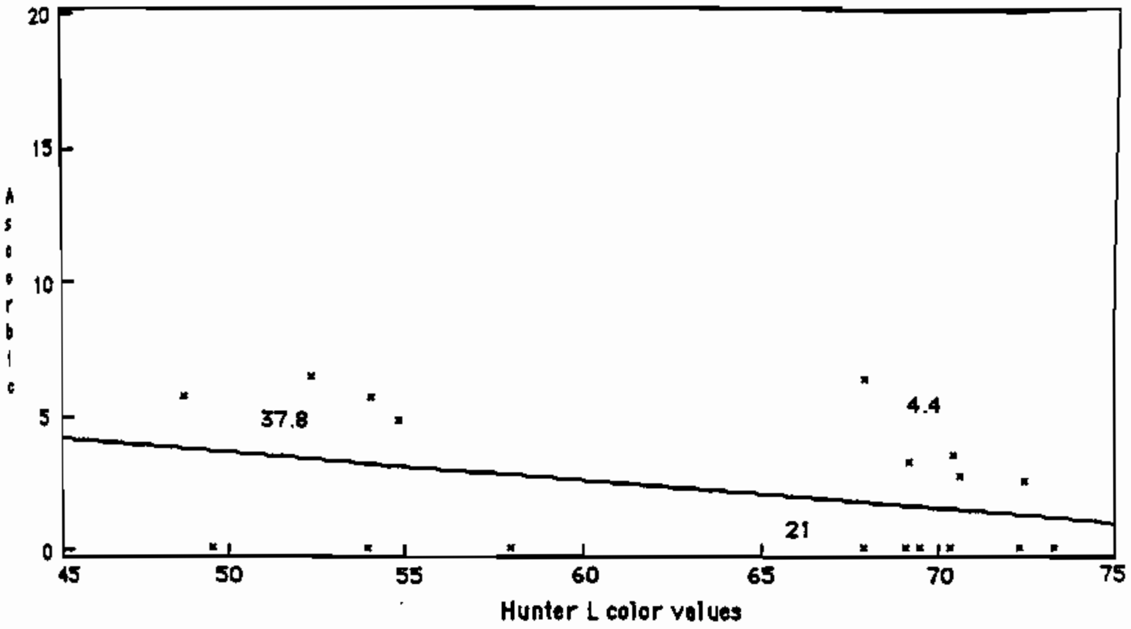

**Figure 2.11a.** Hunter L color values versus ascorbic acid retention (mg./100g.) in dried apples stored at 4.4, 21 or 37.8°C for 48 to 60 months.

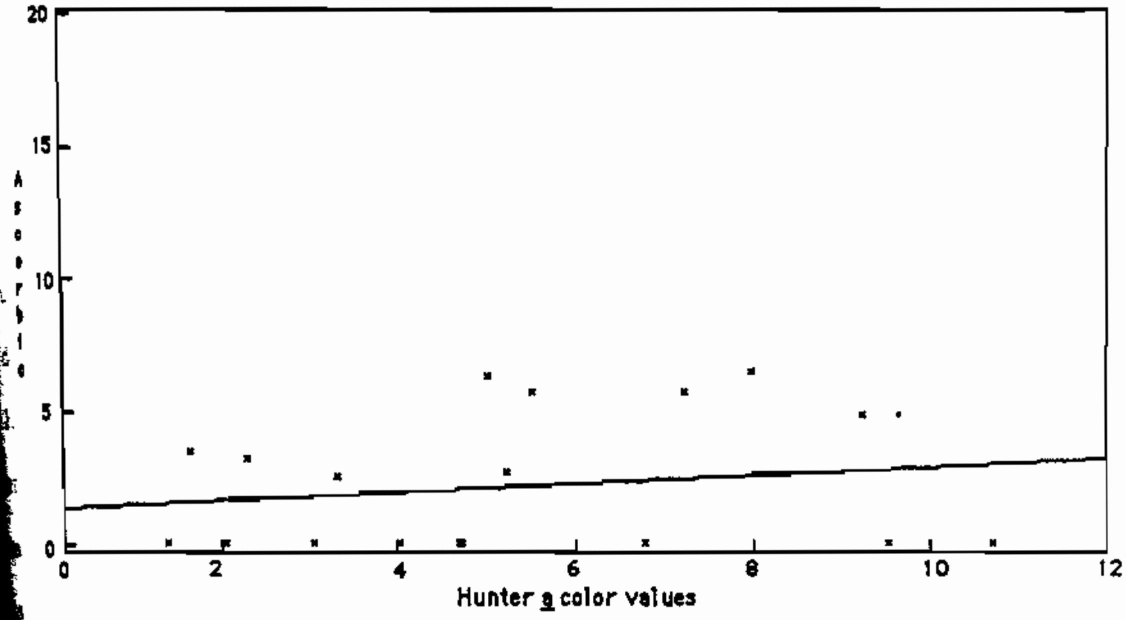

**Figure 2.11b.** Hunter a color values versus ascorbic acid retention (mg./100g.) in dried apples stored at 4.4, 21 or 37.8 °C for 48, 54 or 60 months.

obtained here, browning does occur but a relationship between NEB and ascorbic acid loss is not readily evident (Table 7). Since apples have little amino nitrogen , most of the browning is due to caramelization and furfural formation which does not appear to be as destructive on ascorbic acid.

Table 7. **Mean Values of Hunter Color versus Ascorbic Acid in Dried Tomato and Apple.**

| Temperature °C | Color L | Color a | Ascorbic Acid mg./100 g. |
|---|---|---|---|
| TOMATO | | | |
| 4.4 | 35.77 | 21.77 | 143.69 |
| 21 | 34.64 | 20.05 | 55.84 |
| 37.8 | 18.50 | 5.97 | 9.22 |
| APPLE | | | |
| 4.4 | 71.06 | 3.05 | 1.96 |
| 21 | 65.79 | 4.07 | 1.78 |
| 37.8 | 53.73 | 8.56 | 2.76 |

Table 8 displays mean retention of ascorbic acid at 60 months, sing 24 months as the 100% base. The majority of foods analyzed had a creased retention of ascorbic acid as the temperature increased and a wer retention in air packs. Apples displayed an increased retention 37.8°C due an anomalous increase in ascorbic acid during the last lf of the study. Peaches, green beans and salad blend retained corbic acid well at 4.4 and 21°C. At 37.8°C most foods had proximately 20% retention, showing ascorbic acid's sensitivity to perature and to reactions occurring at 37.8°C.

Carrots, tomatoes and apples exhibited some increased retention of orbic acid at 37.8°C. This may be due to early oxidative loss of

Table 8. **Percent Retention of Ascorbic Acid**

| Food | Temperature °C | | | | | |
|---|---|---|---|---|---|---|
| | 4.4 | 4.4 | 21 | 21 | 37.8 | 37.8 |
| | Atmosphere | | | | | |
| Product | $N_2$* | air | $N_2$ | air | $N_2$ | air |
| Apple | 35.79 | 0.00 | 39.94 | 0.00 | 73.01 | 0.00 |
| Banana | 35.57 | 17.78 | 14.22 | 11.83 | 15.18 | 1.87 |
| Carrot | 20.49 | 12.57 | 17.78 | 14.85 | 20.27 | 14.77 |
| Green Beans | 37.36 | 17.55 | 44.95 | 27.59 | 16.46 | 4.88 |
| Peach | 50.46 | 32.91 | 46.09 | 33.79 | 25.04 | 17.47 |
| Salad Blend | 94.60 | 63.30 | 74.65 | 22.68 | 24.79 | 27.30 |
| mato | 72.93 | 68.54 | 31.87 | 33.05 | 40.15 | 48.34 |

*$N_2$ = Nitrogen packs

exposed ascorbic acid during the first 24 months, then the rate of deterioration decreased or leveled off sometime thereafter with decreased oxygen solubility and a lesser amount of NEB.

Beta-Carotene

The destruction of beta-carotene in the present dried foods was due primarily to an oxidative reaction, as is seen by the large F value a highly significant term in the analysis of variance. Oxidation of beta-carotene can partially be observed by the bleaching of the pigments and the production of off-odors and flavors. Green beans and carrots were especially visible in the bleaching of their pigments in the air packs, some even appeared white.

Salad blend, green beans and carrots each displayed a faster rate of beta-carotene deterioration at 21°C than at 37.8°C, as can be seen in Figure 3.1. It appears that at some temperature between 4.4 and 21°C or 37.8°C, beta-carotene is most susceptible to destruction. laing et al. (1978) reported that although increased temperatures decreases the time of induction of oxidation, the solubility of oxygen round 37.8°C is greatly reduced thus producing, in some cases, a lightly higher or same level of retention of carotene. Also, Boskovic 1979) reported that as the temperature increased, the reversion of cis mers also increased thus producing higher trans carotene values than ected. The loss observed at 21°C is of practical significance, ever the analysis of variance showed the effect of oxygen to be of a greater significance in the deterioration of beta-carotene.

Tomatoes and peaches both showed a slightly greater rate of tene loss from 4.4 to 21°C than at 37.8°C, however, the amount lost

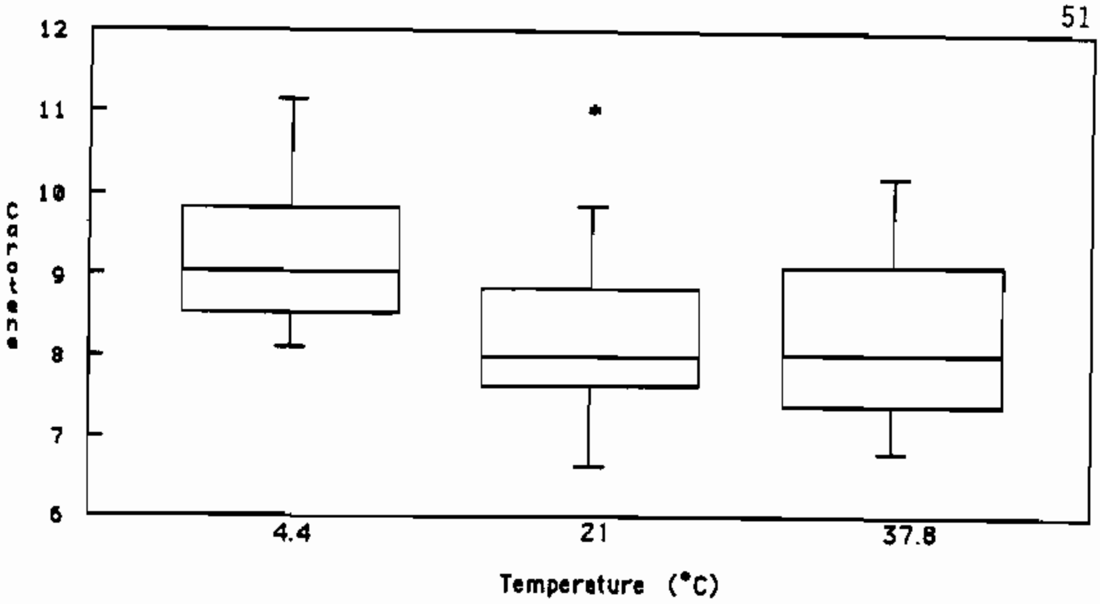

**Figure 3.1.** Storage temperature versus retention of beta-carotene (mg./100g.) in dried salad blend stored at 4.4, 21 or 37.8°C for 42 to 60 months.

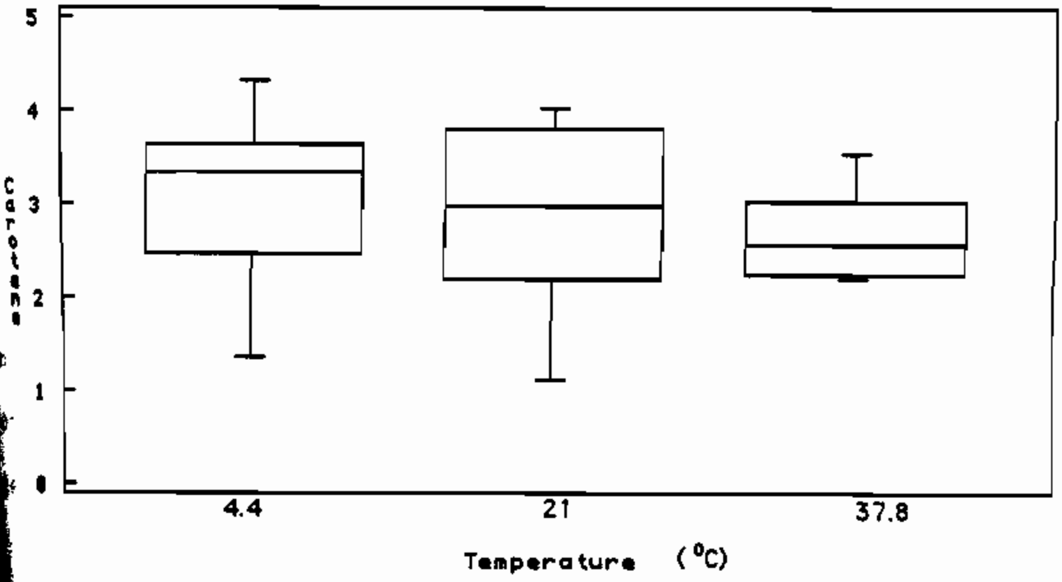

**Figure 3.2.** Boxplot of storage temperature versus retention of beta-carotene (mg./100 g.) in dried vegetable soup.

was not significant. In peaches, the difference in carotene retained between 4.4 and 37.8°C is of practical importance as can be observed by the means, 0.66, 0.54 and 0.46 mg./100 g. at 4.4, 21 and 37.8°C, respectively.

Vegetable soup displayed a steady loss of carotene with increasing temperatures of storage, however the loss of practical importance was seen at 37.8°C by the means, 3.0, 2.9 and 2.7 mg./100 g. for 4.4, 21 and 37.8°C, respectively (Figure 3.2).

Carrots, salad blend, tomato and vegetable soup all were observed to retain beta-carotene fairly well up until 54 months, then a significant drop in retention at 60 months was observed. Figure 3.3 illustrates the time effect in vegetable soup, the mean values being 3.2, 3.3, 2.9 and 2.1 mg./100 g. at 42, 48, 54 and 60 months, respectively.

In tomatoes, beta-carotene did not change significantly from 42 to 60 months of storage (Figure 3.4). This may be attributed to reversion of the cis isomers formed thus maintaining the carotene values fairly constant or possibly a protective effect of the high amounts of lycopene present. Somewhere between 54 and 60 months of storage the rate of autoxidation may become greater than the rate of reversion.

The loss of peach carotene each 6 months is not significant until the difference between 42 and 54 months is considered. They had a significant decrease in carotene after 54 months of storage which carried over to 60 months also (Figure 3.5).

Six dried foods analyzed for beta-carotene were significantly affected by residual oxygen in the sealed cans, but peaches showed no

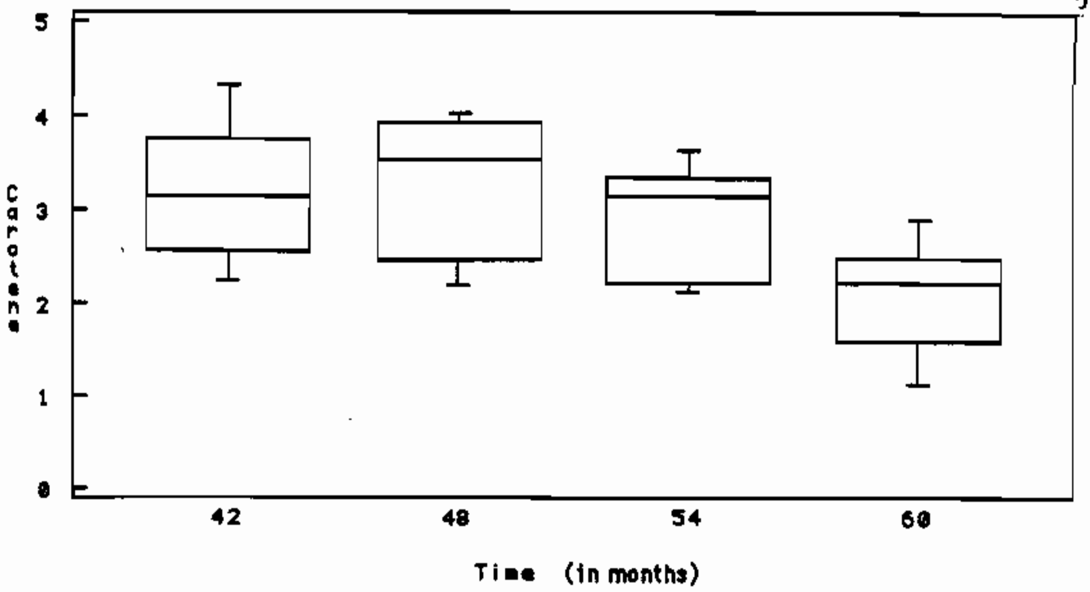

**Figure 3.3** Boxplot of the effect of storage time on the retention of beta-carotene (mg./100 g.) in dried vegetable soup.

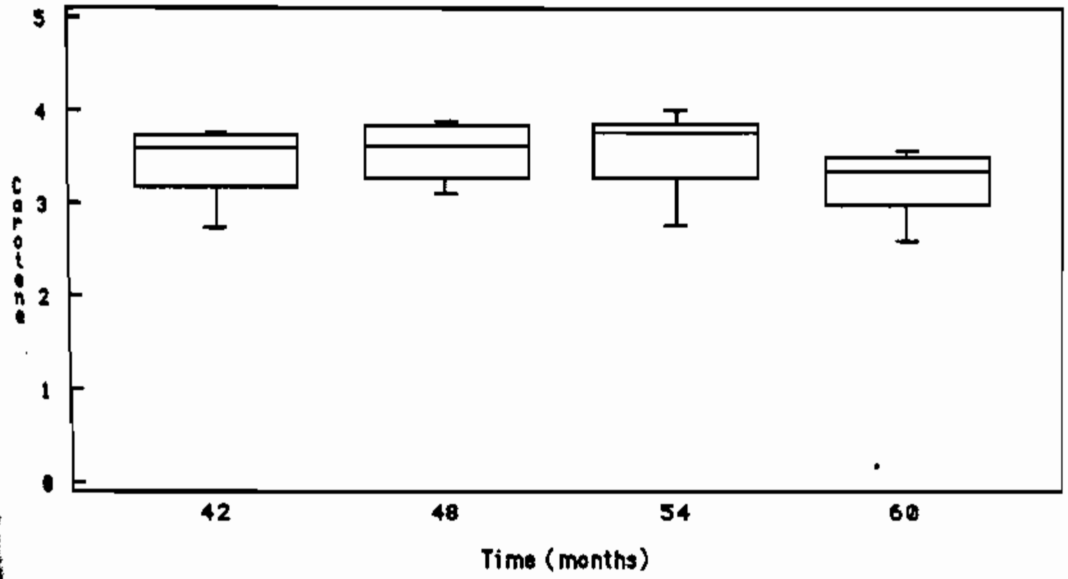

**Figure 3.4.** Mean storage time versus retention of beta-carotene (mg./100 g.) in dried tomato crystals.

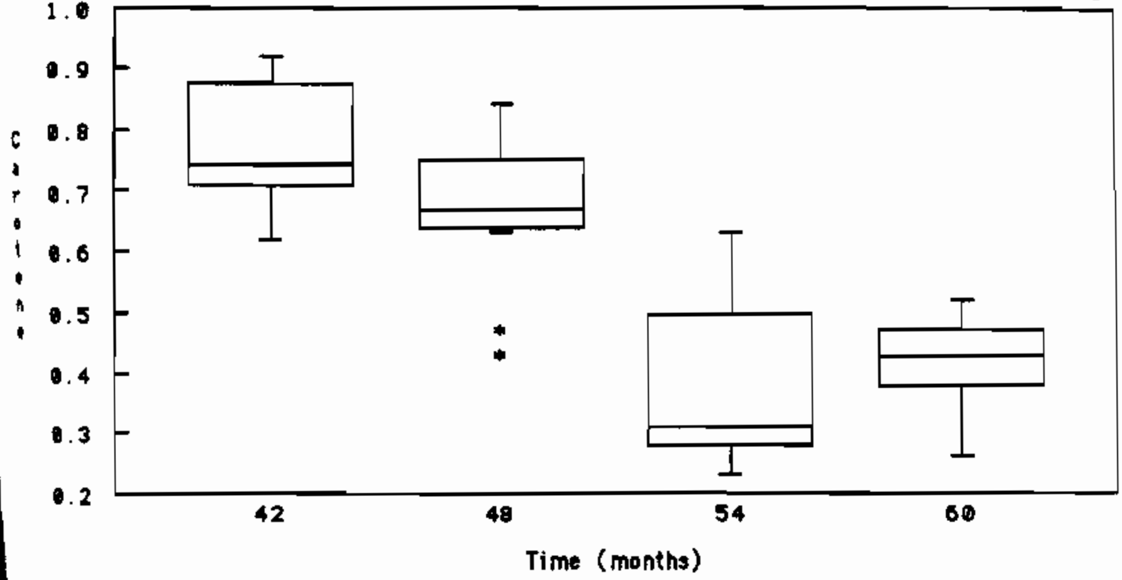

**Figure 3.5** Boxplot of storage time versus retention of beta-carotene (mg./100 g.) in dried peaches.

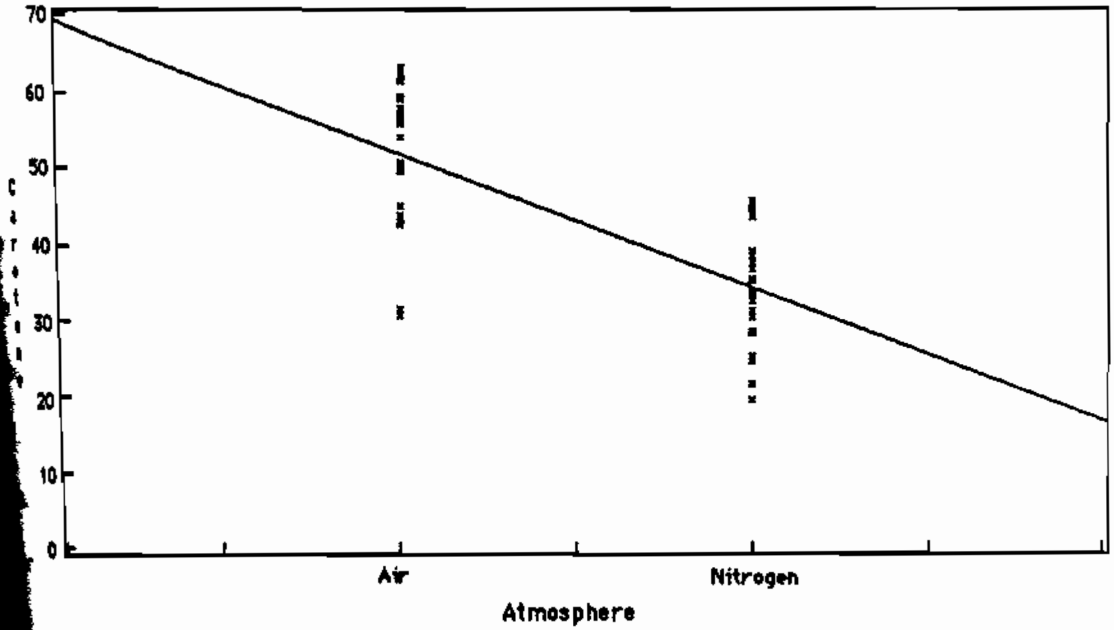

**Figure 3.6a** Package atmosphere versus retention of beta-carotene (mg./100 g.) in dried carrots.

significant effect. The atmospheric effect for carrots is seen in Figure 3.6.

In general, carotene loss had a nearly linear relationship to oxygen taken up by the food, which is readily evident with tomatoes in Figure 3.7, as is the effect of increasing temperature.

Peaches, carrots and green beans had a more rapid decrease of carotene as the oxygen decreased at 21°C than at 37.8°C (Figure 3.8), except at 42 months. Carrots increased in <u>beta</u>-carotene content at 37.8°C after 54 months and slightly after 60 months compared to samples stored at 21°C (Figure 3.9). This could be isomer reversion occurring, analytical error or differences before packaging. Salad blend also exhibited a trend of decreasing carotene as headspace oxygen decreased with increasing temperature. At 42 months, salad blend carotene dropped sharply at 21°C and had higher retention at 37.8°C. Vegetable soup also demonstrated a linear relationship between carotene loss and oxygen uptake at 42 and 54 months (Figure 3.10). The 48 month analysis howed higher retention in carotene at 21°C and higher retention at .8°C in the 60 month analysis. Reasons for these increases are not ar, however previous research indicated that carotene levels can rease with time and temperature due to isomer reversion.

The general linear model showed that the atmospheric effect on -carotene is highly significant in carrots, green beans and tomato. may be due to higher pigment content and availability to oxidation other foods tested. Peaches were most stable to carotene tion as there was no relation between residual oxygen and carotene . Carrots, green beans, tomatoes and peaches had a faster rate

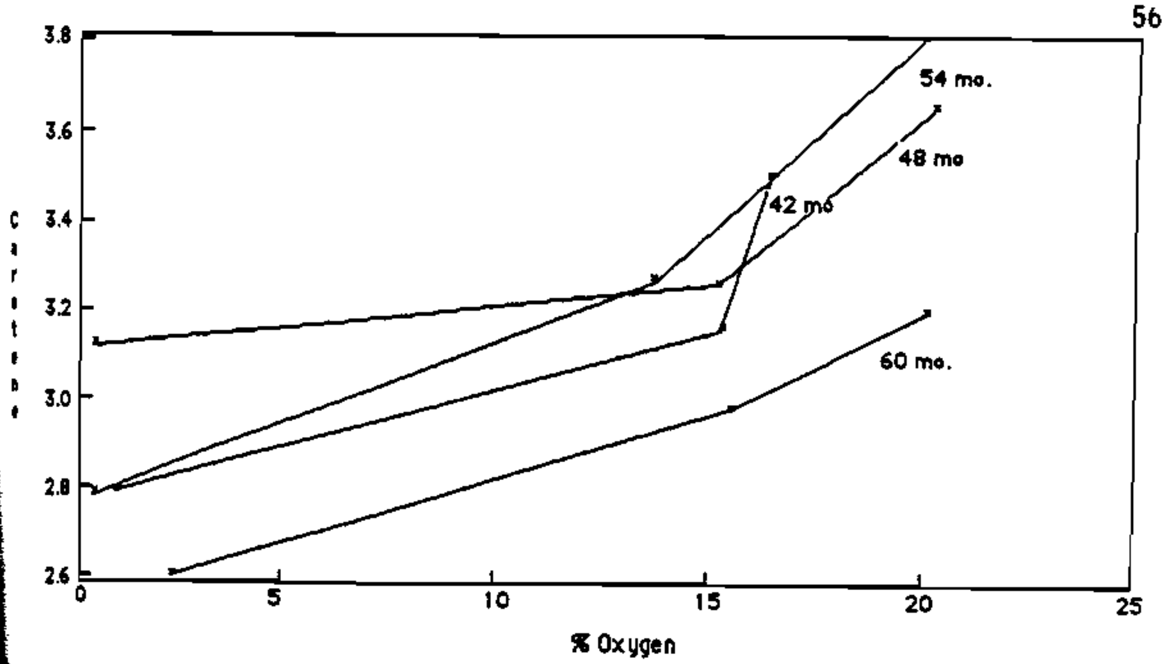

**Figure 3.7** Residual oxygen versus retention of <u>beta</u>-carotene (mg./100 g.) in dried tomato crystals stored between 42 to 60 months.
** The 37.8°C data points are on the far left, 21°C in the middle and the 4.4°C on the far right.

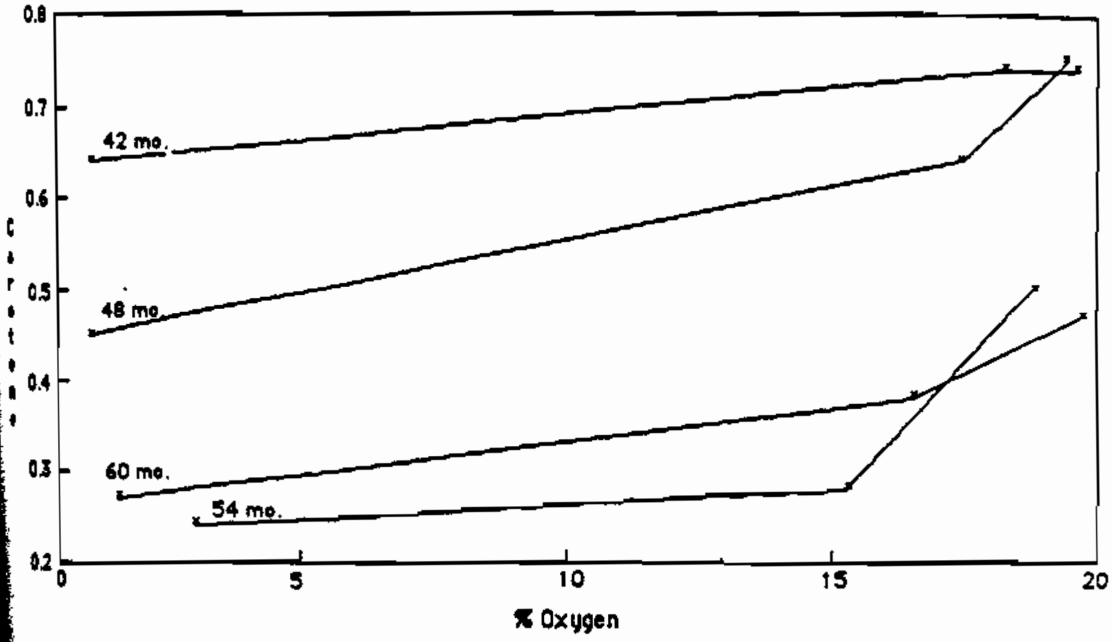

**Figure 3.8** Residual oxygen versus retention of beta-carotene (mg./100 g) in dried peaches stored 42 to 60 months.
** The 37.8°C data points are on the far left, 21°C in the middle and the 4.4°C on the far right.

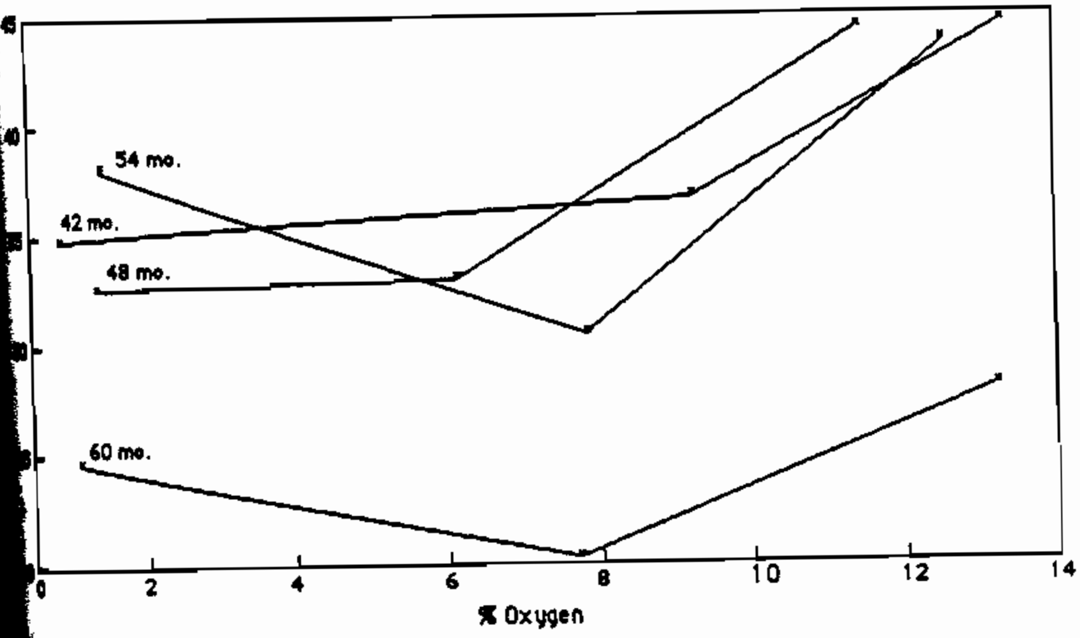

**Figure 3.9** Percent oxygen versus beta-carotene (mg./100 g.) in dried carrots stored 42 to 60 months.
** The 37.8°C data points are on the far left, 21°C in the middle and 4.4°C on the far right.

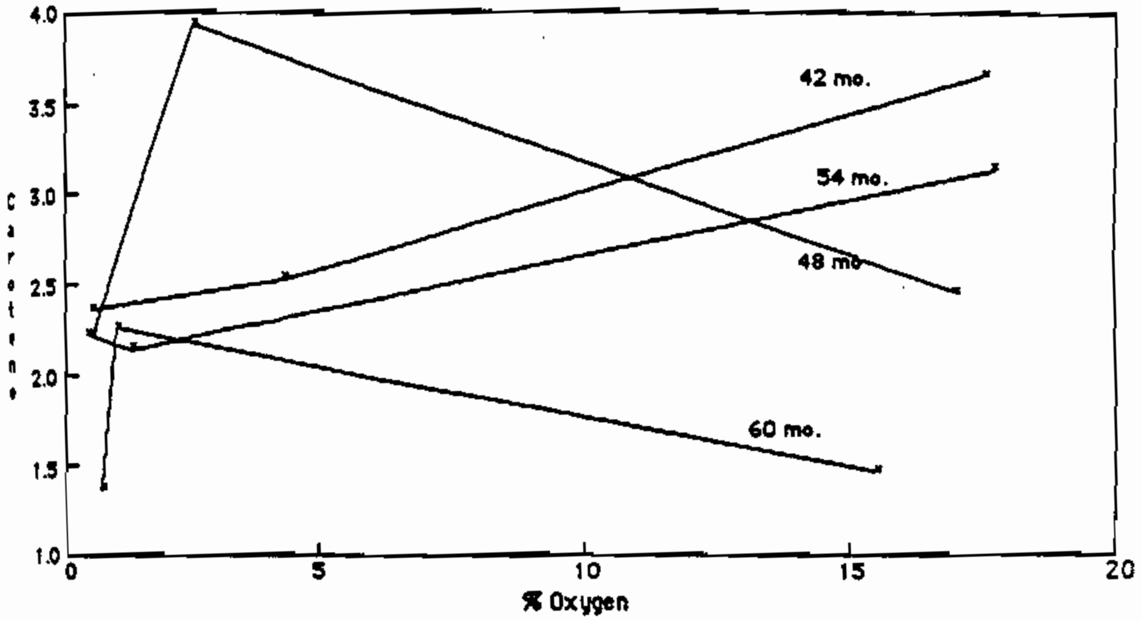

**Figure 3.10** Residual oxygen versus retention of beta-carotene (mg./100g) in dried vegetable soup mix.

** The 37.8°C data points are on the far left, 21°C in the middle and th 4.4°C points are on the far right.

of carotene degradation in air packed samples than nitrogen packed samples across the temperature range (especially from 4.4 to 21°C). This can easily be seen by comparing the means for the interaction in green beans in Table 9.

Table 9. **Beta-Carotene versus Atmosphere in Green Beans and Salad Blend Stored for 42 to 60 Months.**

| Temperature °C | Atmosphere | Beta-Carotene mg./100 g. |
|---|---|---|
| Green Beans | | |
| 4.4 | $N_2$ | 2.81 |
| 4.4 | air | 1.27 |
| 21 | $N_2$ | 2.72 |
| 21 | air | 1.00 |
| 37.8 | $N_2$ | 2.62 |
| 37.8 | air | 1.00 |
| Salad Blend | | |
| 4.4 | $N_2$ | 9.89 |
| 4.4 | air | 8.58 |
| 21 | $N_2$ | 9.14 |
| 21 | air | 7.57 |
| 37.8 | $N_2$ | 8.75 |
| 37.8 | air | 7.79 |

No significance was obtained between Hunter color values and beta-arotene retention except for salad blend and tomato. Salad blend ecreased slightly in the L value with decreases in carotene levels, at 7.8°C. The a values increased significantly at 37.8°C which was also lated to lower carotene values (Figure 3.11). Although tomato ystals appeared burnt in the 37.8°C samples, no significant changes L and a values were obtained.

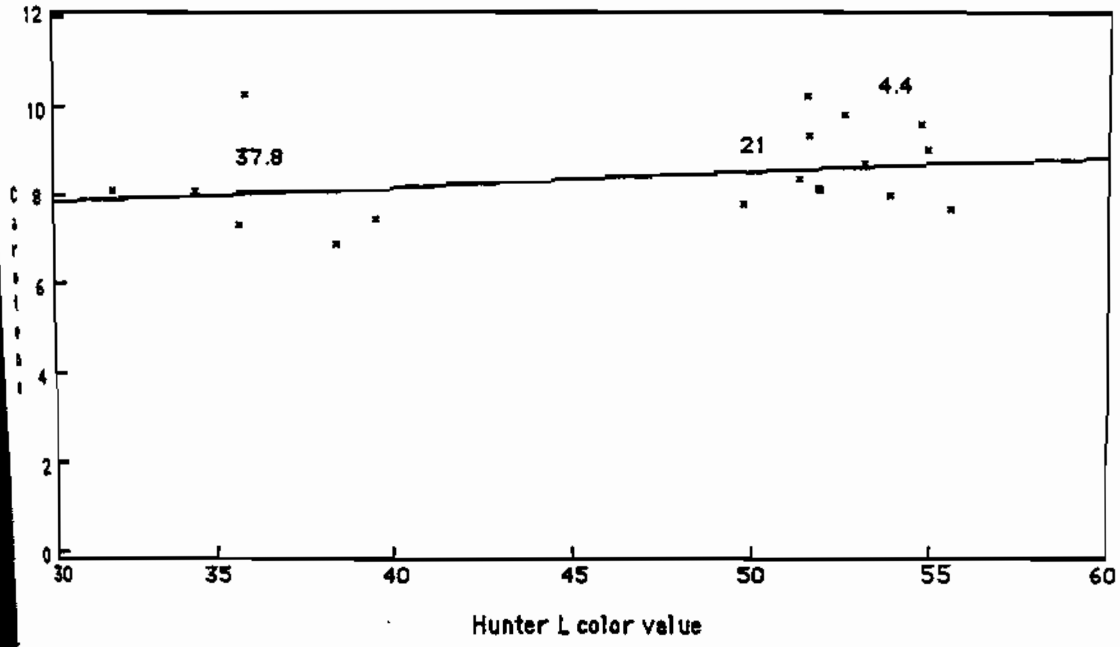

Figure 3.11a Hunter L color values versus retention of beta-carotene (mg./100 g.) in dried salad blend.

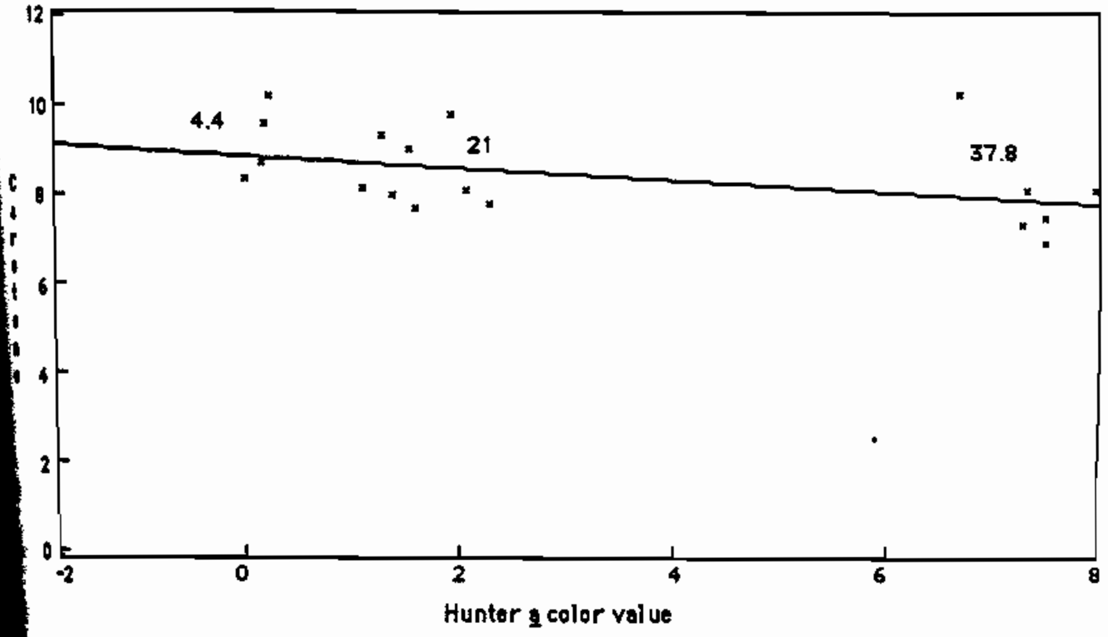

Figure 3.11b Hunter a color values versus retention of beta-carotene (mg./100 g.) in dried salad blend.

Table 10. **Mean Percent Retention of Beta-Carotene and Vitamin A in Dried Foods Stored for 60 Months.**

| | Temperature (°C) | | | | | |
|---|---|---|---|---|---|---|
| Food | 4.4 | 4.4 | 21 | 21 | 37.8 | 37.8 |
| | Atmosphere | | | | | |
| Product | $N_2$* | air | $N_2$ | air | $N_2$ | air |
| Carrot | 45.42 | 44.07 | 83.98 | 42.84 | 72.26 | 57.89 |
| Green Beans | 85.80 | 53.96 | 87.82 | 66.07 | 100 | 44.21 |
| Peaches | 49.04 | 60.26 | 61.11 | 77.55 | 62.12 | 57.45 |
| Tomato | 83.02 | 81.79 | 88.35 | 93.42 | 95.11 | 90.90 |
| Salad Blend | 70.37 | 69.58 | 65.13 | 81.81 | 86.68 | 100 |
| Veg. Soup | 32.60 | 41.95 | 70.39 | 50.37 | 68.39 | 100 |
| Butter (IU Vitamin A) | 78.58 | 64.84 | 66.42 | 73.77 | 74.32 | 62.87 |

* $N_2$ = Nitrogen packs

The general trend seen with beta-carotene (Table 10) is an increased retention with increasing temperatures. Carrot and vegetable soup showed an increased retention from 4.4 to 21°C then a smaller increase at 37.8°C compared to 4.4°C. Green beans, salad blend and tomatoes displayed a relatively stable retention of carotene across storage temperatures. This could be due to a larger loss during the first 24 months of beta-carotene in these foods held at the higher temperatures and a slower rate of deterioration thereafter, whereas in the 4.4°C samples it takes longer to reach the maximum loss. This trend may also be due to the reversion of cis to trans isomers which occurs more rapidly at 37.8°C.

Vitamin A

The Carr/Price analytical method was utilized to measure the total vitamin A content in butter. Stability of vitamin A in butter appears similiar to beta-carotene because oxidative deterioration is the major factor in it's loss. Butter decreased slightly in vitamin A until 54 onths when an increase was observed which decreased again at 60 onths. Vitamin A was sensitive to increasing temperature (Figure .1). Between 4.4 and 21°C there was a greater loss in vitamin A than tween 21 and 37.8°C. The loss of vitamin A was significant at all peratures, thus showing the importance of a low storage temperature any long term storage of dried butter. Also the loss of vitamin A dried butter in air packed samples was significantly greater than se packed in nitrogen (Figure 4.2). The rate of vitamin A loss was same in both atmospheres. There appears to be a relationship ween the decrease in residual oxygen and the loss of vitamin A

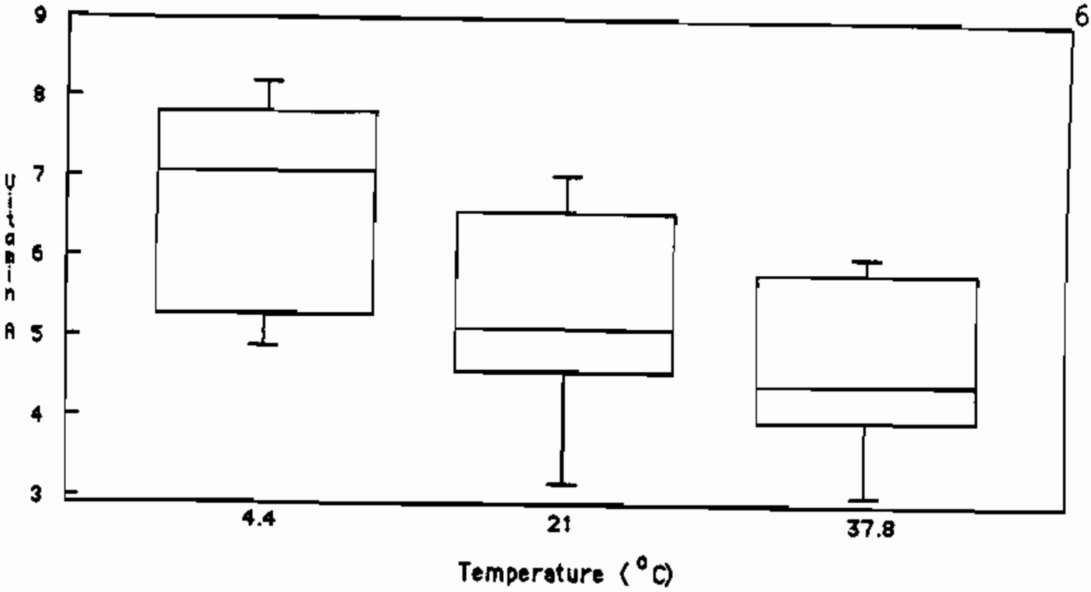

**Figure 4.1** Storage temperature versus retention of vitamin A (IU) in dried butter.

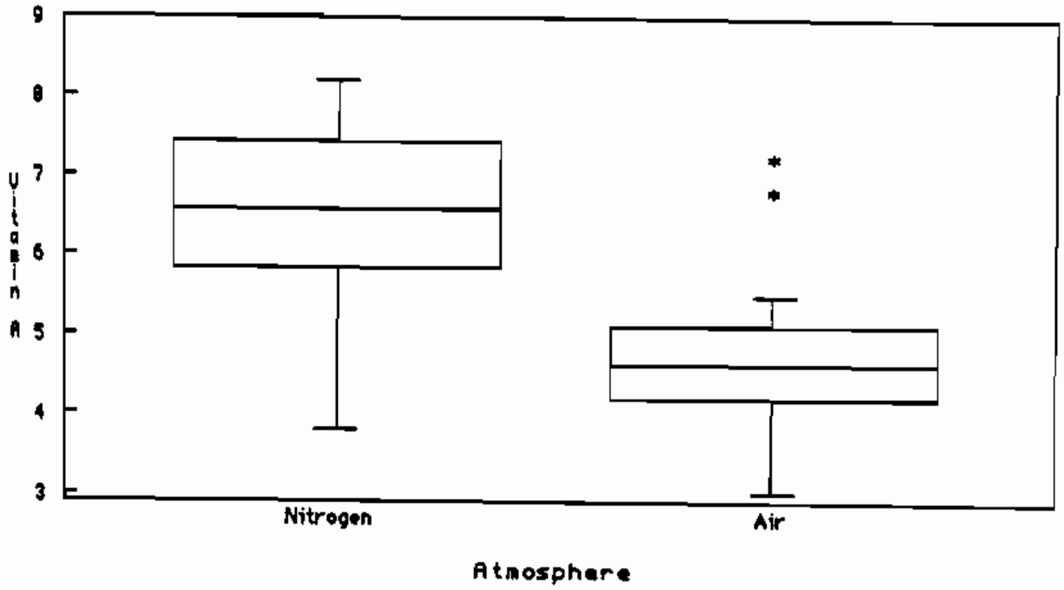

**Figure 4.2** Package atmosphere versus retention of vitamin A (IU) in dried butter.

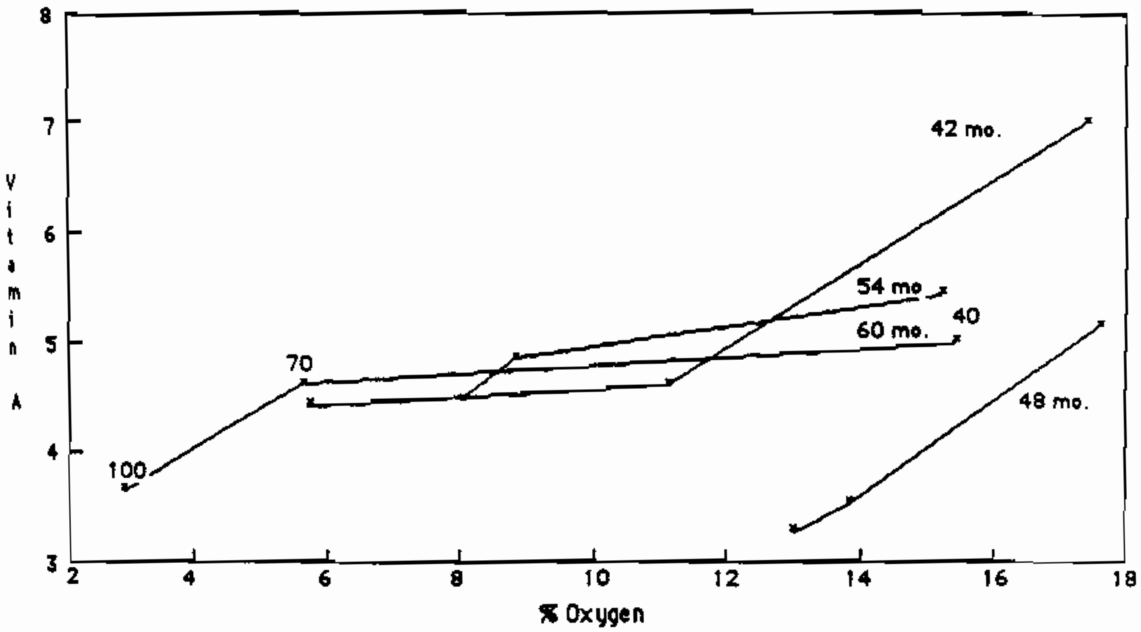

**Figure** 4.3 Residual oxygen versus retention of vitamin A in dried butter.

** The 100°F data is on the far left, the 70°F in the middle and the 100 °F on the far right.

content in butter (Figure 4.3 and Table 11). At 42 months there is a more dramatic drop between 4.4 and 21°C in vitamin A as the oxygen is taken up. At 48 months there was a steady decrease in vitamin A across all temperatures of storage but the oxygen content remained fairly high in the 37.8°C samples. At 54 and 60 months there was a steeper slope between 21 and 37.8°C in the loss of vitamin A. The data appears to show a change in the deterioration of vitamin A such that as the time of storage increased there was a shift from 21 to 37.8°C for the greater deterioration of the vitamin. Nonetheless, packaging of butter in air causes a significant loss of vitamin A to oxidative reactions.

Table 11. **Mean Values of Oxygen and Vitamin A in Dried Butter**

| Temperature<br>C | Oxygen<br>% | Vitamin A<br>IU |
|---|---|---|
| 4.4 | 1.0 | 7.73 |
| 21 | 0.8 | 6.29 |
| 37.8 | 0.7 | 5.36 |

In Table 10 the retention of vitamin A in butter is illustrated or 5 years of storage. The retention of vitamin A remained fairly nstant during the 5 years at all temperatures. This may also be due a greater loss in the first 24 months in the 37.8°C samples which n levels off or slows thereafter, thus giving an appearance of a er retention when compared to the 24 month data.

### e Panel

An analysis of variance was run on taste panel data on all the s except yeast, using the program Rummage II (Scott et al.). The model Y(ijkl) = T(i) + H(k) + A(l) + S(ij) + HS(kij) + AS(lij) + ) + TA(il) + HT(ik) + THA(ikl) + HAS(klij) + E , was used for carrots, apples and stroganoff as representatives of the remaining foods where T= time, H= temperature, A=atmosphere and S= subject. The interactions TA, HT and THA were found to be insignificant for all three foods so these were eliminated from the model for the remaining foods. The adjusted sum of squares was used for the one-tailed F test with a critical F value of 3.95 using a 95% confidence level. A multivariate analysis was not used due to linear dependencies between the four responses and to present the results in the same format as the previous results by Norseth (1986). Four responses were analyzed separately: flavor, appearance (or color), texture and an overall rating; the taste panel response form used is located in Appendix L. All response mean values are located in Appendix K. All responses were obtained from a line scale of o as very poor to 100 as very good.

Peaches, salad blend and tomatoes did not exhibit a significant effect across time for any responses. Butter, eggs, navy beans, and anut butter exhibited no significant response to temperature or tmosphere.

Apples showed a significant linear time effect after 54 months pared to 42 months for appearance, texture, and overall responses. r example, with texture the mean values were 69, 62, 55 and 58 for , 48, 54 and 60 months, respectively. The flavor and overall ponses in bananas showed a significant quadratic decrease in values ss time, as was illustrated by means for flavor: 60, 58, 56 and 49 42, 48, 54 and 60 months, respectively. The means also showed a ificant decrease with increased temperature which was practically ificant at 37.8°C compared to either 4.4 or 21°C. For example the means for overall responses were 72, 65, and 39 at 4.4, 21 and 37.8°C, respectively. The loss in banana chips of consumer acceptability in flavor and in overall with time and with temperature was probably related to oxidative rancidity which had an induction period and after 60 months and/or storage at 37.8°C, rancidity was readily evident.

Only peaches indicated a significant response for change in appearance with the interaction of temperature and atmosphere. The mean values are presented in Table 12. Samples stored at 37.8°C had been eliminated previously because of low acceptability.

Carrots displayed a significant, negative quadratic trend over time for appearance, with the means of 63, 60, 52 and 62 for 42, 48, 54 nd 60 months, respectively. The only decrease of practical ignificance is at 54 months. Only flavor showed a significant mperature effect but all responses decreased at 21°C compared to .4°C which was of practical significance.

Table 12. **Mean Values for Temperature by Atmosphere Effect in Dried Peaches from 42 to 60 Months.**

| Temperature °C | Atmosphere | Appearance Response |
|---|---|---|
| 4.4 | Nitrogen | 77 |
| 4.4 | Air | 70 |
| 21 | Nitrogen | 42 |
| 21 | Air | 39 |

All panel responses for green beans produced a significant tive quadratic trend which was practically significant at 54 months mparison to 42 months. For example, with texture the mean values 69 and 55 at 42 and 54 months. The atmospheric effect on flavor was significant but not of practical importance. The panel responses were all significantly affected by the storage temperature of the sample. For example flavor, appearance, and overall decreased from 67, 71 and 67 at 4.4°C to 58, 58 and 57, respectively at 21°C. The 37.8°C samples were unacceptable before 42 months.

Navy beans had a significant linear and quadratic trend for texture and overall and a significant, negative quadratic trend for flavor but none of these were of practical importance.

All four responses decreased significantly with temperature in salad blend. For example, appearance, flavor and overall decreased from 79, 74, and 73 at 4.4°C to 65, 61 and 61, respectively at 21°C.

Potatoes showed very significant linear decreased responses with time. Texture and overall responses decreased at a much higher rate between the 54 and 60 month samples. The effect of atmosphere on appearance was significant and of practical importance.

Vegetable soup showed a significant time effect on appearance but the 60 month mean of 63 compared to 73 at 42 months is the only ecrease of practical importance. Appearance and texture scores isplayed a significant linear decrease with increasing temperatures. ll response mean values showed a decrease with temperature of ctical importance. For example, with appearance, the mean values 84 and 58 for 4.4 and 21°C, respectively; whereas for overall the n values are 80 and 58 for 4.4 and 21°C. Flavor and overall ponses also had a significant atmospheric effect with decreases from to approximately 65 at 4.4 versus 21°C, respectively.

Flavor, texture and overall scores in butter showed a significantly negative, quadratic trend across time of storage. Only the 48 month mean values were significantly lower than the 42 month values. Butter also had a significant interaction among time, temperature and atmosphere in the texture responses.

Milk flavor values were significantly lower, 40 at 48 months compared to 66 at 42 months.

Eggs displayed a significant effect only in appearance with time. The mean values are 80, 73, 66 and 66 for 42, 48, 54 and 60 months, respectively.

Macaroni showed a significant flavor decrease with time as the mean values show: 80 and 64 for 42 and 54 months, respectively. Macaroni had a significant decrease in scores for flavor, appearance and overall as the temperature increased. This can be illustrated by the mean values for appearance, which are: 80 and 73 at 4.4 and 21°C, respectively.

Rolled oats indicated a significant effect with time in appearance due to time, which is not of practical importance. Wheat showed this same effect with flavor and overall scores. The 37.8°C samples were significantly lower than the 4.4 or 21°C samples, but the 4.4 and 21°C samples showed little or no change. This is illustrated by the mean values for flavor; 78, 77 and 48 at 4.4, 21 and 37.8°C, respectively.

TVP displayed no significant effects. Peanut butter showed significant time effects for flavor, appearance and overall responses.

Stroganoff displayed a time effect which was significant but not practical importance. Only flavor and overall responses showed a decrease in score of practical importance at 60 months compared to 42 or 48 months. Even though the texture responses were the only ones with a significant temperature effect by the F test, all the other responses showed a decrease in mean scores between 4.4 and 21°C which are of practical importance. This can be seen by the means of 77 and 49 at 4.4 and 21°C, respectively for flavor.

In general, it appears that time in this taste panel, is the major factor in these 19 foods which affects the acceptability of the product most. Most of the foods stored at 21°C were still acceptable to consumers, but eggs, carrots, peaches and stroganoff stored at 21°C were unacceptable by 60 months and all the foods except bananas, rolled oats, peanut butter, TVP and wheat were unacceptable by 42 months when stored at 37.8°C. After 60 months, bananas were unacceptable when stored at 37.8°C.

## Summary

The retention of thiamin, ascorbic acid, beta-carotene and vitamin A in dehydrated foods were studied from 42 to 60 months of storage at 4.4, 21 and 37.8°C and in air or nitrogen packs. Thiamin was observed to be fairly stable over time, especially in milk and oats, however it was most susceptible to thermal deterioration and destruction by non-enzymatic browning. The thermal deterioration of thiamin occurred at a maximum rate somewhere between 21 and 37.8°C. Eggs, navy beans and macaroni had a total loss of thiamin at 37.8°C after 42 months. Non-enzymatic browning appeared to accelerate thiamin loss in most foods stored at 37.8°C.

Ascorbic acid is very susceptible to oxidative and thermal deterioration especially at 37.8°C. Apples displayed a total loss of ascorbic acid in the air packed samples. Salad blend and tomatoes showed a 2-5 times decrease in ascorbic acid as the temperature increased from 4.4 to 21 or 37.8°C. Most samples showed an increased loss of ascorbic acid possibly due to oxidation, occurring between 4.4 d 21°C. Most samples also showed that a decrease in residual oxygen s generally related to a decrease in ascorbic acid. Non-enzymatic owning, measured by way of Hunter L and a color values, was related ascorbic acid loss at 37.8°C in all the foods analyzed except for ples.

Beta-carotene deterioration in dried foods was greatest between and 21°C, where the solubility of oxygen is high. The majority of the foods retained beta-carotene well up until 54 months, then decreased at 60 months. This decrease at 60 months was believed due to the rate of oxidation finally exceeding the reversion of cis to trans isomers, a phenomena which seems to be especially apparent in tomatoes. Beta-carotene showed approximately a linear relationship with residual oxygen such that as the residual oxygen decreased, the loss of beta-carotene increased.

Vitamin A in dried butter was retained better in the nitrogen packs than the air packs, and showed a relationship between decreasing oxygen values and increased vitamin A loss. Vitamin A deterioration increased as the temperature of storage increased, especially between 4.4 and 21°C.

Overall, the 4.4°F samples seemed to be the best for consumer acceptability for flavor, appearance, or texture. Sixteen of the nineteen foods tasted by panelists were unacceptable by 42 months when stored at 37.8°C. Time of storage was the main factor in determining consumer acceptability in this study.

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# Appendix A

## Thiamin - Analytical Method

Reagents and apparatus

a) Sodium acetate, 2.5 normal - dissolve 205 g reagent NaOAc anhydrous powder, (BYU chem stores: various chem supply sources), 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 water.

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

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

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

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

h) Sodium hydroxide solution, 15% - dissolve 150 g of reagent NaOH llets, (BYU chem stores), in refrigerated water 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 dessicator. Dissolve in 1 liter 25% ethanol.

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

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 tores), is added to 100 ml 40% KOH in $H_2O$. Reflux 2-3 hours then still at rate of 2-3 drops per second in all-glass apparatus.

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

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

o) Enzyme solution - Dissolve 0.3 g Mylase 100 (US Biochem. Corp. 99) in 50 ml 2.5 N NaOAc. Prepare daily.

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

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

r) Fluorometer - Turner Fluorometer model III.

) 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 ocasionally. 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 water. Centrifuge again for 10-15 minutes, filter the suupernatant. Repeat again, then filter supernatant and also the pellet. Wash well with water). Pour filtrate into 100 ml volumetric flask and make to volume with water. Mix thoroughly.

Purification

Pass 25 ml of filtered solution thru prepared chromatographic olumn. Wash with three 10-ml portions of almost boiling water. Do ot permit surface of liquid to fall below surface of resin.

Elute the thiamin by passing two 10-ml portions of near boiling id KCl solution thru column. Do not permit surface of liquid to fall low surface of resin until final portion of acid-KCl solution has n added. Collect eluate in 25 ml volumetric flask. Cool and dilute 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 for 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 fluoresence 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 according to the formula:

$$\frac{(S \times X) + Y}{W} \times 10$$

Where: S = slope from the standard curve

Y = Y-intercept

W = dry weight

# Appendix B

## 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'$^{TM}$ Grade) in 100 ml of 9 N $H_2SO_4$ and filter. Keep frigerated when not in use; make new each week.

c) 10% Metaphosphoric acid - dissolve 100 g of reagent grade $HPO_3$ llets, (BYU chem stores), in 900 ml $H_2O$ and dilute to 1 liter with 0.

d) 5% Metaphosphoric acid - dilute 500 ml 10% $HPO_3$ to 1 liter with 0.

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

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

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

h) Ascorbic acid standard, 1 mg/ml - dissolve 100 mg L-ascorbic 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 Blender 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).

### idation

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

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

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

### tion of osazone

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

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

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.

### asurement of Color

a) Set spectrophotometer to 540 nm.

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

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

### dards

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

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

) Pipet 20 ml oxidized solution into a 500 ml volumetric flask. g thiourea. Dilute to volume with 5% $HPO_3$.

) Prepare final diluted dehydroascorbic acid solutions containing

1, 2, 4, 5, 8, 10, and 12 mcg per ml by pipetting 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:

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

where

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

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

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

# Appendix C

## Beta-carotene - Analytical Method

### pparatus

a) Chromatographic tube - 12.5 mm id x 30 cm reduced to 10 cm od

be at bottom, pyrex.

b) Vacuum filtration device - for collection of eluate.

c) Spectrophotometer - Bausch and Lomb Spectronic 20.

### gents

a) Acetone - reagent grade, BYU chem stores.

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,

chem stores), in methanol.

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

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

) Absorbent - MgO-filter aid (1:1) heated overnight in drying

60°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 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 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 $H_2O$. 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 <u>beta</u>-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 dry weight, grams; 0.25 is a factor for the extinction coefficient of *beta*-carotene $E^{1\%}$cm = 2500.

# Appendix D

## Vitamin A - Analytical Method

### Reagents and apparatus

a) Methanolic KOH - add 20 g 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 aution. Keep in a dark bottle.

f) Vitamin A reference solution - USP reference standard solution ntaining all-<u>trans</u> retinyl acetate in cottenseed oil.

g) Spectrophotometer - Bausch and Lomb Spectronic 20.

### cedure

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

b) Reflux 10 minutes at 110°C.

c) Cool under 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 nhydrous $Na_2SO_4$ (to remove moisture). Swirl and allow to stand for 1- minutes.

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

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

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

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

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

) Prepare standard curve using several known dilutions of vitamin dard solution. Dilute with $CHCl_3$.

## APPENDIX E. Mean Values of Residual Oxygen (%) in Low-Moisture Foods

| % Oxygen | Time month | Temp C | Atmosphere<br>1=Nitrogen pack<br>2= Air pack |
|---|---|---|---|
| **APPLE** | | | |
| 1.2 | 42 | 4.4 | 1 |
| 20.3 | 42 | 4.4 | 2 |
| 0.9 | 42 | 21 | 1 |
| 19.7 | 42 | 21 | 2 |
| 0.8 | 42 | 37.8 | 1 |
| 14.5 | 42 | 37.8 | 2 |
| 0.5 | 48 | 4.4 | 1 |
| 20.2 | 48 | 4.4 | 2 |
| 0.5 | 48 | 21 | 1 |
| 19.6 | 48 | 21 | 2 |
| 0.2 | 48 | 37.8 | 1 |
| 16.6 | 48 | 37.8 | 2 |
| 1.7 | 54 | 4.4 | 1 |
| 20.9 | 54 | 4.4 | 2 |
| 1.6 | 54 | 21 | 1 |
| 20.7 | 54 | 21 | 2 |
| 1.2 | 54 | 37.8 | 1 |
| 17.4 | 54 | 37.8 | 2 |
| 0.7 | 60 | 4.4 | 1 |
| 19.2 | 60 | 4.4 | 2 |
| 0.8 | 60 | 21 | 1 |
| 18.9 | 60 | 21 | 2 |
| 0.8 | 60 | 37.8 | 1 |
| 17.9 | 60 | 37.8 | 2 |

| % Oxygen | Time months | Temp C | Atmosep<br>1=Nitrogen pack<br>2 = air pack |
|---|---|---|---|
| **BANANA** | | | |
| 0.8 | 42 | 4.4 | 1 |
| 19.0 | 42 | 4.4 | 2 |
| 0.2 | 42 | 21 | 1 |
| 15.6 | 42 | 21 | 2 |
| 0.3 | 42 | 37.8 | 1 |
| 2.4 | 42 | 37.8 | 2 |
| 0.9 | 48 | 4.4 | 1 |
| 19.6 | 48 | 4.4 | 2 |
| 0.6 | 48 | 21 | 1 |
| 14.5 | 48 | 21 | 2 |
| 0.5 | 48 | 37.8 | 1 |
| 9.1 | 48 | 37.8 | 2 |
| 1.0 | 54 | 4.4 | 1 |
| 16.8 | 54 | 4.4 | 2 |
| 0.6 | 54 | 21 | 1 |
| 12.2 | 54 | 21 | 2 |
| 0.7 | 54 | 37.8 | 1 |
| 3.5 | 54 | 37.8 | 2 |
| 0.9 | 60 | 4.4 | 1 |
| 18.4 | 60 | 4.4 | 2 |
| 0.3 | 60 | 21 | 1 |
| 12.1 | 60 | 21 | 2 |
| 0.3 | 60 | 37.8 | 1 |
| 1.6 | 60 | 37.8 | 2 |

**APPENDIX E** (con't.)

| **% Oxygen** | **Time months** | **Temp C** | **Atmosp 1=Nitrogen pack 2= Air pack** |
|---|---|---|---|
| **BUTTER** | | | |
| 0.8 | 42 | 4.4 | 1 |
| 17.4 | 42 | 4.4 | 2 |
| 0.3 | 42 | 21 | 1 |
| 11.1 | 42 | 21 | 2 |
| 0.4 | 42 | 37.8 | 1 |
| 5.7 | 42 | 37.8 | 2 |
| 1.4 | 48 | 4.4 | 1 |
| 17.6 | 48 | 4.4 | 2 |
| 0.8 | 48 | 21 | 1 |
| 13.8 | 48 | 21 | 2 |
| 0.8 | 48 | 37.8 | 1 |
| 13.1 | 48 | 37.8 | 2 |
| 0.7 | 54 | 4.4 | 1 |
| 15.2 | 54 | 4.4 | 2 |
| 1.2 | 54 | 21 | 1 |
| 8.8 | 54 | 21 | 2 |
| 0.9 | 54 | 37.8 | 1 |
| 8.0 | 54 | 37.8 | 2 |
| 1.2 | 60 | 4.4 | 1 |
| 15.4 | 60 | 4.4 | 2 |
| 1.2 | 60 | 21 | 1 |
| 5.6 | 60 | 21 | 2 |
| 0.9 | 60 | 37.8 | 1 |
| 2.9 | 60 | 37.8 | 2 |

| **% Oxygen** | **Time months** | **Temp C** | **Atmosp 1=Nitrogen pack 2=Air pack** |
|---|---|---|---|
| **CARROT** | | | |
| 0.7 | 42 | 4.4 | 1 |
| 13.3 | 42 | 4.4 | 2 |
| 0.4 | 42 | 21 | 1 |
| 9.2 | 42 | 21 | 2 |
| 0.3 | 42 | 37.8 | 1 |
| 0.6 | 42 | 37.8 | 2 |
| 0.4 | 48 | 4.4 | 1 |
| 11.4 | 48 | 4.4 | 2 |
| 0.5 | 48 | 21 | 1 |
| 6.1 | 48 | 21 | 2 |
| 0.6 | 48 | 37.8 | 1 |
| 1.2 | 48 | 37.8 | 2 |
| 1.2 | 54 | 4.4 | 1 |
| 12.5 | 54 | 4.4 | 2 |
| 1.0 | 54 | 21 | 1 |
| 7.8 | 54 | 21 | 2 |
| 0.7 | 54 | 37.8 | 1 |
| 1.3 | 54 | 37.8 | 2 |
| 0.6 | 60 | 4.4 | 1 |
| 13.2 | 60 | 4.4 | 2 |
| 1.2 | 60 | 21 | 1 |
| 7.7 | 60 | 21 | 2 |
| 0.8 | 60 | 37.8 | 1 |
| 0.9 | 60 | 37.8 | 2 |

APPENDIX E (con't.)

| % Oxygen | Time<br>months | Temp<br>C | Atmosp |
|---|---|---|---|
| EGG | | | |
| 0.4 | 42 | 4.4 | 1 |
| 15.2 | 42 | 4.4 | 2 |
| 0.4 | 42 | 21 | 1 |
| 4.2 | 42 | 21 | 2 |
| 0.3 | 42 | 37.8 | 1 |
| 0.9 | 42 | 37.8 | 2 |
| 0.5 | 48 | 4.4 | 1 |
| 14.3 | 48 | 4.4 | 2 |
| 1.4 | 48 | 21 | 1 |
| 13.9 | 48 | 21 | 2 |
| 0.4 | 48 | 37.8 | 1 |
| 0.6 | 48 | 37.8 | 2 |
| 2.1 | 54 | 4.4 | 1 |
| 12.0 | 54 | 4.4 | 2 |
| 1.4 | 54 | 21 | 1 |
| 4.9 | 54 | 21 | 2 |
| 1.6 | 54 | 37.8 | 1 |
| 1.1 | 54 | 37.8 | 2 |
| 0.8 | 60 | 4.4 | 1 |
| 12.8 | 60 | 4.4 | 2 |
| 0.7 | 60 | 21 | 1 |
| 2.6 | 60 | 21 | 2 |
| 0.6 | 60 | 37.8 | 1 |
| 0.8 | 60 | 37.8 | 2 |

| % Oxygen | Time<br>months | Temp<br>C | Atmosp<br>1=Nitrogen pack<br>2=Air pack |
|---|---|---|---|
| GREEN BEANS | | | |
| 0.8 | 42 | 4.4 | 1 |
| 16.9 | 42 | 4.4 | 2 |
| 0.8 | 42 | 21 | 1 |
| 15.8 | 42 | 21 | 2 |
| 0.5 | 42 | 37.8 | 1 |
| 1.4 | 42 | 37.8 | 2 |
| 0.8 | 48 | 4.4 | 1 |
| 16.4 | 48 | 4.4 | 2 |
| 0.8 | 48 | 21 | 1 |
| 15.4 | 48 | 21 | 2 |
| 1.2 | 48 | 37.8 | 1 |
| 1.2 | 48 | 37.8 | 2 |
| 1.1 | 54 | 4.4 | 1 |
| 17.3 | 54 | 4.4 | 2 |
| 0.8 | 54 | 21 | 1 |
| 14.7 | 54 | 21 | 2 |
| 0.6 | 54 | 37.8 | 1 |
| 1.3 | 54 | 37.8 | 2 |
| 1.1 | 60 | 4.4 | 1 |
| 16.3 | 60 | 4.4 | 2 |
| 0.5 | 60 | 21 | 1 |
| 12.8 | 60 | 21 | 2 |
| 0.6 | 60 | 37.8 | 1 |
| 1.0 | 60 | 37.8 | 2 |

APPENDIX E (con't.)

| % Oxygen | Time month | Temp C | Atmosphere 1=Nitrogen pack 2=Air pack |
|---|---|---|---|
| **NAVY BEANS** | | | |
| 1.1 | 42 | 4.4 | 1 |
| 18.6 | 42 | 4.4 | 2 |
| 0.4 | 42 | 21 | 1 |
| 12.6 | 42 | 21 | 2 |
| 0.5 | 42 | 37.8 | 1 |
| 0.8 | 42 | 37.8 | 2 |
| 2.0 | 48 | 4.4 | 1 |
| 18.6 | 48 | 4.4 | 2 |
| 1.0 | 48 | 21 | 1 |
| 12.9 | 48 | 21 | 2 |
| 1.1 | 48 | 37.8 | 1 |
| 1.4 | 48 | 37.8 | 2 |
| 1.9 | 54 | 4.4 | 1 |
| 21.4 | 54 | 4.4 | 2 |
| 0.6 | 54 | 21 | 1 |
| 10.5 | 54 | 21 | 2 |
| 0.9 | 54 | 37.8 | 1 |
| 0.6 | 54 | 37.8 | 2 |
| 0.9 | 60 | 4.4 | 1 |
| 17.0 | 60 | 4.4 | 2 |
| 0.3 | 60 | 21 | 1 |
| 11.1 | 60 | 21 | 2 |
| 0.3 | 60 | 37.8 | 1 |
| 0.8 | 60 | 37.8 | 2 |

| % Oxygen | Time months | Temp C | Atmosphere 1=Nitrogen pack 2=Air pack |
|---|---|---|---|
| **ROLLED OATS** | | | |
| 1.4 | 42 | 4.4 | 1 |
| 15.8 | 42 | 4.4 | 2 |
| 0.2 | 42 | 21 | 1 |
| 11.8 | 42 | 21 | 2 |
| 0.4 | 42 | 37.8 | 1 |
| 3.8 | 42 | 37.8 | 2 |
| 3.2 | 48 | 4.4 | 1 |
| 18.8 | 48 | 4.4 | 2 |
| 1.2 | 48 | 21 | 1 |
| 14.7 | 48 | 21 | 2 |
| 1.2 | 48 | 37.8 | 1 |
| 11.7 | 48 | 37.8 | 2 |
| 2.8 | 54 | 4.4 | 1 |
| 12.0 | 54 | 4.4 | 2 |
| 3.0 | 54 | 21 | 1 |
| 14.0 | 54 | 21 | 2 |
| 3.2 | 54 | 37.8 | 1 |
| 6.5 | 54 | 37.8 | 2 |
| 1.3 | 60 | 4.4 | 1 |
| 15.5 | 60 | 4.4 | 2 |
| 0.4 | 60 | 21 | 1 |
| 10.2 | 60 | 21 | 2 |
| 0.4 | 60 | 37.8 | 1 |
| 4.0 | 60 | 37.8 | 2 |

APPENDIX E (con't.)

| % Oxygen | Time months | Temp C | Atmosphere 1=Nitrogen pack 2=Air pack |
|---|---|---|---|
| MACARONI | | | |
| 3.4 | 42 | 4.4 | 1 |
| 19.1 | 42 | 4.4 | 2 |
| 0.3 | 42 | 21 | 1 |
| 5.4 | 42 | 21 | 2 |
| 0.2 | 42 | 37.8 | 1 |
| 0.6 | 42 | 37.8 | 2 |
| 4.6 | 48 | 4.4 | 1 |
| 20.6 | 48 | 4.4 | 2 |
| 0.4 | 48 | 21 | 1 |
| 2.0 | 48 | 21 | 2 |
| 0.4 | 48 | 37.8 | 1 |
| 0.2 | 48 | 37.8 | 2 |
| 5.5 | 54 | 4.4 | 1 |
| 17.0 | 54 | 4.4 | 2 |
| 0.7 | 54 | 21 | 1 |
| 5.3 | 54 | 21 | 2 |
| 0.7 | 54 | 37.8 | 1 |
| 0.6 | 54 | 37.8 | 2 |
| 3.1 | 60 | 4.4 | 1 |
| 18.9 | 60 | 4.4 | 2 |
| 0.4 | 60 | 21 | 1 |
| 3.2 | 60 | 21 | 2 |
| 0.2 | 60 | 37.8 | 1 |
| 0.6 | 60 | 37.8 | 2 |

| % Oxygen | Time months | Temp C | Atmosphere 1=Nitrogen pack 2=Air pack |
|---|---|---|---|
| MILK | | | |
| 2.6 | 42 | 4.4 | 1 |
| 19.2 | 42 | 4.4 | 2 |
| 1.8 | 42 | 21 | 1 |
| 18.3 | 42 | 21 | 2 |
| 0.5 | 42 | 37.8 | 1 |
| 8.8 | 42 | 37.8 | 2 |
| 2.6 | 48 | 4.4 | 1 |
| 20.4 | 48 | 4.4 | 2 |
| 2.2 | 48 | 21 | 1 |
| 18.6 | 48 | 21 | 2 |
| 0.6 | 48 | 37.8 | 1 |
| 11.6 | 48 | 37.8 | 2 |
| 3.4 | 54 | 4.4 | 1 |
| 18.6 | 54 | 4.4 | 2 |
| 2.2 | 54 | 21 | 1 |
| 12.8 | 54 | 21 | 2 |
| 1.4 | 54 | 37.8 | 1 |
| 8.1 | 54 | 37.8 | 2 |
| 2.8 | 60 | 4.4 | 1 |
| 19.6 | 60 | 4.4 | 2 |
| 2.0 | 60 | 21 | 1 |
| 18.4 | 60 | 21 | 2 |
| 0.6 | 60 | 37.8 | 1 |
| 14.6 | 60 | 37.8 | 2 |

APPENDIX E (con't)

**PEACH**

| % Oxygen | Time months | Temp C | Atmosphere<br>1=Nitrogen pack<br>2=Air pack |
|---|---|---|---|
| 1.4 | 42 | 4.4 | 1 |
| 19.6 | 42 | 4.4 | 2 |
| 1.0 | 42 | 21 | 1 |
| 18.2 | 42 | 21 | 2 |
| 1.6 | 42 | 37.8 | 1 |
| 0.8 | 42 | 37.8 | 2 |
| 1.2 | 48 | 4.4 | 1 |
| 19.4 | 48 | 4.4 | 2 |
| 1.1 | 48 | 21 | 1 |
| 17.4 | 48 | 21 | 2 |
| 0.6 | 48 | 37.8 | 1 |
| 0.8 | 48 | 37.8 | 2 |
| 1.4 | 54 | 4.4 | 1 |
| 18.8 | 54 | 4.4 | 2 |
| 1.3 | 54 | 21 | 1 |
| 15.3 | 54 | 21 | 2 |
| 0.9 | 54 | 37.8 | 1 |
| 3.0 | 54 | 37.8 | 2 |
| 1.0 | 60 | 4.4 | 1 |
| 19.8 | 60 | 4.4 | 2 |
| 1.0 | 60 | 21 | 1 |
| 16.5 | 60 | 21 | 2 |
| 0.8 | 60 | 37.8 | 1 |
| 1.4 | 60 | 37.5 | 2 |

**SALAD BLEND**

| % Oxygen | Time month | Temp C | Atmosphere<br>1=Nitrogen pack<br>2=Air pack |
|---|---|---|---|
| 1.0 | 42 | 4.4 | 1 |
| 15.6 | 42 | 4.4 | 2 |
| 0.6 | 42 | 21 | 1 |
| 13.6 | 42 | 21 | 2 |
| 0.4 | 42 | 37.8 | 1 |
| 2.3 | 42 | 37.8 | 2 |
| 1.0 | 48 | 4.4 | 1 |
| 17.0 | 48 | 4.4 | 2 |
| 0.4 | 48 | 21 | 1 |
| 13.2 | 48 | 21 | 2 |
| 0.2 | 48 | 37.8 | 1 |
| 0.4 | 48 | 37.8 | 2 |
| 1.4 | 54 | 4.4 | 1 |
| 14.8 | 54 | 4.4 | 2 |
| 0.6 | 54 | 21 | 1 |
| 10.9 | 54 | 21 | 2 |
| 0.7 | 54 | 37.8 | 1 |
| 0.7 | 54 | 37.8 | 2 |
| 1.4 | 60 | 4.4 | 1 |
| 13.7 | 60 | 4.4 | 2 |
| 1.0 | 60 | 21 | 1 |
| 8.3 | 60 | 21 | 2 |
| 1.1 | 60 | 37.8 | 1 |
| 2.3 | 60 | 37.8 | 2 |

APPENDIX E (con't)

| % Oxygen | Time months | Temp C | Atmosphere 1=Nitrogen pack 2=Air pack |
|---|---|---|---|
| STROGANOFF | | | |
| 1.0 | 42 | 4.4 | 1 |
| 19.4 | 42 | 4.4 | 2 |
| 0.3 | 42 | 21 | 1 |
| 4.6 | 42 | 21 | 2 |
| 0.4 | 42 | 37.8 | 1 |
| 0.8 | 42 | 37.8 | 2 |
| 1.0 | 48 | 4.4 | 1 |
| 18.0 | 48 | 4.4 | 2 |
| 0.2 | 48 | 21 | 1 |
| 2.4 | 48 | 21 | 2 |
| 0.3 | 48 | 37.8 | 1 |
| 0.4 | 48 | 37.8 | 2 |
| 1.8 | 54 | 4.4 | 1 |
| 18.3 | 54 | 4.4 | 2 |
| 0.9 | 54 | 21 | 1 |
| 2.1 | 54 | 21 | 2 |
| 0.8 | 54 | 37.8 | 1 |
| 0.8 | 54 | 37.8 | 2 |
| 1.0 | 60 | 4.4 | 1 |
| 17.0 | 60 | 4.4 | 2 |
| 0.9 | 60 | 21 | 1 |
| 3.6 | 60 | 21 | 2 |
| 1.0 | 60 | 37.8 | 1 |
| 1.0 | 60 | 37.8 | 2 |

| % Oxygen | Time months | Temp C | Atmosphere 1=Nitrogen pack 2=Air pack |
|---|---|---|---|
| TOMATO | | | |
| 1.0 | 42 | 4.4 | 1 |
| 16.4 | 42 | 4.4 | 2 |
| 0.4 | 42 | 21 | 1 |
| 15.4 | 42 | 21 | 2 |
| 0.5 | 42 | 37.8 | 1 |
| 1.0 | 42 | 37.8 | 2 |
| 0.6 | 48 | 4.4 | 1 |
| 20.2 | 48 | 4.4 | 2 |
| 0.1 | 48 | 21 | 1 |
| 15.2 | 48 | 21 | 2 |
| 1.5 | 48 | 37.8 | 1 |
| 0.4 | 48 | 37.8 | 2 |
| 2.0 | 54 | 4.4 | 1 |
| 19.9 | 54 | 4.4 | 2 |
| 0.8 | 54 | 21 | 1 |
| 13.7 | 54 | 21 | 2 |
| 0.6 | 54 | 37.8 | 1 |
| 0.4 | 54 | 37.8 | 2 |
| 2.6 | 60 | 4.4 | 1 |
| 20.1 | 60 | 4.4 | 2 |
| 2.1 | 60 | 21 | 1 |
| 15.5 | 60 | 21 | 2 |
| 1.3 | 60 | 37.8 | 1 |
| 2.4 | 60 | 37.8 | 2 |

APPENDIX E (con't)

| % Oxygen | Time months | Temp C | Atmosphere 1=Nitrogen pack 2=Air pack |
|---|---|---|---|
| TVP | | | |
| 2.0 | 42 | 4.4 | 1 |
| 7.7 | 42 | 4.4 | 2 |
| 0.4 | 42 | 21 | 1 |
| 5.2 | 42 | 21 | 2 |
| 0.8 | 42 | 37.8 | 1 |
| 2.0 | 42 | 37.8 | 2 |
| 1.6 | 48 | 4.4 | 1 |
| 17.6 | 48 | 4.4 | 2 |
| 2.0 | 48 | 21 | 1 |
| 12.6 | 48 | 21 | 2 |
| 1.7 | 48 | 37.8 | 1 |
| 4.1 | 48 | 37.8 | 2 |
| 1.4 | 54 | 4.4 | 1 |
| 5.6 | 54 | 4.4 | 2 |
| 1.2 | 54 | 21 | 1 |
| 6.8 | 54 | 21 | 2 |
| 0.9 | 54 | 37.8 | 1 |
| 1.6 | 54 | 37.8 | 2 |
| 0.4 | 60 | 4.4 | 1 |
| 5.6 | 60 | 4.4 | 2 |
| 0.1 | 60 | 21 | 1 |
| 6.2 | 60 | 21 | 2 |
| 0.1 | 60 | 37.8 | 1 |
| 1.6 | 60 | 37.8 | 2 |

| % Oxygen | Time months | Temp C | Atmosphere 1=Nitrogen pack 2=Air pack |
|---|---|---|---|
| WHEAT | | | |
| 1.6 | 42 | 4.4 | 1 |
| 15.6 | 42 | 4.4 | 2 |
| 0.9 | 42 | 21 | 1 |
| 10.1 | 42 | 21 | 2 |
| 0.6 | 42 | 37.8 | 1 |
| 1.2 | 42 | 37.8 | 2 |
| 1.4 | 48 | 4.4 | 1 |
| 16.0 | 48 | 4.4 | 2 |
| 0.7 | 48 | 21 | 1 |
| 6.7 | 48 | 21 | 2 |
| 0.8 | 48 | 37.8 | 1 |
| 1.3 | 48 | 37.8 | 2 |
| * | 54 | 4.4 | 1 |
| 16.2 | 54 | 4.4 | 2 |
| 0.5 | 54 | 21 | 1 |
| 4.2 | 54 | 21 | 2 |
| 0.6 | 54 | 37.8 | 1 |
| 0.4 | 54 | 37.8 | 2 |
| 0.6 | 60 | 4.4 | 1 |
| 15.1 | 60 | 4.4 | 2 |
| 0.2 | 60 | 21 | 1 |
| 3.9 | 60 | 21 | 2 |
| * | 60 | 37.8 | 1 |
| 1.2 | 60 | 37.8 | 2 |

NOTE * = No oxygen values were obtained due to malfunction of the oxygen analyzer.

APPENDIX E (con't.)

| % Oxygen | Time months | Temp C | Atmosphere 1=Nitrogen pack 2=Air pack |
|---|---|---|---|
| YEAST | | | |
| 0.6 | 42 | 4.4 | 1 |
| 6.8 | 42 | 4.4 | 2 |
| 0.2 | 42 | 21 | 1 |
| 2.8 | 42 | 21 | 2 |
| 0.4 | 42 | 37.8 | 1 |
| 0.9 | 42 | 37.8 | 2 |
| 0.2 | 48 | 4.4 | 1 |
| 9.4 | 48 | 4.4 | 2 |
| 1.7 | 48 | 21 | 1 |
| 3.2 | 48 | 21 | 2 |
| 0.6 | 48 | 37.8 | 1 |
| 0.4 | 48 | 37.8 | 2 |
| 0.5 | 54 | 4.4 | 1 |
| 8.2 | 54 | 4.4 | 2 |
| 1.1 | 54 | 21 | 1 |
| 13.6 | 54 | 21 | 2 |
| 0.6 | 54 | 37.8 | 1 |
| 1.0 | 54 | 37.8 | 2 |
| 1.2 | 60 | 4.4 | 1 |
| 4.3 | 60 | 4.4 | 2 |
| 0.6 | 60 | 21 | 1 |
| 2.0 | 60 | 21 | 2 |
| 1.1 | 60 | 37.8 | 1 |
| 1.8 | 60 | 37.8 | 2 |

APPENDIX F.

### Percent Moisture of Vacuum-Dried Foods

| | Time | Temperature (°C) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 4.4 | 4.4 | 21 | 21 | 37.8 | 37.8 |
| | | Atmosphere | | | | | |
| | months | $N_2$ | air | $N_2$ | air | $N_2$ | air |
| APPLE | initial | 3.36 | | | | | |
| | 42 | 7.37 | 6.98 | 6.30 | 8.74 | 7.95 | 7.54 |
| | 48 | 5.50 | 5.91 | 6.37 | 6.42 | 7.05 | 6.98 |
| | 54 | 6.37 | 6.23 | 5.05 | 5.84 | 5.94 | 5.10 |
| | 60 | 5.21 | 4.23 | 4.07 | 5.00 | 5.20 | 4.70 |
| BANANA | initial | 2.41 | | | | | |
| | 42 | 2.58 | 2.62 | 2.60 | 2.55 | 2.61 | 2.83 |
| | 48 | 2.52 | 2.48 | 2.43 | 2.58 | 2.54 | 2.57 |
| | 54 | 2.52 | 2.46 | 2.56 | 2.58 | 2.42 | 2.68 |
| | 60 | 2.61 | 2.49 | 2.67 | 2.56 | 2.62 | 2.66 |
| BUTTER | initial | 1.00 | | | | | |
| | 42 | 1.10 | 1.13 | 1.13 | 1.10 | 1.13 | 1.19 |
| | 48 | 1.04 | 1.04 | 0.90 | 1.02 | 1.06 | 1.14 |
| | 54 | 0.67 | 0.77 | 0.71 | 0.79 | 0.87 | 0.90 |
| | 60 | 2.41 | 2.07 | 2.09 | 2.09 | 2.54 | 2.56 |
| G. BEANS | initial | 5.83 | | | | | |
| | 42 | 9.26 | 9.60 | 9.97 | 8.46 | 10.53 | 10.91 |
| | 48 | 10.39 | 9.90 | 10.46 | 9.94 | 10.66 | 10.95 |
| | 54 | 9.17 | 8.80 | 9.79 | 8.79 | 10.37 | 9.43 |
| | 60 | 12.26 | 12.39 | 13.02 | 12.86 | 13.08 | 11.61 |
| N. BEAN | initial | 9.53 | | | | | |
| | 42 | 9.60 | 9.57 | 9.28 | 10.14 | 10.28 | 9.73 |
| | 48 | 10.88 | 9.64 | 9.84 | 9.57 | 10.59 | 10.12 |
| | 54 | 9.30 | 9.75 | 9.32 | 9.86 | 10.25 | 9.82 |
| | 60 | 9.18 | 9.88 | 8.99 | 9.40 | 10.32 | 9.94 |
| CARROT | initial | 5.17 | | | | | |
| | 42 | 9.04 | 9.69 | 9.78 | 9.35 | 10.97 | 10.77 |
| | 48 | 9.56 | 9.35 | 9.59 | 9.16 | 9.83 | 9.18 |
| | 54 | 9.69 | 10.00 | 9.74 | 9.08 | 9.68 | 9.40 |
| | 60 | 9.21 | 9.02 | 8.72 | 6.39 | 8.05 | 9.31 |

Appendix F (cont.)

|  | Time | Temperature (°C) 4.4 | 4.4 | 21 | 21 | 37.8 | 37.8 |
|---|---|---|---|---|---|---|---|
|  |  | Atmosphere |  |  |  |  |  |
|  | months | $N_2$ | air | $N_2$ | air | $N_2$ | air |
| EGG | initial | 4.20 |  |  |  |  |  |
|  | 42 | 4.01 | 4.14 | 4.27 | 3.96 | 6.74 | 6.52 |
|  | 48 | 4.41 | 4.53 | 6.45 | 6.59 | 4.84 | 5.06 |
|  | 54 | 4.61 | 4.74 | 4.28 | 4.64 | 5.91 | 6.09 |
|  | 60 | 3.98 | 3.97 | 4.47 | 4.52 | 6.19 | 5.95 |
| MACARONI | initial | 11.95 |  |  |  |  |  |
|  | 42 | 11.72 | 11.68 | 11.89 | 11.61 | 11.76 | 11.76 |
|  | 48 | 11.16 | 10.62 | 11.18 | 10.87 | 11.66 | 11.12 |
|  | 54 | 12.26 | 11.96 | 11.98 | 12.04 | 12.41 | 12.05 |
|  | 60 | 12.23 | 11.83 | 12.11 | 11.12 | 12.54 | 12.25 |
| MILK | initial | 2.78 |  |  |  |  |  |
|  | 42 | 3.06 | 3.26 | 3.29 | 2.98 | 3.88 | 3.21 |
|  | 48 | 4.19 | 4.79 | 3.85 | 4.98 | 4.63 | 4.04 |
|  | 54 | 3.43 | 3.62 | 3.78 | 3.58 | 3.89 | 3.97 |
|  | 60 | 2.78 | 2.95 | 3.35 | 3.43 | 3.62 | 3.38 |
| OATS | initial | 9.69 |  |  |  |  |  |
|  | 42 | 9.52 | 9.72 | 9.64 | 9.46 | 9.40 | 9.60 |
|  | 48 | 9.38 | 9.43 | 9.09 | 9.62 | 9.38 | 9.27 |
|  | 54 | 9.58 | 9.75 | 9.81 | 9.71 | 9.84 | 9.96 |
|  | 60 | 9.33 | 10.06 | 9.68 | 9.64 | 10.04 | 10.18 |
| P. BUTTER | initial | 1.40 |  |  |  |  |  |
|  | 42 | 1.65 | 1.06 | 1.68 | 1.32 | 1.36 | 1.44 |
|  | 48 | 1.20 | 0.99 | 0.94 | 1.09 | 1.15 | 0.69 |
|  | 54 | 1.51 | 1.17 | 1.39 | 1.23 | 1.38 | 1.41 |
|  | 60 | 1.26 | 1.25 | 1.39 | 1.20 | 1.37 | 1.36 |
| PEACH | initial | 5.96 |  |  |  |  |  |
|  | 42 | 13.54 | 13.94 | 12.36 | 11.82 | 16.94 | 16.83 |
|  | 48 | 13.99 | 12.92 | 12.25 | 13.94 | 16.44 | 15.51 |
|  | 54 | 12.67 | 13.54 | 13.82 | 13.23 | 16.26 | 17.02 |
|  | 60 | 12.04 | 12.60 | 12.99 | 12.63 | 14.57 | 15.45 |

Appendix F (cont.)

|  | Time | Temperature ($^{o}C$) |  |  |  |  |  |
|---|---|---|---|---|---|---|---|
|  |  | 4.4 | 4.4 | 21 | 21 | 37.8 | 37.8 |
|  |  | Atmosphere |  |  |  |  |  |
|  | months | $N_2$ | air | $N_2$ | air | $N_2$ | air |
| P | initial | 7.33 |  |  |  |  |  |
| O | 42 | 6.96 | 7.21 | 7.32 | 6.92 | 7.24 | 7.23 |
| T | 48 | 7.74 | 7.45 | 7.56 | 7.65 | 7.50 | 7.57 |
| A | 54 | 7.71 | 7.88 | 7.89 | 7.77 | 7.91 | 8.02 |
| T | 60 | 7.71 | 7.89 | 7.95 | 7.59 | 7.75 | 7.86 |
| O |  |  |  |  |  |  |  |
| S. | initial | 6.98 |  |  |  |  |  |
| B | 42 | 8.59 | 9.92 | 9.82 | 8.64 | 10.32 | 10.35 |
| L | 48 | 11.73 | 11.56 | 9.72 | 9.04 | 10.70 | 10.74 |
| E | 54 | 10.11 | 10.81 | 11.31 | 10.87 | 11.19 | 11.78 |
| N | 60 | 6.26 | 7.79 | 9.26 | 10.53 | 10.61 | 10.74 |
| D |  |  |  |  |  |  |  |
| S | initial | 6.60 |  |  |  |  |  |
| T | 42 | 6.85 | 7.58 | 7.06 | 7.13 | 7.98 | 8.04 |
| R | 48 | 7.36 | 7.89 | 7.51 | 7.87 | 8.20 | 8.39 |
| O | 54 | 7.47 | 7.65 | 8.03 | 8.31 | 8.46 | 8.77 |
| G. | 60 | 6.88 | 7.23 | 7.37 | 7.79 | 8.47 | 8.47 |
| T | initial | 8.23 |  |  |  |  |  |
| O | 42 | 12.39 | 14.02 | 14.39 | 11.99 | 15.12 | 15.48 |
| M | 48 | 15.56 | 15.92 | 16.51 | 16.22 | 14.37 | 15.22 |
| A | 54 | 15.19 | 16.26 | 16.47 | 15.26 | 16.23 | 16.48 |
| T | 60 | 8.94 | 8.95 | 13.81 | 14.83 | 15.33 | 15.38 |
| O |  |  |  |  |  |  |  |
|  | initial | 5.70 |  |  |  |  |  |
| T | 42 | 6.64 | 2.03 | 7.10 | 6.78 | 6.52 | 7.00 |
| V | 48 | 7.18 | 6.58 | 6.76 | 2.73 | 7.01 | 6.68 |
| P | 54 | 6.26 | 6.45 | 7.18 | 6.65 | 7.21 | 6.66 |
|  | 60 | 6.49 | 6.52 | 6.96 | 6.62 | 6.79 | 6.84 |
| V. | initial | 7.93 |  |  |  |  |  |
| S | 42 | 9.04 | 9.06 | 9.59 | 8.85 | 10.36 | 10.26 |
| O | 48 | 10.39 | 10.23 | 10.53 | 10.20 | 10.67 | 10.48 |
| U | 54 | 9.35 | 9.59 | 10.04 | 9.79 | 10.49 | 10.33 |
| P | 60 | 7.53 | 8.48 | 9.82 | 9.67 | 10.09 | 10.68 |

Appendix F (cont.)

| | | Temperature (°C) | | | | | |
|---|---|---|---|---|---|---|---|
| | Time | 4.4 | 4.4 | 21 | 21 | 37.8 | 37.8 |
| | | Atmosphere | | | | | |
| | months | $N_2$ | air | $N_2$ | air | $N_2$ | air |
| W | initial | 9.72 | | | | | |
| H | 42 | 10.06 | 10.32 | 10.20 | 9.94 | 10.11 | 9.66 |
| E | 48 | 10.47 | 10.61 | 10.45 | 10.44 | 10.81 | 10.11 |
| A | 54 | 9.87 | 10.13 | 10.16 | 9.92 | 10.15 | 9.75 |
| T | 60 | 9.92 | 10.22 | 10.01 | 10.26 | 10.28 | 9.87 |
| Y | initial | 7.36 | | | | | |
| E | 42 | 7.68 | 8.38 | 7.72 | 8.00 | 8.68 | 8.19 |
| A | 48 | 7.94 | 8.06 | 7.86 | 8.21 | 7.99 | 8.02 |
| S | 54 | 7.66 | 7.87 | 7.73 | 7.81 | 7.88 | 7.87 |
| T | 60 | 7.65 | 7.77 | 7.77 | 7.82 | 7.79 | 4.78 |

## APPENDIX G Mean Hunter Color Values in Low-Moisture Foods

| Color | | Time | Temp | Atmosphere |
|---|---|---|---|---|
| L | a | months | C | 1=Nitrogen pack<br>2=Air pack |
| **APPLE** | | | | |
| 67.92 | 5.01 | 48 | 4.4 | 1 |
| 73.24 | 3.03 | 48 | 4.4 | 2 |
| 48.69 | 5.51 | 48 | 21 | 1 |
| 67.90 | 4.70 | 48 | 21 | 2 |
| 52.27 | 7.97 | 48 | 37.8 | 1 |
| 49.53 | 10.68 | 48 | 37.8 | 2 |
| 70.32 | 1.63 | 54 | 4.4 | 1 |
| 72.25 | 1.37 | 54 | 4.4 | 2 |
| 69.12 | 2.29 | 54 | 21 | 1 |
| 69.48 | 2.04 | 54 | 21 | 2 |
| 53.95 | 7.21 | 54 | 37.8 | 1 |
| 57.96 | 6.78 | 54 | 37.8 | 2 |
| 72.39 | 3.30 | 60 | 4.4 | 1 |
| 70.28 | 4.00 | 60 | 4.4 | 2 |
| 70.53 | 5.20 | 60 | 21 | 1 |
| 69.03 | 4.68 | 60 | 21 | 2 |
| 54.79 | 9.24 | 60 | 37.8 | 1 |
| 53.92 | 9.52 | 60 | 37.8 | 2 |
| **BANANA** | | | | |
| 50.13 | 6.70 | 48 | 4.4 | 1 |
| 53.53 | 6.06 | 48 | 4.4 | 2 |
| 55.42 | 6.2 | 48 | 21 | 1 |
| 51.69 | 7.45 | 48 | 21 | 2 |
| 49.63 | 8.07 | 48 | 37.8 | 1 |
| 54.00 | 6.20 | 48 | 37.8 | 2 |
| 52.14 | 4.50 | 54 | 4.4 | 1 |
| 55.09 | 4.03 | 54 | 4.4 | 2 |
| 53.61 | 4.48 | 54 | 21 | 1 |
| 52.48 | 5.00 | 54 | 21 | 2 |
| 53.81 | 5.92 | 54 | 37.8 | 1 |
| 55.06 | 4.68 | 54 | 37.8 | 2 |
| 53.04 | 6.78 | 60 | 4.4 | 1 |
| 53.21 | 6.78 | 60 | 4.4 | 2 |
| 54.07 | 7.02 | 60 | 21 | 1 |
| 56.06 | 5.34 | 60 | 21 | 2 |
| 52.94 | 7.41 | 60 | 37.8 | 1 |
| 52.01 | 7.27 | 60 | 37.8 | 2 |
| **BUTTER** | | | | |
| 93.31 | 1.57 | 48 | 4.4 | 1 |
| 93.54 | 1.28 | 48 | 4.4 | 2 |
| 93.01 | 1.27 | 48 | 21 | 1 |
| 93.19 | 0.20 | 48 | 21 | 2 |
| 91.67 | 1.48 | 48 | 37.8 | 1 |
| 91.95 | 0.25 | 48 | 37.8 | 2 |
| 93.42 | -0.90 | 54 | 4.4 | 1 |
| 93.75 | -1.13 | 54 | 4.4 | 2 |
| 93.38 | -1.05 | 54 | 21 | 1 |
| 3.57 | -1.76 | 54 | 21 | 2 |
| 92.89 | -1.40 | 54 | 37.8 | 1 |
| 92.37 | -1.46 | 54 | 37.8 | 2 |
| 93.00 | 1.39 | 60 | 4.4 | 1 |
| 92.99 | 1.05 | 60 | 4.4 | 2 |
| 92.82 | 1.06 | 60 | 21 | 1 |
| 92.96 | -0.18 | 60 | 21 | 2 |
| 91.93 | 1.18 | 60 | 37.8 | 1 |
| [illegible] | [illegible] | 60 | 37.8 | 2 |

APPENDIX G (con't.)

| Color | | Time | Temp | Atmosphere |
|---|---|---|---|---|
| L | a | months | C | 1=Nitrogen pack<br>2=Air pack |
| CARROT | | | | |
| 40.20 | 21.58 | 48 | 4.4 | 1 |
| 43.48 | 18.54 | 48 | 4.4 | 2 |
| 38.79 | 17.41 | 48 | 21 | 1 |
| 41.46 | 13.39 | 48 | 21 | 2 |
| 24.61 | 4.68 | 48 | 37.8 | 1 |
| 26.27 | 5.12 | 48 | 37.8 | 2 |
| 55.53 | 16.02 | 54 | 4.4 | 1 |
| 63.53 | 12.35 | 54 | 4.4 | 2 |
| 52.32 | 15.89 | 54 | 21 | 1 |
| 60.55 | 12.80 | 54 | 21 | 2 |
| 38.46 | 10.36 | 54 | 37.8 | 1 |
| 39.95 | 9.12 | 54 | 37.8 | 2 |
| 44.66 | 26.08 | 60 | 4.4 | 1 |
| 50.78 | 21.14 | 60 | 4.4 | 2 |
| 40.64 | 21.80 | 60 | 21 | 1 |
| 43.48 | 17.83 | 60 | 21 | 2 |
| 25.80 | 9.03 | 60 | 37.8 | 1 |
| 26.63 | 9.75 | 60 | 37.8 | 2 |
| Eggs | | | | |
| 87.25 | 3.57 | 48 | 4.4 | 1 |
| 87.50 | 3.34 | 48 | 4.4 | 2 |
| 84.57 | 4.14 | 48 | 21 | 1 |
| 84.55 | 3.72 | 48 | 21 | 2 |
| 53.38 | 14.15 | 48 | 37.8 | 1 |
| 53.95 | 13.96 | 48 | 37.8 | 2 |
| 87.65 | -.65 | 54 | 4.4 | 1 |
| 87.91 | -.54 | 54 | 4.4 | 2 |
| 86.18 | -.13 | 54 | 21 | 1 |
| 85.84 | 0.14 | 54 | 21 | 2 |
| 54.40 | 11.33 | 54 | 37.8 | 1 |
| 55.34 | 11.54 | 54 | 37.8 | 2 |
| 86.16 | 3.51 | 60 | 4.4 | 1 |
| 86.81 | 3.35 | 60 | 4.4 | 2 |
| 84.00 | 4.18 | 60 | 21 | 1 |
| 83.75 | 3.82 | 60 | 21 | 2 |
| 59.98 | 11.63 | 60 | 37.8 | 1 |
| 60.63 | 11.43 | 60 | 37.8 | 2 |
| GREEN BEANS | | | | |
| 22.46 | -0.78 | 48 | 4.4 | 1 |
| 26.03 | 0.01 | 48 | 4.4 | 2 |
| 22.99 | 1.00 | 48 | 21 | 1 |
| 22.34 | 1.28 | 48 | 21 | 2 |
| 16.85 | 2.04 | 48 | 37.8 | 1 |
| 17.31 | 2.09 | 48 | 37.8 | 2 |
| 22.44 | -2.19 | 54 | 4.4 | 1 |
| 26.92 | -1.87 | 54 | 4.4 | 2 |
| 23.16 | -0.07 | 54 | 21 | 1 |
| 21.62 | 0.04 | 54 | 21 | 2 |
| 17.54 | 1.55 | 54 | 37.8 | 1 |
| 19.77 | 1.57 | 54 | 37.8 | 2 |
| 23.51 | -0.16 | 60 | 4.4 | 1 |
| 26.32 | 0.12 | 60 | 4.4 | 2 |
| 22.57 | 1.86 | 60 | 21 | 1 |
| 25.65 | 1.23 | 60 | 21 | 2 |
| 28.27 | 2.98 | 60 | 37.8 | 1 |
| 36.62 | 3.62 | 60 | 37.8 | 2 |

APPENDIX G (con't.)

| Color |  | Time | Temp | Atmosphere |
|---|---|---|---|---|
| L | a | months | C | 1=Nitrogen pack<br>2=Air pack |
| **MILK** |  |  |  |  |
| 93.38 | -2.02 | 48 | 4.4 | 1 |
| 92.98 | -1.94 | 48 | 4.4 | 2 |
| 92.85 | -1.98 | 48 | 21 | 1 |
| 92.66 | -1.86 | 48 | 21 | 2 |
| 91.72 | -1.31 | 48 | 37.8 | 1 |
| 92.30 | -1.46 | 48 | 37.8 | 2 |
| 93.50 | -1.99 | 60 | 4.4 | 1 |
| 93.75 | -2.03 | 60 | 4.4 | 2 |
| 93.62 | -2.02 | 60 | 21 | 1 |
| 93.60 | -1.99 | 60 | 21 | 2 |
| 93.06 | -1.72 | 60 | 37.8 | 1 |
| 93.46 | -1.82 | 60 | 37.8 | 2 |
| **MACARONI** |  |  |  |  |
| 50.01 | 5.78 | 48 | 4.4 | 1 |
| 51.97 | 5.70 | 48 | 4.4 | 2 |
| 50.60 | 7.71 | 48 | 21 | 1 |
| 50.62 | 7.33 | 48 | 21 | 2 |
| 27.92 | 15.16 | 48 | 37.8 | 1 |
| 28.27 | 14.74 | 48 | 37.8 | 2 |
| * | * | 54 | 4.4 | 1 |
| 54.00 | 5.54 | 54 | 4.4 | 2 |
| 49.06 | 7.99 | 54 | 21 | 1 |
| 51.51 | 7.37 | 54 | 21 | 2 |
| 22.01 | 10.68 | 54 | 37.8 | 1 |
| 23.27 | 11.52 | 54 | 37.8 | 2 |
| 63.35 | 3.54 | 60 | 4.4 | 1 |
| 64.76 | 3.60 | 60 | 4.4 | 2 |
| 59.46 | 6.57 | 60 | 21 | 1 |
| 60.31 | 5.61 | 60 | 21 | 2 |
| 27.57 | 11.84 | 60 | 37.8 | 1 |
| 34.02 | 12.61 | 60 | 37.8 | 2 |
| **NAVY BEANS** |  |  |  |  |
| 63.89 | 1.83 | 54 | 4.4 | 1 |
| 63.33 | 1.84 | 54 | 4.4 | 2 |
| 62.46 | 2.09 | 54 | 21 | 1 |
| 62.57 | 2.14 | 54 | 21 | 2 |
| 52.49 | 6.64 | 54 | 37.8 | 1 |
| 52.30 | 6.44 | 54 | 37.8 | 2 |
| 62.25 | 2.27 | 60 | 4.4 | 1 |
| 61.71 | 2.20 | 60 | 4.4 | 2 |
| 61.32 | 2.39 | 60 | 21 | 1 |
| 61.08 | 2.27 | 60 | 21 | 2 |
| 48.54 | 6.80 | 60 | 37.8 | 1 |
| 48.60 | 7.17 | 60 | 37.8 | 2 |

| Color |  | Time | Temp | Atmosphere |
|---|---|---|---|---|
| L | a | month | C | 1=Nitrogen pack<br>2=Air pack |
| ROLLED OATS |  |  |  |  |
| 75.65 | 2.59 | 48 | 4.4 | 1 |
| 76.27 | 2.39 | 48 | 4.4 | 2 |
| 76.72 | 2.82 | 48 | 21 | 1 |
| 76.06 | 2.48 | 48 | 21 | 2 |
| 76.72 | 2.42 | 48 | 37.8 | 1 |
| 76.06 | 2.61 | 48 | 37.8 | 2 |
| 75.65 | 1.40 | 54 | 4.4 | 1 |
| 75.31 | 1.39 | 54 | 4.4 | 2 |
| 75.10 | 1.48 | 54 | 21 | 1 |
| 75.64 | 1.25 | 54 | 21 | 2 |
| 75.82 | 1.30 | 54 | 37.8 | 1 |
| 74.69 | 1.57 | 54 | 37.8 | 2 |
| 75.17 | 2.51 | 60 | 4.4 | 1 |
| 74.65 | 2.51 | 60 | 4.4 | 2 |
| 75.40 | 2.39 | 60 | 21 | 1 |
| 75.58 | 2.34 | 60 | 21 | 2 |
| 74.85 | 2.60 | 60 | 37.8 | 1 |
| 74.92 | 2.43 | 60 | 37.8 | 2 |
| PEACH |  |  |  |  |
| 36.38 | 17.36 | 48 | 4.4 | 1 |
| 39.07 | 17.05 | 48 | 4.4 | 2 |
| 31.56 | 15.50 | 48 | 21 | 1 |
| 32.84 | 13.20 | 48 | 21 | 2 |
| 16.62 | 1.31 | 48 | 37.8 | 1 |
| 15.73 | 1.14 | 48 | 37.8 | 2 |
| 38.07 | 14.99 | 54 | 4.4 | 1 |
| 44.91 | 15.65 | 54 | 4.4 | 2 |
| 29.03 | 12.10 | 54 | 21 | 1 |
| 35.43 | 13.07 | 54 | 21 | 2 |
| 16.38 | 1.31 | 54 | 37.8 | 1 |
| 15.57 | 1.05 | 54 | 37.8 | 2 |
| 38.96 | 18.63 | 60 | 4.4 | 1 |
| 37.33 | 18.19 | 60 | 4.4 | 2 |
| 29.98 | 14.24 | 60 | 21 | 1 |
| 27.94 | 12.90 | 60 | 21 | 2 |
| 17.84 | 3.71 | 60 | 37.8 | 1 |
| 15.32 | 2.06 | 60 | 37.8 | 2 |
| P.BUTTER |  |  |  |  |
| 69.73 | 7.28 | 48 | 4.4 | 1 |
| 70.42 | 6.85 | 48 | 4.4 | 2 |
| 69.44 | 7.21 | 48 | 21 | 1 |
| 70.34 | 6.97 | 48 | 21 | 2 |
| 69.98 | 7.06 | 48 | 37.8 | 1 |
| 70.63 | 6.80 | 48 | 37.8 | 2 |
| 70.52 | 5.07 | 54 | 4.4 | 1 |
| 71.23 | 4.68 | 54 | 4.4 | 2 |
| 71.29 | 4.75 | 54 | 21 | 1 |
| 71.78 | 4.40 | 54 | 21 | 2 |
| 70.48 | 4.91 | 54 | 37.8 | 1 |
| 71.63 | 4.78 | 54 | 37.8 | 2 |
| 68.82 | 7.56 | 60 | 4.4 | 1 |
| 69.71 | 7.31 | 60 | 4.4 | 2 |
| 69.49 | 7.41 | 60 | 21 | 1 |
| 70.26 | 7.10 | 60 | 21 | 2 |
| 69.05 | 7.66 | 60 | 37.8 | 1 |
| 70.49 | 7.08 | 60 | 37.8 | 2 |

## APPENDIX G (con't.)

| Color | | Time | Temp | Atmosphere |
|---|---|---|---|---|
| L | a | month | C | 1=Nitrogen pack<br>2=Air pack |
| **POTATO** | | | | |
| 85.87 | -0.52 | 48 | 4.4 | 1 |
| 86.89 | -1.24 | 48 | 4.4 | 2 |
| 85.06 | -0.18 | 48 | 21 | 1 |
| 84.91 | -0.22 | 48 | 21 | 2 |
| 55.94 | 15.03 | 48 | 37.8 | 1 |
| 56.57 | 14.94 | 48 | 37.8 | 2 |
| 87.20 | -2.60 | 54 | 4.4 | 1 |
| 87.84 | -2.71 | 54 | 4.4 | 2 |
| 85.88 | -2.06 | 54 | 21 | 1 |
| 86.24 | -2.33 | 54 | 21 | 2 |
| 62.57 | 10.88 | 54 | 37.8 | 1 |
| 61.35 | 11.45 | 54 | 37.8 | 2 |
| 86.23 | -0.68 | 60 | 4.4 | 1 |
| 87.89 | -2.71 | 60 | 4.4 | 2 |
| 84.27 | 0.27 | 60 | 21 | 1 |
| 83.40 | 0.55 | 60 | 21 | 2 |
| 60.04 | 12.87 | 60 | 37.8 | 1 |
| 61.36 | 12.34 | 60 | 37.8 | 2 |
| **SALAD BLEND** | | | | |
| 51.40 | 0.16 | 48 | 4.4 | 1 |
| 53.06 | 0.10 | 48 | 4.4 | 2 |
| 52.47 | 1.88 | 48 | 21 | 1 |
| 51.75 | 1.06 | 48 | 21 | 2 |
| 31.85 | 7.95 | 48 | 37.8 | 1 |
| 35.43 | 7.26 | 48 | 37.8 | 2 |
| 54.63 | 0.11 | 54 | 4.4 | 1 |
| 54.85 | 1.49 | 54 | 4.4 | 2 |
| 51.84 | 2.05 | 54 | 21 | 1 |
| 53.77 | 1.33 | 54 | 21 | 2 |
| 35.57 | 6.66 | 54 | 37.8 | 1 |
| 34.20 | 7.29 | 54 | 37.8 | 2 |
| 51.53 | 1.23 | 60 | 4.4 | 1 |
| 51.26 | -0.06 | 60 | 4.4 | 2 |
| 49.67 | 2.25 | 60 | 21 | 1 |
| 55.50 | 1.56 | 60 | 21 | 2 |
| 39.31 | 7.48 | 60 | 37.8 | 1 |
| 38.17 | 7.48 | 60 | 37.8 | 2 |
| **TOMATO** | | | | |
| 35.06 | 21.79 | 48 | 4.4 | 1 |
| 35.58 | 21.58 | 48 | 4.4 | 2 |
| 33.67 | 20.59 | 48 | 21 | 1 |
| 34.43 | 20.36 | 48 | 21 | 2 |
| 15.38 | 2.44 | 48 | 37.8 | 1 |
| 15.57 | 3.02 | 48 | 37.8 | 2 |
| 36.32 | 22.27 | 54 | 4.4 | 1 |
| 37.65 | 21.47 | 54 | 4.4 | 2 |
| 36.12 | 19.88 | 54 | 21 | 1 |
| 37.03 | 19.55 | 54 | 21 | 2 |
| 18.75 | 6.41 | 54 | 37.8 | 1 |
| 19.44 | 6.06 | 54 | 37.8 | 2 |
| 34.59 | 21.98 | 60 | 4.4 | 1 |
| 35.44 | 21.54 | 60 | 4.4 | 2 |
| 32.59 | 19.95 | 60 | 21 | 1 |
| 34.03 | 19.97 | 60 | 21 | 2 |
| 18.81 | 7.12 | 60 | 37.8 | 1 |
| 23.09 | 10.82 | 60 | 37.8 | 2 |

## APPENDIX G (con't.)

| Color | | Time | Temp | Atmosphere |
|---|---|---|---|---|
| L | a | months | C | 1=Nitrogen pack<br>2=Air pack |
| **TVP** | | | | |
| 42.56 | 6.55 | 48 | 4.4 | 1 |
| 42.00 | 6.45 | 48 | 4.4 | 2 |
| 41.57 | 6.76 | 48 | 21 | 1 |
| 35.76 | 6.36 | 48 | 21 | 2 |
| 39.95 | 7.13 | 48 | 37.8 | 1 |
| 35.84 | 7.29 | 48 | 37.8 | 2 |
| 32.57 | 4.76 | 54 | 4.4 | 1 |
| 33.27 | 4.50 | 54 | 4.4 | 2 |
| 31.27 | 4.99 | 54 | 21 | 1 |
| 31.19 | 4.80 | 54 | 21 | 2 |
| 33.83 | 5.15 | 54 | 37.8 | 1 |
| 33.87 | 4.61 | 54 | 37.8 | 2 |
| 36.53 | 6.63 | 60 | 4.4 | 1 |
| 35.24 | 6.28 | 60 | 4.4 | 2 |
| 36.94 | 6.77 | 60 | 21 | 1 |
| 37.65 | 6.75 | 60 | 21 | 2 |
| 33.72 | 7.04 | 60 | 37.8 | 1 |
| 34.88 | 7.06 | 60 | 37.8 | 2 |
| **VEG SOUP** | | | | |
| 41.70 | 10.77 | 48 | 4.4 | 1 |
| 42.06 | 10.51 | 48 | 4.4 | 2 |
| 35.46 | 9.58 | 48 | 21 | 1 |
| 33.81 | 8.31 | 48 | 21 | 2 |
| 30.47 | 5.85 | 48 | 37.8 | 1 |
| 22.44 | 5.24 | 48 | 37.8 | 2 |
| 42.47 | 9.30 | 54 | 4.4 | 1 |
| 43.90 | 9.01 | 54 | 4.4 | 2 |
| 41.03 | 4.32 | 54 | 21 | 1 |
| 36.95 | 5.39 | 54 | 21 | 2 |
| 33.35 | 4.70 | 54 | 37.8 | 1 |
| 20.61 | 5.02 | 54 | 37.8 | 2 |
| 42.07 | 10.04 | 60 | 4.4 | 1 |
| 43.64 | 8.96 | 60 | 4.4 | 2 |
| 32.02 | 8.57 | 60 | 21 | 1 |
| 31.87 | 7.36 | 60 | 21 | 2 |
| 27.62 | 5.01 | 60 | 37.8 | 1 |
| 22.70 | 5.09 | 60 | 37.8 | 2 |
| **WHEAT** | | | | |
| 41.20 | 8.22 | 48 | 4.4 | 1 |
| 41.23 | 7.88 | 48 | 4.4 | 2 |
| 41.07 | 8.52 | 48 | 21 | 1 |
| 39.93 | 8.37 | 48 | 21 | 2 |
| 38.16 | 10.42 | 48 | 37.8 | 1 |
| 37.61 | 9.83 | 48 | 37.8 | 2 |
| 41.92 | 8.35 | 60 | 4.4 | 1 |
| 42.17 | 8.01 | 60 | 4.4 | 2 |
| 42.11 | 8.46 | 60 | 21 | 1 |
| 40.28 | 8.50 | 60 | 21 | 2 |
| 36.07 | 9.92 | 60 | 37.8 | 1 |
| 37.58 | 10.35 | 60 | 37.8 | 2 |

APPENDIX G (con't.)

| Color | | Time | Temp | Atmosphere |
|---|---|---|---|---|
| L | a | months | C | 1=Nitrogen pack<br>2=Air pack |
| YEAST | | | | |
| 57.12 | 4.11 | 48 | 4.4 | 1 |
| 52.94 | 4.46 | 48 | 4.4 | 2 |
| 54.68 | 4.62 | 48 | 21 | 1 |
| 55.17 | 4.44 | 48 | 21 | 2 |
| 51.38 | 11.23 | 48 | 37.8 | 1 |
| 53.22 | 9.22 | 48 | 37.8 | 2 |
| 51.29 | 3.86 | 54 | 4.4 | 1 |
| 50.94 | 3.64 | 54 | 4.4 | 2 |
| 54.10 | 3.90 | 54 | 21 | 1 |
| 51.64 | 4.09 | 54 | 21 | 2 |
| 50.82 | 6.94 | 54 | 37.8 | 1 |
| 52.30 | 7.38 | 54 | 37.8 | 2 |
| 51.15 | 4.65 | 60 | 4.4 | 1 |
| 51.86 | 4.60 | 60 | 4.4 | 2 |
| 51.43 | 5.03 | 60 | 21 | 1 |
| 52.75 | 4.98 | 60 | 21 | 2 |
| 53.12 | 6.10 | 60 | 37.8 | 1 |
| 55.00 | 6.36 | 60 | 37.8 | 2 |

## APPENDIX H Mean Thiamin Values In Low-Moisture Foods

**EGG**

| Thiamin mg./100g | Time month | Temp C | Atmosphere<br>1=Nitrogen pack<br>2=Air pack |
|---|---|---|---|
| 0.17 | 42 | 4.4 | 1 |
| 0.14 | 42 | 4.4 | 2 |
| 0.18 | 42 | 21 | 1 |
| 0.16 | 42 | 21 | 2 |
| 0 | 42 | 37.8 | 1 |
| 0 | 42 | 37.8 | 2 |
| 0.14 | 48 | 4.4 | 1 |
| 0.12 | 48 | 4.4 | 2 |
| 0.13 | 48 | 21 | 1 |
| 0.12 | 48 | 21 | 2 |
| 0 | 48 | 37.8 | 1 |
| 0 | 48 | 37.8 | 2 |
| 0.16 | 54 | 4.4 | 1 |
| 0.15 | 54 | 4.4 | 2 |
| 0.16 | 54 | 21 | 1 |
| 0.13 | 54 | 21 | 2 |
| 0 | 54 | 37.8 | 1 |
| 0 | 54 | 37.8 | 2 |
| 0.16 | 60 | 4.4 | 1 |
| 0.16 | 60 | 4.4 | 2 |
| 0.16 | 60 | 21 | 1 |
| 0.12 | 60 | 21 | 2 |
| 0 | 60 | 37.8 | 1 |
| 0 | 60 | 37.8 | 2 |

**MACARONI**

| Thiamin mg./100g. | Time months | Temp C | Atmosphere<br>1=Nitrogen pack<br>2=Air pack |
|---|---|---|---|
| 0.68 | 42 | 4.4 | 1 |
| 0.50 | 42 | 4.4 | 2 |
| 0.61 | 42 | 21 | 1 |
| 0.53 | 42 | 21 | 2 |
| 0.01 | 42 | 37.8 | 1 |
| 0.01 | 42 | 37.8 | 2 |
| 0.77 | 48 | 4.4 | 1 |
| 0.63 | 48 | 4.4 | 2 |
| 0.50 | 48 | 21 | 1 |
| 0.41 | 48 | 21 | 2 |
| 0.01 | 48 | 37.8 | 1 |
| 0.00 | 48 | 37.8 | 2 |
| 0.76 | 54 | 4.4 | 1 |
| 0.46 | 54 | 4.4 | 2 |
| 0.49 | 54 | 21 | 1 |
| 0.41 | 54 | 21 | 2 |
| 0 | 54 | 37.8 | 1 |
| 0 | 54 | 37.8 | 2 |
| 0.78 | 60 | 4.4 | 1 |
| 0.52 | 60 | 4.4 | 2 |
| 0.41 | 60 | 21 | 1 |
| 0.32 | 60 | 21 | 2 |
| 0 | 60 | 37.8 | 1 |
| 0 | 60 | 37.8 | 2 |

## APPENDIX H (con't)

| Thiamin mg./100g. | Time months | Temp C | Atmosphere 1=Nitrogen pack 2=Air pack |
|---|---|---|---|
| NAVY BEAN | | | |
| 0.52 | 42 | 4.4 | 1 |
| 0.44 | 42 | 4.4 | 2 |
| 0.41 | 42 | 21 | 1 |
| 0.34 | 42 | 21 | 2 |
| 0.45 | 48 | 4.4 | 1 |
| 0.42 | 48 | 4.4 | 2 |
| 0.37 | 48 | 21 | 1 |
| 0.30 | 48 | 21 | 2 |
| 0.48 | 54 | 4.4 | 1 |
| 0.45 | 54 | 4.4 | 2 |
| 0.44 | 54 | 21 | 1 |
| 0.26 | 54 | 21 | 2 |
| 0.51 | 60 | 4.4 | 1 |
| 0.47 | 60 | 4.4 | 2 |
| 0.31 | 60 | 21 | 1 |
| 0.28 | 60 | 21 | 2 |

| Thiamin mg./100g. | Time months | Temp C | Atmosphere 1=Nitrogen pack 2=Air pack |
|---|---|---|---|
| MILK | | | |
| 0.16 | 42 | 4.4 | 1 |
| 0.15 | 42 | 4.4 | 2 |
| 0.16 | 42 | 21 | 1 |
| 0.14 | 42 | 21 | 2 |
| 0.15 | 42 | 37.8 | 1 |
| 0.14 | 42 | 37.8 | 2 |
| 0.15 | 48 | 4.4 | 1 |
| 0.13 | 48 | 4.4 | 2 |
| 0.14 | 48 | 21 | 1 |
| 0.13 | 48 | 21 | 2 |
| 0.13 | 48 | 37.8 | 1 |
| 0.12 | 48 | 37.8 | 2 |
| 0.15 | 54 | 4.4 | 1 |
| 0.14 | 54 | 4.4 | 2 |
| 0.13 | 54 | 21 | 1 |
| 0.12 | 54 | 21 | 2 |
| 0.12 | 54 | 37.8 | 1 |
| 0.10 | 54 | 37.8 | 2 |
| 0.16 | 60 | 4.4 | 1 |
| 0.14 | 60 | 4.4 | 2 |
| 0.15 | 60 | 21 | 1 |
| 0.14 | 60 | 21 | 2 |
| 0.12 | 60 | 37.8 | 1 |
| 0.09 | 60 | 37.8 | 2 |

APPENDIX H (con't.)

| Thiamin mg./100g. | Time month | Temp C | Atmosphere<br>1=Nitrogen pack<br>2=Air pack |
|---|---|---|---|
| ROLLED OATS | | | |
| 0.74 | 42 | 4.4 | 1 |
| 0.61 | 42 | 4.4 | 2 |
| 0.59 | 42 | 21 | 1 |
| 0.56 | 42 | 21 | 2 |
| 0.52 | 42 | 37.8 | 1 |
| 0.43 | 42 | 37.8 | 2 |
| 0.63 | 48 | 4.4 | 1 |
| 0.54 | 48 | 4.4 | 2 |
| 0.50 | 48 | 21 | 1 |
| 0.44 | 48 | 21 | 2 |
| 0.46 | 48 | 37.8 | 1 |
| 0.43 | 48 | 37.8 | 2 |
| 0.69 | 54 | 4.4 | 1 |
| 0.60 | 54 | 4.4 | 2 |
| 0.50 | 54 | 21 | 1 |
| 0.49 | 54 | 21 | 2 |
| 0.52 | 54 | 37.8 | 1 |
| 0.50 | 54 | 37.8 | 2 |
| 0.67 | 60 | 4.4 | 1 |
| 0.56 | 60 | 4.4 | 2 |
| 0.65 | 60 | 21 | 1 |
| 0.54 | 60 | 21 | 2 |
| 0.49 | 60 | 37.8 | 1 |
| 0.47 | 60 | 37.8 | 2 |

| Thiamin mg./100g. | Time months | Temp C | Atmosphere<br>1=Nitrogen pack<br>2=Air pack |
|---|---|---|---|
| STROGANOFF | | | |
| 0.46 | 42 | 4.4 | 1 |
| 0.44 | 42 | 4.4 | 2 |
| 0.34 | 42 | 21 | 1 |
| 0.31 | 42 | 21 | 2 |
| 0.06 | 42 | 37.8 | 1 |
| 0.04 | 42 | 37.8 | 2 |
| 0.40 | 48 | 4.4 | 1 |
| 0.36 | 48 | 4.4 | 2 |
| 0.38 | 48 | 21 | 1 |
| 0.30 | 48 | 21 | 2 |
| 0.08 | 48 | 37.8 | 1 |
| 0.07 | 48 | 37.8 | 2 |
| 0.42 | 54 | 4.4 | 1 |
| 0.33 | 54 | 4.4 | 2 |
| 0.36 | 54 | 21 | 1 |
| 0.32 | 54 | 21 | 2 |
| 0.12 | 54 | 37.8 | 1 |
| 0.10 | 54 | 37.8 | 2 |
| 0.42 | 60 | 4.4 | 1 |
| 0.21 | 60 | 4.4 | 2 |
| 0.32 | 60 | 21 | 1 |
| 0.26 | 60 | 21 | 2 |
| 0.10 | 60 | 37.8 | 1 |
| 0.13 | 60 | 37.8 | 2 |

APPENDIX E (con't.)

| Thiamin mg./100g. | Time months | Temp C | Atmosphere 1=Nitrogen pack 2=Air pack |
|---|---|---|---|
| VEG. SOUP | | | |
| 0.30 | 42 | 4.4 | 1 |
| 0.30 | 42 | 4.4 | 2 |
| 0.28 | 42 | 21 | 1 |
| 0.26 | 42 | 21 | 2 |
| 0.10 | 42 | 37.8 | 1 |
| 0.08 | 42 | 37.8 | 2 |
| 0.32 | 48 | 4.4 | 1 |
| 0.26 | 48 | 4.4 | 2 |
| 0.32 | 48 | 21 | 1 |
| 0.30 | 48 | 21 | 2 |
| 0.11 | 48 | 37.8 | 1 |
| 0.10 | 48 | 37.8 | 2 |
| 0.33 | 54 | 4.4 | 1 |
| 0.29 | 54 | 4.4 | 2 |
| 0.30 | 54 | 21 | 1 |
| 0.24 | 54 | 21 | 2 |
| 0.14 | 54 | 37.8 | 1 |
| 0.14 | 54 | 37.8 | 2 |
| 0.22 | 60 | 4.4 | 1 |
| 0.19 | 60 | 4.4 | 2 |
| 0.25 | 60 | 21 | 1 |
| 0.20 | 60 | 21 | 2 |
| 0.19 | 60 | 37.8 | 1 |
| 0.14 | 60 | 37.8 | 2 |

| Thiamin mg./100g. | Time months | Temp C | Atmosphere 1=Nitrogen pack 2=Air pack |
|---|---|---|---|
| TVP | | | |
| 4.18 | 42 | 4.4 | 1 |
| 3.08 | 42 | 4.4 | 2 |
| 4.12 | 42 | 21 | 1 |
| 3.40 | 42 | 21 | 2 |
| 1.44 | 42 | 37.8 | 1 |
| 1.06 | 42 | 37.8 | 2 |
| 3.83 | 48 | 4.4 | 1 |
| 3.33 | 48 | 4.4 | 2 |
| 3.20 | 48 | 21 | 1 |
| 2.48 | 48 | 21 | 2 |
| 1.64 | 48 | 37.8 | 1 |
| 1.30 | 48 | 37.8 | 2 |
| 5.29 | 54 | 4.4 | 1 |
| 4.55 | 54 | 4.4 | 2 |
| 4.51 | 54 | 21 | 1 |
| 3.59 | 54 | 21 | 2 |
| 2.38 | 54 | 37.8 | 1 |
| 1.74 | 54 | 37.8 | 2 |
| 5.11 | 60 | 4.4 | 1 |
| 4.53 | 60 | 4.4 | 2 |
| 4.33 | 60 | 21 | 1 |
| 3.92 | 60 | 21 | 2 |
| 1.72 | 60 | 37.8 | 1 |
| 1.17 | 60 | 37.8 | 2 |

APPENDIX H (con't.)

| Thiamin mg./100g. | Time months | Temp C | Atmosphere<br>1=Nitrogen pack<br>2=Air pack |
|---|---|---|---|
| YEAST | | | |
| 3.83 | 42 | 4.4 | 1 |
| 3.75 | 42 | 4.4 | 2 |
| 2.86 | 42 | 21 | 1 |
| 2.73 | 42 | 21 | 2 |
| 0.99 | 42 | 37.8 | 1 |
| 0.45 | 42 | 37.8 | 2 |
| 3.23 | 48 | 4.4 | 1 |
| 2.70 | 48 | 4.4 | 2 |
| 2.72 | 48 | 21 | 1 |
| 2.51 | 48 | 21 | 2 |
| 1.20 | 48 | 37.8 | 1 |
| 0.80 | 48 | 37.8 | 2 |
| 3.43 | 54 | 4.4 | 1 |
| 3.10 | 54 | 4.4 | 2 |
| 2.64 | 54 | 21 | 1 |
| 2.16 | 54 | 21 | 2 |
| 1.38 | 54 | 37.8 | 1 |
| 0.67 | 54 | 37.8 | 2 |
| 3.17 | 60 | 4.4 | 1 |
| 2.76 | 60 | 4.4 | 2 |
| 2.42 | 60 | 21 | 1 |
| 1.92 | 60 | 21 | 2 |
| 1.24 | 60 | 37.8 | 1 |
| 0.42 | 60 | 37.8 | 2 |

| Thiamin mg./100g. | Time month | Temp C | Atmosphere<br>1=Nitrogen pack<br>2=Air pack |
|---|---|---|---|
| WHEAT | | | |
| 0.36 | 42 | 4.4 | 1 |
| 0.34 | 42 | 4.4 | 2 |
| 0.36 | 42 | 21 | 1 |
| 0.26 | 42 | 21 | 2 |
| 0.17 | 42 | 37.8 | 1 |
| 0.08 | 42 | 37.8 | 2 |
| 0.40 | 48 | 4.4 | 1 |
| 0.37 | 48 | 4.4 | 2 |
| 0.29 | 48 | 21 | 1 |
| 0.26 | 48 | 21 | 2 |
| 0.12 | 48 | 37.8 | 1 |
| 0.05 | 48 | 37.8 | 2 |
| 0.42 | 54 | 4.4 | 1 |
| 0.36 | 54 | 4.4 | 2 |
| 0.31 | 54 | 21 | 1 |
| 0.27 | 54 | 21 | 2 |
| 0.07 | 54 | 37.8 | 1 |
| 0.03 | 54 | 37.8 | 2 |
| 0.32 | 60 | 4.4 | 1 |
| 0.25 | 60 | 4.4 | 2 |
| 0.30 | 60 | 21 | 1 |
| 0.23 | 60 | 21 | 2 |
| 0 | 60 | 37.8 | 1 |
| 0 | 60 | 37.8 | 2 |

## APPENDIX I. Mean Values of Ascorbic Acid in Low-Moisture Foods

| Vitamin C mg./100 g. | Time month | Temp C | Atmosphere<br>1=Nitrogen pack<br>2=Air pack |
|---|---|---|---|
| **APPLE** | | | |
| 3.66 | 42 | 4.4 | 1 |
| 0 | 42 | 4.4 | 2 |
| 2.82 | 42 | 21 | 1 |
| 0 | 42 | 21 | 2 |
| 5.31 | 42 | 37.8 | 1 |
| 0 | 42 | 37.8 | 2 |
| 6.20 | 48 | 4.4 | 1 |
| 0 | 48 | 4.4 | 2 |
| 5.61 | 48 | 21 | 1 |
| 0 | 48 | 21 | 2 |
| 6.38 | 48 | 37.8 | 1 |
| 0 | 48 | 37.8 | 2 |
| 3.68 | 54 | 4.4 | 1 |
| 0 | 54 | 4.4 | 2 |
| 3.43 | 54 | 21 | 1 |
| 0 | 54 | 21 | 2 |
| 5.62 | 54 | 37.8 | 1 |
| 0 | 54 | 37.8 | 2 |
| 2.42 | 60 | 4.4 | 1 |
| 0 | 60 | 4.4 | 2 |
| 2.64 | 60 | 21 | 1 |
| 0 | 60 | 21 | 2 |
| 4.76 | 60 | 37.8 | 1 |
| 0 | 60 | 37.8 | 2 |

| Vitamin C mg.\100g. | Time months | Temp C | Atmosphere<br>1=Nitrogen pack<br>2=Air pack |
|---|---|---|---|
| **BANANA** | | | |
| 9.65 | 42 | 4.4 | 1 |
| 8.84 | 42 | 4.4 | 2 |
| 8.47 | 42 | 21 | 1 |
| 5.53 | 42 | 21 | 2 |
| 4.58 | 42 | 37.8 | 1 |
| 3.56 | 42 | 37.8 | 2 |
| 7.29 | 48 | 4.4 | 1 |
| 6.74 | 48 | 4.4 | 2 |
| 6.04 | 48 | 21 | 1 |
| 3.92 | 48 | 21 | 2 |
| 4.18 | 48 | 37.8 | 1 |
| 0.80 | 48 | 37.8 | 2 |
| 4.03 | 54 | 4.4 | 1 |
| 2.01 | 54 | 4.4 | 2 |
| 4.25 | 54 | 21 | 1 |
| 2.13 | 54 | 21 | 2 |
| 3.40 | 54 | 37.8 | 1 |
| 1.62 | 54 | 37.8 | 2 |
| 4.81 | 60 | 4.4 | 1 |
| 2.32 | 60 | 4.4 | 2 |
| 1.65 | 60 | 21 | 1 |
| 0.73 | 60 | 21 | 2 |
| 1.62 | 60 | 37.8 | 1 |
| 0.15 | 60 | 37.8 | 2 |

APPENDIX I (con't.)

| Vitamin C mg./100g. | Time months | Temp C | Atmosphere<br>1=Nitrogen pack<br>2=Air pack |
|---|---|---|---|
| CARROT | | | |
| 8.83 | 42 | 4.4 | 1 |
| 8.46 | 42 | 4.4 | 2 |
| 6.37 | 42 | 21 | 1 |
| 3.19 | 42 | 21 | 2 |
| 3.77 | 42 | 37.8 | 1 |
| 3.04 | 42 | 37.8 | 2 |
| 13.41 | 48 | 4.4 | 1 |
| 11.82 | 48 | 4.4 | 2 |
| 12.74 | 48 | 21 | 1 |
| 9.83 | 48 | 21 | 2 |
| 10.69 | 48 | 37.8 | 1 |
| 5.99 | 48 | 37.8 | 2 |
| 10.58 | 54 | 4.4 | 1 |
| 7.94 | 54 | 4.4 | 2 |
| 8.90 | 54 | 21 | 1 |
| 5.79 | 54 | 21 | 2 |
| 5.17 | 54 | 37.8 | 1 |
| 3.35 | 54 | 37.8 | 2 |
| 7.67 | 60 | 4.4 | 1 |
| 4.32 | 60 | 4.4 | 2 |
| 6.28 | 60 | 21 | 1 |
| 4.58 | 60 | 21 | 2 |
| 6.41 | 60 | 37.8 | 1 |
| 4.24 | 60 | 37.8 | 2 |

| Vitamin C mg./100g. | Time months | Temp C | Atmosphere<br>1=Nitrogen pack<br>2=Air pack |
|---|---|---|---|
| GREEN BEANS | | | |
| 43.39 | 42 | 4.4 | 1 |
| 37.37 | 42 | 4.4 | 2 |
| 23.81 | 42 | 21 | 1 |
| 15.71 | 42 | 21 | 2 |
| 5.19 | 42 | 37.8 | 1 |
| 1.90 | 42 | 37.8 | 2 |
| 44.64 | 48 | 4.4 | 1 |
| 34.98 | 48 | 4.4 | 2 |
| 16.05 | 48 | 21 | 1 |
| 8.82 | 48 | 21 | 2 |
| 5.50 | 48 | 37.8 | 1 |
| 1.90 | 48 | 37.8 | 2 |
| 43.16 | 54 | 4.4 | 1 |
| 34.81 | 54 | 4.4 | 2 |
| 17.32 | 54 | 21 | 1 |
| 5.03 | 54 | 21 | 2 |
| 5.58 | 54 | 37.8 | 1 |
| 5.04 | 54 | 37.8 | 2 |
| 17.71 | 60 | 4.4 | 1 |
| 5.71 | 60 | 4.4 | 2 |
| 17.66 | 60 | 21 | 1 |
| 6.35 | 60 | 21 | 2 |
| 4.04 | 60 | 37.8 | 1 |
| 0.92 | 60 | 37.8 | 2 |

APPENDIX I (con't.)

| Vitamin C mg./100g. | Time months | Temp C | Atmosphere 1=Nitrogen pack 2=Air pack |
|---|---|---|---|
| **PEACHES** | | | |
| 5.54 | 42 | 4.4 | 1 |
| 4.89 | 42 | 4.4 | 2 |
| 5.70 | 42 | 21 | 1 |
| 4.45 | 42 | 21 | 2 |
| 6.10 | 42 | 37.8 | 1 |
| 5.33 | 42 | 37.8 | 2 |
| 7.39 | 48 | 4.4 | 1 |
| 6.36 | 48 | 4.4 | 2 |
| 4.60 | 48 | 21 | 1 |
| 3.86 | 48 | 21 | 2 |
| 5.38 | 48 | 37.8 | 1 |
| 2.92 | 48 | 37.8 | 2 |
| 6.99 | 54 | 4.4 | 1 |
| 5.86 | 54 | 4.4 | 2 |
| 4.85 | 54 | 21 | 1 |
| 3.04 | 54 | 21 | 2 |
| 6.18 | 54 | 37.8 | 1 |
| 5.29 | 54 | 37.8 | 2 |
| 5.97 | 60 | 4.4 | 1 |
| 3.27 | 60 | 4.4 | 2 |
| 4.84 | 60 | 21 | 1 |
| 2.94 | 60 | 21 | 2 |
| 4.26 | 60 | 37.8 | 1 |
| 2.36 | 60 | 37.8 | 2 |

| Vitamin C mg./100g. | Time months | Temp C | Atmosphere 1=Nitrogen pack 2=Air pack |
|---|---|---|---|
| **SALAD BLEND** | | | |
| 228.99 | 42 | 4.4 | 1 |
| 200.22 | 42 | 4.4 | 2 |
| 175.73 | 42 | 21 | 1 |
| 81.32 | 42 | 21 | 2 |
| 8.96 | 42 | 37.8 | 1 |
| 6.18 | 42 | 37.8 | 2 |
| 246.12 | 48 | 4.4 | 1 |
| 229.42 | 48 | 4.4 | 2 |
| 148.31 | 48 | 21 | 1 |
| 62.88 | 48 | 21 | 2 |
| 12.09 | 48 | 37.8 | 1 |
| 9.90 | 48 | 37.8 | 2 |
| 239.18 | 54 | 4.4 | 1 |
| 188.00 | 54 | 4.4 | 2 |
| 172.85 | 54 | 21 | 1 |
| 64.61 | 54 | 21 | 2 |
| 13.17 | 54 | 37.8 | 1 |
| 9.82 | 54 | 37.8 | 2 |
| 200.58 | 60 | 4.4 | 1 |
| 113.68 | 60 | 4.4 | 2 |
| 128.22 | 60 | 21 | 1 |
| 27.01 | 60 | 21 | 2 |
| 8.59 | 60 | 37.8 | 1 |
| 5.70 | 60 | 37.8 | 2 |

APPENDIX I (con't.)

| Vitamin C mg./100g. | Time months | Temp C | Atmosphere 1=Nitrogen pack 2=Air pack |
|---|---|---|---|
| TOMATO | | | |
| 161.13 | 42 | 4.4 | 1 |
| 137.44 | 42 | 4.4 | 2 |
| 69.88 | 42 | 21 | 1 |
| 57.12 | 42 | 21 | 2 |
| 6.52 | 42 | 37.8 | 1 |
| 5.28 | 42 | 37.8 | 2 |
| 159.04 | 48 | 4.4 | 1 |
| 142.49 | 48 | 4.4 | 2 |
| 62.99 | 48 | 21 | 1 |
| 60.00 | 48 | 21 | 2 |
| 9.38 | 48 | 37.8 | 1 |
| 6.64 | 48 | 37.8 | 2 |
| 149.91 | 54 | 4.4 | 1 |
| 145.23 | 54 | 4.4 | 2 |
| 57.08 | 54 | 21 | 1 |
| 50.99 | 54 | 21 | 2 |
| 9.06 | 54 | 37.8 | 1 |
| 5.66 | 54 | 37.8 | 2 |
| 128.45 | 60 | 4.4 | 1 |
| 125.82 | 60 | 4.4 | 2 |
| 45.99 | 60 | 21 | 1 |
| 42.68 | 60 | 21 | 2 |
| 16.24 | 60 | 37.8 | 1 |
| 14.98 | 60 | 37.8 | 2 |

## APPENDIX J Mean Values of Beta-Carotene in Low-Moisture Foods

| Beta-Carotene mg./100 g. | Time months | Temp C | Atmosphere<br>1=Nitrogen pack<br>2=Air pack |
|---|---|---|---|
| CARROT | | | |
| 62.45 | 42 | 4.4 | 1 |
| 44.52 | 42 | 4.4 | 2 |
| 58.58 | 42 | 21 | 1 |
| 36.57 | 42 | 21 | 2 |
| 56.38 | 42 | 37.8 | 1 |
| 34.79 | 42 | 37.8 | 2 |
| 56.52 | 48 | 4.4 | 1 |
| 44.29 | 48 | 4.4 | 2 |
| 53.48 | 48 | 21 | 1 |
| 32.92 | 48 | 21 | 2 |
| 43.76 | 48 | 37.8 | 1 |
| 32.54 | 48 | 37.8 | 2 |
| 55.54 | 54 | 4.4 | 1 |
| 43.61 | 54 | 4.4 | 2 |
| 50.08 | 54 | 21 | 1 |
| 30.34 | 54 | 21 | 2 |
| 61.01 | 54 | 37.8 | 1 |
| 38.08 | 54 | 37.8 | 2 |
| 30.62 | 60 | 4.4 | 1 |
| 27.81 | 60 | 4.4 | 2 |
| 49.14 | 60 | 21 | 1 |
| 20.14 | 60 | 21 | 2 |
| 42.30 | 60 | 37.8 | 1 |
| 24.54 | 60 | 37.8 | 2 |

| Beta-carotene mg./100 g. | Time months | Temp C | Atmosphere |
|---|---|---|---|
| GREEN BEANS | | | |
| 2.98 | 42 | 4.4 | 1 |
| 1.84 | 42 | 4.4 | 2 |
| 2.79 | 42 | 21 | 1 |
| 1.15 | 42 | 21 | 2 |
| 2.76 | 42 | 37.8 | 1 |
| 1.35 | 42 | 37.8 | 2 |
| 2.86 | 48 | 4.4 | 1 |
| 1.10 | 48 | 4.4 | 2 |
| 2.80 | 48 | 21 | 1 |
| 1.04 | 48 | 21 | 2 |
| 2.34 | 48 | 37.8 | 1 |
| 1.59 | 48 | 37.8 | 2 |
| 2.62 | 54 | 4.4 | 1 |
| 1.05 | 54 | 4.4 | 2 |
| 2.54 | 54 | 21 | 1 |
| 1.06 | 54 | 21 | 2 |
| 2.68 | 54 | 37.8 | 1 |
| 0.67 | 54 | 37.8 | 2 |
| 2.78 | 60 | 4.4 | 1 |
| 1.09 | 60 | 4.4 | 2 |
| 2.74 | 60 | 21 | 1 |
| 0.74 | 60 | 21 | 2 |
| 2.72 | 60 | 37.8 | 1 |
| 0.42 | 60 | 37.8 | 2 |

APPENDIX J (con't.)

| Beta-Carotene mg./100g. | Time month | Temp C | Atmosphere 1=Nitrogen pack 2=Air pack |
|---|---|---|---|
| PEACHES | | | |
| 0.90 | 42 | 4.4 | 1 |
| 0.74 | 42 | 4.4 | 2 |
| 0.88 | 42 | 21 | 1 |
| 0.74 | 42 | 21 | 2 |
| 0.72 | 42 | 37.8 | 1 |
| 0.64 | 42 | 37.8 | 2 |
| 0.82 | 48 | 4.4 | 1 |
| 0.75 | 48 | 4.4 | 2 |
| 0.67 | 48 | 21 | 1 |
| 0.64 | 48 | 21 | 2 |
| 0.67 | 48 | 37.8 | 1 |
| 0.45 | 48 | 37.8 | 2 |
| 0.62 | 54 | 4.4 | 1 |
| 0.50 | 54 | 4.4 | 2 |
| 0.33 | 54 | 21 | 1 |
| 0.28 | 54 | 21 | 2 |
| 0.30 | 54 | 37.8 | 1 |
| 0.24 | 54 | 37.8 | 2 |
| 0.51 | 60 | 4.4 | 1 |
| 0.47 | 60 | 4.4 | 2 |
| 0.44 | 60 | 21 | 1 |
| 0.38 | 60 | 21 | 2 |
| 0.41 | 60 | 37.8 | 1 |
| 0.27 | 60 | 37.8 | 2 |

| Beta-Carotene mg./100g. | Time months | Temp C | Atmosphere 1=Nitrogen pack 2=Air pack |
|---|---|---|---|
| SALAD BLEND | | | |
| 10.70 | 42 | 4.4 | 1 |
| 8.46 | 42 | 4.4 | 2 |
| 11.04 | 42 | 21 | 1 |
| 6.66 | 42 | 21 | 2 |
| 9.36 | 42 | 37.8 | 1 |
| 8.98 | 42 | 37.8 | 2 |
| 10.14 | 48 | 4.4 | 1 |
| 8.65 | 48 | 4.4 | 2 |
| 9.72 | 48 | 21 | 1 |
| 8.10 | 48 | 21 | 2 |
| 8.03 | 48 | 37.8 | 1 |
| 7.26 | 48 | 37.8 | 2 |
| 9.50 | 54 | 4.4 | 1 |
| 8.94 | 54 | 4.4 | 2 |
| 8.05 | 54 | 21 | 1 |
| 7.91 | 54 | 21 | 2 |
| 10.19 | 54 | 37.8 | 1 |
| 8.03 | 54 | 37.8 | 2 |
| 9.24 | 60 | 4.4 | 1 |
| 8.28 | 60 | 4.4 | 2 |
| 7.75 | 60 | 21 | 1 |
| 7.63 | 60 | 21 | 2 |
| 7.42 | 60 | 37.8 | 1 |
| 6.88 | 60 | 37.8 | 2 |

APPENDIX J (con't.)

| Beta-Carotene mg./100g. | Time months | Temp C | Atmosphere 1=Nitrogen pack 2=Air pack |
|---|---|---|---|
| TOMATO | | | |
| 3.65 | 42 | 4.4 | 1 |
| 3.50 | 42 | 4.4 | 2 |
| 3.75 | 42 | 21 | 1 |
| 3.16 | 42 | 21 | 2 |
| 3.74 | 42 | 37.8 | 1 |
| 2.79 | 42 | 37.8 | 2 |
| 3.84 | 48 | 4.4 | 1 |
| 3.65 | 48 | 4.4 | 2 |
| 3.83 | 48 | 21 | 1 |
| 3.26 | 48 | 21 | 2 |
| 3.55 | 48 | 37.8 | 1 |
| 3.12 | 48 | 37.8 | 2 |
| 3.98 | 54 | 4.4 | 1 |
| 3.80 | 54 | 4.4 | 2 |
| 3.83 | 54 | 21 | 1 |
| 3.27 | 54 | 21 | 2 |
| 3.68 | 54 | 37.8 | 1 |
| 2.78 | 54 | 37.8 | 2 |
| 3.52 | 60 | 4.4 | 1 |
| 3.20 | 60 | 4.4 | 2 |
| 3.49 | 60 | 21 | 1 |
| 2.98 | 60 | 21 | 2 |
| 3.50 | 60 | 37.8 | 1 |
| 2.60 | 60 | 37.8 | 2 |

| Beta-Carotene mg./100g. | Time months | Temp C | Atmosphere 1=Nitrogen pack 2=Air pack |
|---|---|---|---|
| VEG SOUP | | | |
| 4.11 | 42 | 4.4 | 1 |
| 3.65 | 42 | 4.4 | 2 |
| 3.56 | 42 | 21 | 1 |
| 2.53 | 42 | 21 | 2 |
| 2.83 | 42 | 37.8 | 1 |
| 2.36 | 42 | 37.8 | 2 |
| 3.58 | 48 | 4.4 | 1 |
| 2.45 | 48 | 4.4 | 2 |
| 4.00 | 48 | 21 | 1 |
| 3.93 | 48 | 21 | 2 |
| 3.52 | 48 | 37.8 | 1 |
| 2.21 | 48 | 37.8 | 2 |
| 3.58 | 54 | 4.4 | 1 |
| 3.13 | 54 | 4.4 | 2 |
| 3.34 | 54 | 21 | 1 |
| 2.14 | 54 | 21 | 2 |
| 3.18 | 54 | 37.8 | 1 |
| 2.22 | 54 | 37.8 | 2 |
| 2.37 | 60 | 4.4 | 1 |
| 1.46 | 60 | 4.4 | 2 |
| 2.33 | 60 | 21 | 1 |
| 1.36 | 60 | 21 | 2 |
| 2.77 | 60 | 37.8 | 1 |
| 2.26 | 60 | 37.8 | 2 |

# APPENDIX K Mean Response Values for Taste Panel Data

| | Time months | | Temperature C | | Atmosphere | |
|---|---|---|---|---|---|---|
| **APPLE** | | | | | | |
| Flavor | 42 | 62.81 | 4.4 | 58.09 | Nitrogen | 57.72 |
| | 48 | 61.09 | | | | |
| | 54 | 54.77 | 21 | 60.06 | Air | 60.44 |
| | 60 | 57.84 | | | | |
| Appearance | 42 | 73.73 | 4.4 | 72.68 | Nitrogen | 71.12 |
| | 48 | 72.07 | | | | |
| | 54 | 65.53 | 21 | 65.62 | Air | 67.18 |
| | 60 | 65.28 | | | | |
| Texture | 42 | 69.23 | 4.4 | 61.08 | Nitrogen | 60.32 |
| | 48 | 62.24 | | | | |
| | 54 | 55.43 | 21 | 61.59 | Air | 62.36 |
| | 60 | 58.45 | | | | |
| Overall | 42 | 66.50 | 4.4 | 61.55 | Nitrogen | 60.78 |
| | 48 | 62.26 | | | | |
| | 54 | 55.91 | 21 | 61.18 | Air | 61.95 |
| | 60 | 60.80 | | | | |

- The response scale used is 0 = very poor and 100 = excellent

| | Time months | | Temperature C | | Atmosphere | |
|---|---|---|---|---|---|---|
| **BANANA** | | | | | | |
| Flavor | 42 | 59.82 | 4.4 | 72.88 | Nitrogen | 63.98 |
| | 48 | 58.42 | | | | |
| | 54 | 56.13 | 21 | 61.87 | Air | 47.93 |
| | 60 | 49.46 | | | | |
| | | | 37.8 | 33.12 | | |
| Appearance | 42 | 69.56 | 4.4 | 75.42 | Nitrogen | 69.60 |
| | 48 | 73.74 | | | | |
| | 54 | 70.04 | 21 | 73.74 | Air | 72.88 |
| | 60 | 71.81 | | | | |
| | | | 37.8 | 64.55 | | |
| Texture | 42 | 77.89 | 4.4 | 78.10 | Nitrogen | 74.75 |
| | 48 | 74.42 | | | | |
| | 54 | 70.00 | 21 | 75.72 | Air | 72.38 |
| | 60 | 71.95 | | | | |
| | | | 37.8 | 66.88 | | |
| Overall | 42 | 61.91 | 4.4 | 72.23 | Nitrogen | 64.80 |
| | 48 | 60.68 | | | | |
| | 54 | 57.55 | 21 | 64.67 | Air | 52.36 |
| | 60 | 54.18 | | | | |
| | | | 37.8 | 38.84 | | |

- The response scale used is 0 = very poor and 100 = excellent

APPENDIX K (con't.)

| | Time months | | Temperature C | | Atmosphere | |
|---|---|---|---|---|---|---|
| **BUTTER** | | | | | | |
| Flavor | | | | | | |
| | 42 | 69.58 | 4.4 | | Nitrogen | |
| | 48 | 52.63 | | 67.89 | | 67.47 |
| | 54 | 61.30 | 21 | | Air | |
| | 60 | 61.38 | | 54.56 | | 54.98 |
| Appearance | | | | | | |
| | 42 | 82.86 | 4.4 | | Nitrogen | |
| | 48 | 78.34 | | 82.59 | | 81.99 |
| | 54 | 82.29 | 21 | | Air | |
| | 60 | 83.74 | | 81.03 | | 81.62 |
| Texture | | | | | | |
| | 42 | 76.02 | 4.4 | | Nitrogen | |
| | 48 | 56.48 | | 68.07 | | 68.22 |
| | 54 | 65.39 | 21 | | Air | |
| | 60 | 69.27 | | 65.51 | | 65.37 |
| Overall | | | | | | |
| | 42 | 72.48 | 4.4 | | Nitrogen | |
| | 48 | 57.72 | | 70.39 | | 68.99 |
| | 54 | 62.21 | 21 | | Air | |
| | 60 | 64.42 | | 58.02 | | 59.42 |

* The response scale used was 0 = very poor 100 = excellent

| | | | | | | |
|---|---|---|---|---|---|---|
| **CARROT** | | | | | | |
| Flavor | 42 | 63.16 | 4.4 | | Nitrogen | |
| | 48 | 62.64 | | 70.47a | | 66.64 |
| | 54 | 56.62 | 21 | | Air | |
| | 60 | 59.99 | | 50.73b | | 54.56 |
| Appearance | | | | | | |
| | 42 | 62.81 | 4.4 | | Nitrogen | |
| | 48 | 59.59 | | 70.55 | | 69.44 |
| | 54 | 52.58 | 21 | | Air | |
| | 60 | 62.59 | | 48.23 | | 49.35 |
| Texture | | | | | | |
| | 42 | 69.09 | 4.4 | | Nitrogen | |
| | 48 | 66.34 | | 70.30 | | 69.27 |
| | 54 | 60.21 | 21 | | Air | |
| | 60 | 64.88 | | 59.96 | | 60.99 |
| Overall | | | | | | |
| | 42 | 63.65 | 4.4 | | Nitrogen | |
| | 48 | 61.49 | | 69.52 | | 67.36 |
| | 54 | 53.42 | 21 | | Air | |
| | 60 | 61.08 | | 50.30 | | 52.46 |

* The response scale used is 0 = very poor and 100 = excellent

** Mean values followed by different letters are significantly different at the 0.05 level.

APPENDIX K (con't)

| | Time Months | | Temperature C | | Atmosphere | |
|---|---|---|---|---|---|---|
| **EGGS** | | | | | | |
| Flavor | | | | | | |
| | 42 | 61.31 | 4.4 | | Nitrogen | |
| | 48 | 57.98 | | 68.71 | | 68.32 |
| | 54 | 60.37 | 21 | | Air | |
| | 60 | 61.51 | | 51.87 | | 51.87 |
| Appearance | | | | | | |
| | 42 | 79.54 | 4.4 | | Nitrogen | |
| | 48 | 72.90 | | 85.80 | | 73.31 |
| | 54 | 65.95 | 21 | | Air | |
| | 60 | 66.35 | | 56.57 | | 69.06 |
| Texture | | | | | | |
| | 42 | 74.26 | 4.4 | | Nitrogen | |
| | 48 | 67.58 | | 76.22 | | 74.38 |
| | 54 | 70.65 | 21 | | Air | |
| | 60 | 71.89 | | 65.97 | | 67.81 |
| Overall | | | | | | |
| | 42 | 67.34 | 4.4 | | Nitrogen | |
| | 48 | 63.00 | | 73.01 | | 70.58 |
| | 54 | 62.45 | 21 | | Air | |
| | 60 | 63.67 | | 55.22 | | 57.66 |

* The response scale used was 0 = very poor and 100 = excellent

| | Time Months | | Temperature C | | Atmosphere | |
|---|---|---|---|---|---|---|
| **GREEN BEANS** | | | | | | |
| Flavor | | | | | | |
| | 42 | 66.84 | 4.4 | | Nitrogen | |
| | 48 | 60.72 | | 66.99 | | 63.44a |
| | 54 | 56.89 | 21 | | Air | |
| | 60 | 65.23 | | 57.84 | | 61.40b |
| Appearance | | | | | | |
| | 42 | 70.38 | 4.4 | | Nitrogen | |
| | 48 | 64.14 | | 71.05 | | 61.16 |
| | 54 | 59.89 | 21 | | Air | |
| | 60 | 64.15 | | 58.23 | | 68.12 |
| Texture | | | | | | |
| | 42 | 68.91 | 4.4 | | Nitrogen | |
| | 48 | 63.15 | | 67.19 | | 62.35 |
| | 54 | 55.22 | 21 | | Air | |
| | 60 | 61.56 | | 57.23 | | 62.06 |
| Overall | | | | | | |
| | 42 | 67.50 | 4.4 | | Nitrogen | |
| | 48 | 62.79 | | 68.40 | | 62.55 |
| | 54 | 57.22 | 21 | | Air | |
| | 60 | 64.60 | | 57.65 | | 63.50 |

* The response scale used is 0 =very poor 100 =excellent

** Mean values followed by a different letter are significantly different at the 0.05 level.

APPENDIX K (con't.)

| | Time months | | Temperature C | | Atmosphere | |
|---|---|---|---|---|---|---|
| **MACARONI** | | | | | | |
| Flavor | | | | | | |
| | 42 | 80.06 | 4.4 | | Nitrogen | |
| | 48 | 72.88 | | 76.76 | | 73.76 |
| | 54 | 63.85 | 21 | | Air | |
| | 60 | 74.73 | | 69.01 | | 71.99 |
| Appearance | | | | | | |
| | 42 | 86.17 | 4.4 | | Nitrogen | |
| | 48 | 78.79 | | 80.45 | | 76.17 |
| | 54 | 69.13 | 21 | | Air | |
| | 60 | 73.83 | | 73.51 | | 77.79 |
| Texture | | | | | | |
| | 42 | 78.66 | 4.4 | | Nitrogen | |
| | 48 | 73.64 | | 73.84a | | 73.48 |
| | 54 | 66.68 | 21 | | Air | |
| | 60 | 75.96 | | 73.63b | | 73.99 |
| Overall | | | | | | |
| | 42 | 80.31 | 4.4 | | Nitrogen | |
| | 48 | 73.17 | | 76.32 | | 73.23 |
| | 54 | 65.00 | 21 | | Air | |
| | 60 | 73.68 | | 69.76 | | 72.85 |

* The resopnse scale used is 0 = very poor and 100 = excellent

** Mean values followed by a different letter are significantly different at a 0.05 level.

| | Time months | | Temperature C | | Atmosphere | |
|---|---|---|---|---|---|---|
| **MILK** | | | | | | |
| Flavor | | | | | | |
| | 42 | 65.96 | 4.4 | | Nitrogen | |
| | 48 | 40.36 | | 53.08 | | 57.58 |
| | 54 | 58.63 | 21 | | Air | |
| | 60 | 56.42 | | 57.59 | | 53.09 |
| Appearance | | | | | | |
| | 42 | 89.68 | 4.4 | | Nitrogen | |
| | 48 | 83.46 | | 84.09 | | 84.86 |
| | 54 | 84.04 | 21 | | Air | |
| | 60 | 81.18 | | 85.09 | | 84.32 |
| Texture | | | | | | |
| | 42 | 86.35 | 4.4 | | Nitrogen | |
| | 48 | 68.39 | | 77.13 | | 78.70 |
| | 54 | 83.87 | 21 | | Air | |
| | 60 | 76.79 | | 80.56 | | 78.99 |
| Overall | | | | | | |
| | 42 | 72.91 | 4.4 | | Nitrogen | |
| | 48 | 48.77 | | 60.91 | | 63.82 |
| | 54 | 65.53 | 21 | | Air | |
| | 60 | 62.86 | | 64.13 | | 61.23 |

* The response scale used is 0 = very poor and 100 = excellent

## APPENDIX K. Mean Response Values for Taste Panel Data

**ROLLED OATS**

| | Time months | | Temperature C | | Atmosphere | |
|---|---|---|---|---|---|---|
| Flavor | 42 | 65.18 | 4.4 | | Nitrogen | |
| | 48 | 72.24 | | 71.52 | | 68.05 |
| | 54 | 66.64 | 21 | | Air | |
| | 60 | 66.85 | | 63.94 | | 67.40 |
| Appearance | | | | | | |
| | 42 | 65.32 | 4.4 | | Nitrogen | |
| | 48 | 83.92 | | 82.47 | | 83.01 |
| | 54 | 79.71 | 21 | | Air | |
| | 60 | 76.69 | | 80.35 | | 79.81 |
| Texture | | | | | | |
| | 42 | 70.24 | 4.4 | | Nitrogen | |
| | 48 | 74.96 | | 73.34 | | 72.53 |
| | 54 | 72.20 | 21 | | Air | |
| | 60 | 67.63 | | 69.17 | | 69.98 |
| Overall | | | | | | |
| | 42 | 69.84 | 4.4 | | Nitrogen | |
| | 48 | 73.58 | | 73.48 | | 72.72 |
| | 54 | 69.42 | 21 | | Air | |
| | 60 | 69.15 | | 67.51 | | 68.78 |

• The response scale used is 0 = very poor and 100 = excellent

**PEACH**

| | | | | | | |
|---|---|---|---|---|---|---|
| Flavor | | | | | | |
| | 42 | 68.59 | 4.4 | | Nitrogen | |
| | 48 | 60.93 | | 72.16 | | 64.89 |
| | 54 | 64.16 | 21 | | Air | |
| | 60 | 64.59 | | 56.98 | | 64.25 |
| Appearance | | | | | | |
| | 42 | 59.01 | 4.4 | | Nitrogen | |
| | 48 | 56.84 | | 73.36 | | 59.09 |
| | 54 | 56.99 | 21 | | Air | |
| | 60 | 54.44 | | 40.28 | | 54.54 |
| Texture | | | | | | |
| | 42 | 68.07 | 4.4 | | Nitrogen | |
| | 48 | 62.70 | | 70.65 | | 65.65 |
| | 54 | 64.98 | 21 | | Air | |
| | 60 | 65.27 | | 59.86 | | 64.86 |
| Overall | | | | | | |
| | 42 | 66.61 | 4.4 | | Nitrogen | |
| | 48 | 58.93 | | 71.70 | | 62.89 |
| | 54 | 61.38 | 21 | | Air | |
| | 60 | 61.23 | | 52.37 | | 61.19 |

• The response scale used is 0 = very poor and 100 = excellent

APPENDIX K (con't)

| | Time months | | Temperature C | | Atmosphere | |
|---|---|---|---|---|---|---|
| **PEANUT BUTTER** | | | | | | |
| Flavor | | | | | | |
| | 42 | 70.89 | 4.4 | | Nitrogen | |
| | 48 | 60.93 | | 72.16 | | 64.89 |
| | 54 | 64.16 | 21 | | Air | |
| | 60 | 64.59 | | 56.98 | | 64.25 |
| Appearance | | | | | | |
| | 42 | 59.01 | 4.4 | | Nitrogen | |
| | 48 | 56.84 | | 73.36 | | 59.09 |
| | 54 | 56.99 | 21 | | Air | |
| | 60 | 54.44 | | 40.28 | | 54.54 |
| Texture | | | | | | |
| | 42 | 68.07 | 4.4 | | Nitrogen | |
| | 48 | 62.70 | | 70.65 | | 65.65 |
| | 54 | 59.86 | 21 | | Air | |
| | 60 | 65.27 | | 59.86 | | 64.86 |
| Overall | | | | | | |
| | 42 | 66.61 | 4.4 | | Nitrogen | |
| | 48 | 58.93 | | 71.70 | | 62.89 |
| | 54 | 61.38 | 21 | | Air | |
| | 60 | 61.23 | | 52.37 | | 61.19 |

* The response scale used is 0 = very poor and 100 = excellent

| | | | | | | |
|---|---|---|---|---|---|---|
| **POTATO** | | | | | | |
| Flavor | | | | | | |
| | 42 | 81.44 | 4.4 | | Nitrogen | |
| | 48 | 73.76 | | 83.64 | | 78.08 |
| | 54 | 75.09 | 21 | | Air | |
| | 60 | 72.86 | | 67.94 | | 73.49 |
| Appearance | | | | | | |
| | 42 | 90.83 | 4.4 | | Nitrogen | |
| | 48 | 83.20 | | 87.48 | | 82.47a |
| | 54 | 80.27 | 21 | | Air | |
| | 60 | 74.57 | | 76.96 | | 81.96b |
| Texture | | | | | | |
| | 42 | 84.84 | 4.4 | | Nitrogen | |
| | 48 | 77.88 | | 82.66 | | 78.29 |
| | 54 | 83.33 | 21 | | Air | |
| | 60 | 65.60 | | 73.17 | | 77.54 |
| Overall | | | | | | |
| | 42 | 82.55 | 4.4 | | Nitrogen | |
| | 48 | 75.85 | | 77.68 | | 75.71 |
| | 54 | 77.26 | 21 | | Air | |
| | 60 | 58.20 | | 69.26 | | 71.23 |

* The response scale used is 0 = very poor and 100 = excellent

** Means followed by a different letter are significantly different at the 0.05 level.

APPENDIX K (con't.)

NAVY BEANS

| | Time months | | Temperature C | | Atmosphere | |
|---|---|---|---|---|---|---|
| Flavor | | | | | | |
| | 42 | 82.12 | 4.4 | | Nitrogen | |
| | 48 | 66.58 | | 77.78 | | 75.79 |
| | 54 | 74.11 | 21 | | Air | |
| | 60 | 72.60 | | 69.93 | | 71.92 |
| Appearance | | | | | | |
| | 42 | 84.11 | 4.4 | | Nitrogen | |
| | 48 | 77.88 | | 83.16 | | 81.45 |
| | 54 | 84.20 | 21 | | Air | |
| | 60 | 79.74 | | 79.81 | | 81.52 |
| Texture | | | | | | |
| | 42 | 80.32 | 4.4 | | Nitrogen | |
| | 48 | 61.63 | | 74.12 | | 70.59 |
| | 54 | 66.85 | 21 | | Air | |
| | 60 | 63.45 | | 62.01 | | 65.53 |
| Overall | | | | | | |
| | 42 | 81.81 | 4.4 | | Nitrogen | |
| | 48 | 66.38 | | 76.48 | | 73.98 |
| | 54 | 71.09 | 21 | | Air | |
| | 60 | 67.99 | | 67.16 | | 69.65 |

* The response scale used is 0 = very poor and 100 = excellent

SALAD BLEND

| | Time months | | Temperature C | | Atmosphere | |
|---|---|---|---|---|---|---|
| Flavor | | | | | | |
| | 42 | 68.28 | 4.4 | | Nitrogen | |
| | 48 | 69.18 | | 73.51a | | 68.42a |
| | 54 | 67.43 | 21 | | Air | |
| | 60 | 63.56 | | 60.72b | | 65.81a |
| Appearance | | | | | | |
| | 42 | 76.49 | 4.4 | | Nitrogen | |
| | 48 | 65.36 | | 79.29a | | 72.67a |
| | 54 | 74.99 | 21 | | Air | |
| | 60 | 71.61 | | 64.94b | | 71.56a |
| Texture | | | | | | |
| | 42 | 71.98 | 4.4 | | Nitrogen | |
| | 48 | 68.18 | | 74.00a | | 70.82a |
| | 54 | 70.09 | 21 | | Air | |
| | 60 | 69.49 | | 65.87b | | 69.06a |
| Overall | | | | | | |
| | 42 | 70.02 | 4.4 | | Nitrogen | |
| | 48 | 65.23 | | 72.77a | | 68.29a |
| | 54 | 67.41 | 21 | | Air | |
| | 60 | 65.08 | | 61.11b | | 65.59a |

* The response scale used is 0 = very poor and 100 = excellent

** Mean values followed by a different letter are significantly different at the 0.05 level.

## APPENDIX K (con't)

| | Time months | | Temperature C | | Atmosphere | |
|---|---|---|---|---|---|---|
| **STROGANOFF** | | | | | | |
| Flavor | | | | | | |
| | 42 | 71.13 | 4.4 | | Nitrogen | |
| | 48 | 62.54 | | 77.28 | | 64.70 |
| | 54 | 65.64 | 21 | | Air | |
| | 60 | 54.40 | | 49.58 | | 62.15 |
| Appearance | | | | | | |
| | 42 | 80.29 | 4.4 | | Nitrogen | |
| | 48 | 69.81 | | 82.74 | | 74.63 |
| | 54 | 71.86 | 21 | | Air | |
| | 60 | 71.57 | | 64.02 | | 72.14 |
| Texture | | | | | | |
| | 42 | 80.08 | 4.4 | | Nitrogen | |
| | 48 | 72.05 | | 81.12a | | 76.53 |
| | 54 | 78.93 | 21 | | Air | |
| | 60 | 72.75 | | 70.78b | | 75.38 |
| Overall | | | | | | |
| | 42 | 72.60 | 4.4 | | Nitrogen | |
| | 48 | 65.50 | | 79.28 | | 67.87 |
| | 54 | 69.25 | 21 | | Air | |
| | 60 | 59.39 | | 54.09 | | 65.49 |

* The response scale used is 0 = very poor 100 = excellent

** Mean values followed by a different letter are significantly different at the 0.05 level.

| | | | | | | |
|---|---|---|---|---|---|---|
| **TOMATO** | | | | | | |
| Flavor | | | | | | |
| | 42 | 51.28 | 4.4 | | Nitrogen | |
| | 48 | 52.17 | | 56.51 | | 58.79 |
| | 54 | 59.61 | 21 | | Air | |
| | 60 | 62.19 | | 56.11 | | 53.83 |
| Appearance | | | | | | |
| | 42 | 87.07 | 4.4 | | Nitrogen | |
| | 48 | 79.17 | | 84.04 | | 82.93 |
| | 54 | 82.63 | 21 | | Air | |
| | 60 | 81.45 | | 81.12 | | 82.23 |
| Texture | | | | | | |
| | 42 | 79.16 | 4.4 | | Nitrogen | |
| | 48 | 69.62 | | 75.80 | | 76.61 |
| | 54 | 77.95 | 21 | | Air | |
| | 60 | 76.38 | | 75.75 | | 74.94 |
| Overall | | | | | | |
| | 42 | 59.66 | 4.4 | | Nitrogen | |
| | 48 | 58.00 | | 61.57 | | 63.72 |
| | 54 | 62.88 | 21 | | Air | |
| | 60 | 65.95 | | 61.67 | | 59.53 |

* The response scale used is 0 = very poor 100 = excellent

APPENDIX K (con't.)

| | Time months | | Temperature C | | Atmosphere | |
|---|---|---|---|---|---|---|
| **TVP** | | | | | | |
| Flavor | | | | | | |
| | 42 | 70.19 | 4.4 | | Nitrogen | |
| | 48 | 66.02 | | 69.53 | | 73.34 |
| | 54 | 74.51 | 21 | | Air | |
| | 60 | 66.83 | | 69.25 | | 65.44 |
| Appearance | | | | | | |
| | 42 | 86.50 | 4.4 | | Nitrogen | |
| | 48 | 76.90 | | 81.31 | | 81.35 |
| | 54 | 84.44 | 21 | | Air | |
| | 60 | 76.91 | | 81.01 | | 81.03 |
| Texture | | | | | | |
| | 42 | 76.69 | 4.4 | | Nitrogen | |
| | 48 | 78.70 | | 75.01 | | 76.64 |
| | 54 | 78.70 | 21 | | Air | |
| | 60 | 73.11 | | 74.74 | | 73.12 |
| Overall | | | | | | |
| | 42 | 73.72 | 4.4 | | Nitrogen | |
| | 48 | 67.73 | | 71.74 | | 75.13 |
| | 54 | 76.33 | 21 | | Air | |
| | 60 | 69.03 | | 71.67 | | 68.28 |

* The response scale used is 0 = very poor and 100 = excellent

| | | | | | | |
|---|---|---|---|---|---|---|
| **VEGETABLE SOUP** | | | | | | |
| Flavor | | | | | | |
| | 42 | 72.15 | 4.4 | | Nitrogen | |
| | 48 | 65.17 | | 79.24a | | 72.66a |
| | 54 | 70.32 | 21 | | Air | |
| | 60 | 65.86 | | 57.51a | | 64.09b |
| Appearance | | | | | | |
| | 42 | 78.18 | 4.4 | | Nitrogen | |
| | 48 | 67.33 | | 83.68a | | 72.72a |
| | 54 | 75.27 | 21 | | Air | |
| | 60 | 63.64 | | 58.52b | | 69.49a |
| Texture | | | | | | |
| | 42 | 76.48 | 4.4 | | Nitrogen | |
| | 48 | 70.66 | | 79.91a | | 74.83a |
| | 54 | 76.98 | 21 | | Air | |
| | 60 | 73.18 | | 68.73b | | 73.81a |
| Overall | | | | | | |
| | 42 | 74.29 | 4.4 | | Nitrogen | |
| | 48 | 67.12 | | 80.48a | | 72.86a |
| | 54 | 70.92 | 21 | | Air | |
| | 60 | 65.80 | | 58.59a | | 66.41b |

* The response scale used is 0 = very poor and 100 = excellent

** Mean values followed by a different letter are significantly different at the 0.05 level.

APPENDIX K (con't)

| Time months | | Temperature C | | Atmosphere | |
|---|---|---|---|---|---|
| **WHEAT** | | | | | |
| Flavor | | | | | |
| 42 | 68.44 | 4.4 | 78.49a | Nitrogen | 67.41a |
| 48 | 66.52 | 21 | 77.53a | Air | 68.97a |
| 54 | 72.66 | 37.8 | 48.54b | | |
| 60 | 65.14 | | | | |
| Appearance | | | | | |
| 42 | 86.96 | 4.4 | 84.26a | Nitrogen | 80.29a |
| 48 | 75.29 | 21 | 84.14a | Air | 80.09a |
| 54 | 82.13 | 37.8 | 72.18a | | |
| 60 | 76.40 | | | | |
| Texture | | | | | |
| 42 | 77.88 | 4.4 | 79.23a | Nitrogen | 74.64a |
| 48 | 72.51 | 21 | 79.71a | Air | 76.65a |
| 54 | 80.09 | 37.8 | 67.99a | | |
| 60 | 72.09 | | | | |
| Overall | | | | | |
| 42 | 72.54 | 4.4 | 79.65a | Nitrogen | 69.99a |
| 48 | 68.53 | 21 | 78.96a | Air | 71.38a |
| 54 | 74.23 | 37.8 | 53.45b | | |
| 60 | 67.46 | | | | |

* The response scale used is 0 = very poor and 100 = excellent

** Mean values followed by a different letter are different at the 0.05 level.

APPENDIX L. Taste panel Response Form

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 ______________________________

---

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

APPENDIX M **Mean Values of Yeast Activity (ml.)**

| Time | Temperature (°C) | | | | | |
|---|---|---|---|---|---|---|
| | 4.4 | 4.4 | 21 | 21 | 37.8 | 37.8 |
| | Atmosphere | | | | | |
| months | $N_2$ | air | $N_2$ | air | $N_2$ | air |
| initial | 5.0 | 5.0 | 2.0 | 2.0 | 0.3 | 0.25 |
| 42 | 1.66 | 1.00 | 0.5 | 0.25 | trace | trace |
| 48 | 1.55 | 0.95 | 0.48 | 0.11 | trace | trace |
| 54 | 1.80 | 0.90 | 0.33 | 0.22 | trace | trace |
| 60 | 1.25 | 0.85 | 0.15 | 0.05 | trace | trace |

Procedure: Mixture 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°C) water. The volume of the gas evolved in four minutes was measured. Results are listed in the table above.

# Nutrient Retention and Sensory Quality in Low-Moisture Foods Stored 42 to 60 months: Effect of Storage Temperature, Time and Oxygen Level.

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## ABSTRACT

Eighteen low-moisture foods packaged with and without nitrogen flushing were stored at 4.4, 21.1 and 37.8°C for 42 to 60 months and analyzed for thiamin, ascorbic acid, vitamin A and/or beta-carotene, and evaluated by a taste panel. Foods tested were apples, banana slices, green beans, navy beans, butter, carrots, egg mix, non-fat dry milk, rolled oats, peaches, salad blend, macaroni, stroganoff, tomato crystals, vegetable noodle soup, texturized vegetable protein, whole wheat and yeast. Peanut butter and potatoes were also tested by the taste panel.

Thiamin retention was most affected at the higher storage temperatures; eggs, navy beans and macaroni had a total loss of thiamin after 42 months at 37.8°C. Non-enzymatic browning occurring in the foods stored at 37.8°C also appeared to affect thiamin retention. Oxidative and thermal destruction accounted for most of the ascorbic acid loss, especially evident in salad blend and tomatoes. Non-enzymatic browning occurring in the foods also was related to loss of ascorbic acid. Beta-carotene and vitamin A both underwent deterioration especially in the 21°C samples. Reversion of *cis* to *trans* isomers seemed to occur in some foods, especially tomato crystals.

Panelists rated the dried foods stored at 4.4°C as barely acceptable after 60 months. Eggs, carrots, peaches and stroganoff were unacceptable after 60 months at 21°C. The majority of the foods at 37.8°C were unacceptable by 42 months and bananas after 60 months. The foods stored at the higher temperatures decreased the palatability markedly.

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