AN ABSTRACT OF THE THESIS OF

Joan Barrett for the degree of Master of Science in Foods and Nutrition presented on February 19, 1980.

Title: Ascorbic Acid and Vitamin B-6 Retention in Broccoli and Green Peppers After Home Dehydration and Storage.

Abstract approved: Margy Woodburn, Ph.D.

Fresh broccoli (Brassica oleracea) and green peppers (Capsicum frutescen) were dried in a home-made portable electric food dryer to different moisture contents by varying the drying times. The percent retention of ascorbic acid and vitamin B-6 was measured in these samples. In addition, a representative sample from each of the three drying times was stored in a 37°C incubator for 11 to 13.5 weeks for broccoli and 8 to 9.5 weeks for green peppers. The retention of ascorbic acid and vitamin B-6 was determined in these samples.

The ascorbic acid level was greatly reduced after dehydration and again after storage in both broccoli and green pepers. An average of 2.8 mg/g dry weight or 31% of the ascorbic acid present after blanching was retained in the broccoli after dehydration. An average of 11% of that present after drying or 0.41 mg/g dry weight remained in

the dried broccoli after storage. Green peppers lost more ascorbic acid than broccoli in the drying process and after storage. An average of 3.0 mg/g dry weight or 17% of the ascorbic acid present in the fresh peppers was retained in the dried peppers. Of that 17%, only 16% or 0.53 mg/g dry weight was present at the end of the storage period. The length of the drying period had no effect (0.05) on the retention of ascorbic acid after dehydration or after storage in broccoli or green peppers.

The extent of vitamin B-6 losses due to the drying procedure or to storage was much less pronounced than the ascorbic acid losses in both the broccoli and green peppers. The drying procedure resulted in retentions of 90% of the vitamin B-6 that was present in the broccoli after blanching, or an average of 11.5 mcg/g dry weight. An average of 31.5 mcg/g dry weight or 72% of this B-6 was retained in green pepers after dehydration. The length of drying time had no effect (0.05 level) on the retention of vitamin B-6 in either the broccoli or the green peppers. The extent of vitamin B-6 losses occurring during storage depended on the product as well as the moisture content during storage. Retention of vitamin B-6 in dried broccoli after storage was not affected (0.05) by the length of the drying period. An average of 6.6 mcg/g dry weight or 57% of the B-6 in the dried broccoli was present after storage. Green peppers dried the longest time, thus to the lower moisture contents, retained more vitamin B-6 (0.05 level) than those peppers dried the shortest time which retained the most moisture. Retention of vitamin B-6 in green peppers did not differ with the two longer drying times. Green peppers removed in sampling period 1 retained an average of 16.5 mcg/g dry weight of vitamin B-6. The samples removed in sampling periods 2 and 3 retained 24.5 and 26.4 mcg/g dry weight of B-6, respectively.

Ascorbic Acid and Vitamin B-6 Retention in Broccoli and Green Peppers After Home Dehydration and Storage

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Ascorbic Acid and Vitamin B-6 Retention
In Broccoli and Green Peppers After
Home Dehydration and Storage

INTRODUCTION

In recent years, home dehydration of foods has once again become a popular means of food preservation. Numerous books on the subject of food drying have been published, for example, Anderson and Andrews, 1974; Beyer, 1976; DeLong, 1979; Macmaniman, 1974. A wide variety of foods may be dried, including herbs, fruits, vegetables, grains, meats and fish. The drying process is accomplished rather easily using the sun, an oven or a food dryer. Once dried, the foods are only one-ninth to one-third as bulky and weigh between 6 to 20% of their fresh counterparts (Mrak, 1943). Furthermore, they do not require the continual need for electricity during storage as do frozen products.

While offering so many advantages, dehydrated foods have their disadvantages. Insufficient blanching treatments or drying may cause premature deterioration as well as excessive destruction of nutrients during storage. Losses in the nutritional value occur during blanching, drying and storage. The extent of these losses is extremely variable. As a consequence, the nutritional contribution of dried foods in the diet is not certain.

The aims of this investigation were (1) to determine if drying time had an affect on the retention of ascorbic acid and vitamin B-6 in broccoli and green peppers and (2) to determine if the moisture level of the dried sample during storage affected the retention of ascorbic acid and vitamin B-6 in broccoli and green peppers.

Broccoli and green peppers were selected because the ascorbic acid and vitamin B-6 contents are relatively high. In addition, both vegetables are readily available and easily dried in the home. Inconsistent drying rates and variability in vitamin levels within the replications were anticipated with the broccoli because of the irregular shape of the pieces to be dried and the uneven distribution of the vitamin in the stem, leaf and flower portions of the plant. Green peppers are one part and cut into strips were expected to dry at about the same rate in each replication.

REVIEW OF LITERATURE

Principles of Dehydration. Dehydration is one of the oldest methods of food preservation. It is defined as "the operation in which water activity of a food is lowered by removal of all water normally present through vaporization or sublimation" (Karel, 1976, page 309). Not included in this definition is the removal of water by extraction in solvents or the lowering of free water by the incorporation of osmotic agents. For most vegetables, 92 to 96% of the water is removed during the drying process (Tressler, 1942). With only limited water available, both microbial growth and chemical reactions occurring in the dried food during storage are restricted.

All foods do not dry to the same extent. One factor that may influence the extent of drying is the state of the water in foods. The water may exist as bound or free water. Bound water is defined as "that part of the water content of a product which remains in it in an unchanged (or 'bound') state after application of the usual drying procedures, such as freezing, chemical dehydration, etc. and which can be expelled only by heating to 100 to 110^{o} for a sufficiently long time" (Kuprianoff, 1958, page 18). Free water makes up the greater proportion of water in foods and behaves as ordinary water in that it exerts a vapor pressure very close to the vapor pressure of pure water at the same temperature (Labuza, 1970). Frequently, the state of water in foods is expressed by the term "water activity" which is directly related to vapor pressure. Water activity is a better indicator than moisture content of the availability of water in foods for physical, chemical and biological reactions. At high moisture contents the water activity is close to 1.0 and food deterioration is rapid. Below 50% moisture, the water activity falls rapidly. Figure 1 illustrates the dependence of various deteriorative reaction rates on the water activity. Dehydrated vegetables generally fall in the 5 to 10% moisture range with corresponding relative humidities (water activities) of approximately 20% (Makower and Dehority, 1943).

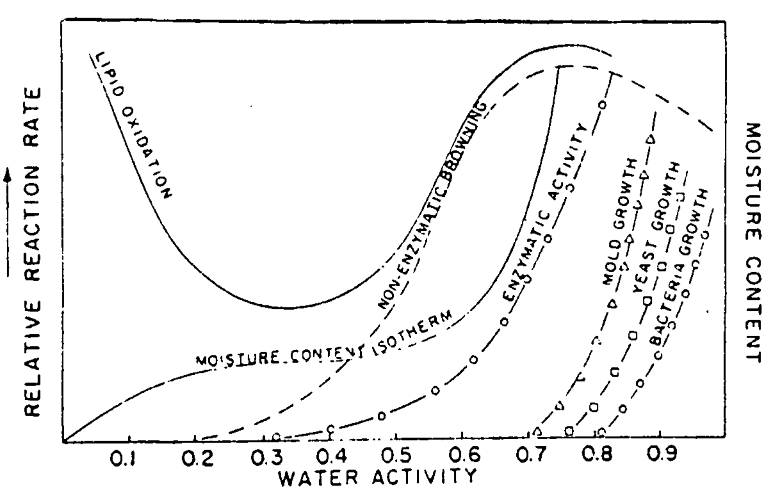

Figure 1. Relative reaction rates of deteriorative reactions as a function of the water activity of foods. From Labuza, 1970.

Water is removed from the food during dehydration by evaporation. The amount of heat called 'the latent heat of vaporization' required to change 454g of water to a vapor is about 250 kcal (Cruess, 1943)[b]. In comparison, the energy required to increase the temperature of 454g of water from 15°C to the boiling point, 100°C, is approximately 39 kcal. In other words, six times more heat is needed to evaporate 454g of water once the boiling point is reached than to raise the temperature of the same amount of water 85°C. As the water at the surface vaporizes, it is continually replenished from the water within the tissue due to concentration gradients established or by pressure differences which arise in the capillaries.

During dehydration, a constant rate period and one or more falling rate periods with respect to water removal may be observed (Karel, 1976). The constant rate period continues so long as the internal moisture is sufficient to saturate the surface of the product. Once areas of the drying substance are no longer saturated with water, the falling rate period begins. During the falling rate period, water is transported to the surface from an area where saturation conditions still prevail. In this period, the water is transported in the vapor state. As more and more water is removed, the resistance within the food increases and the rate of water removal decreases, thus the falling rate period.

In all methods of drying, a source of heat is required. Home dehydration may be achieved using the sun, an oven or a food dryer. Commercially, foods are dried using the sun, controlled heat, dehydration under vacuum and spray or drum drying. To facilitate the removal of moisture, the air is circulated by mechanical means or natural drafts.

Whether home or commercial drying procedures are utilized, the dried products are not equivalent to the freshly cooked or canned product; however, they in themselves should be desirable. In the case of vegetables, the product should contain about 5% moisture (Hollingshead, 1943; Makower and Dehority, 1943; Salwin, 1959; Tressler, 1942). Textural, flavor and aroma changes as well as alterations in appearance and nutritional value should be minimal. Poor quality dehydrated vegetables may have one or more of the following characteristics: tough or woody texture, slow or incomplete dehydration, loss of juiciness usually associated with the fresh food, lack of flavor, off-flavors or odors, poor color or negligible nutrient retention.

<u>Nutrient Retention in Dehydrated Vegetables</u>. Retention of nutrients in dried vegetables is dependent on the drying procedures used along with the chemical nature of the nutrient being examined. Since conditions for the dehydration of vegetables have not been standardized in terms

of blanching time, drying times and storage conditions, there is a wide variation in the literature regarding nutrient retention in dried vegetables. Factors affecting the drying rate are the initial moisture content of the vegetable and the rate the moisture diffuses to the surface during drying, the size and shape of the vegetable and the particular vegetable being dried, the velocity of the air and relative humidity within the dryer, the tray load and amount of vegetables being dried, and whether or not the vegetable has been blanched. Vitamins may be destroyed during processing by one or more of the following: heat, especially in an alkaline medium; strong acids; light and oxygen. In addition to destruction, the water-soluble vitamins are lost in cooking when moist heat methods are used due to the leaching of the vitamin into the cooking liquid.

Ascorbic acid. Ascorbic acid is one of the most labile nutrients and is often chosen as an index of nutrient retention and the quality of processed foods. It is a six carbon compound closely related to monosaccharides (Figure 2). It is found almost exclusively in plant materials with liver being the only animal food considered to contain a significant amount. The chemical nature of the vitamin makes it very unstable during processing. Ascorbic acid is soluble in water and easily

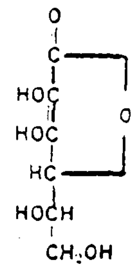

Figure 2. Structure of ascorbic acid.

destroyed by heat, oxidation and alkali, but is stable in acid. Oxidation of ascorbic acid ($C_6H_8O_6$) yields dehydroascorbic acid ($C_6H_6O_6$). This form of ascorbic acid is equally well utilized by the body and the oxidation process is reversible. However, dehydroascorbic acid is susceptible to further oxidation which results in diketogulonic acid, a biologically inactive form of ascorbic acid. This process is irreversible. The amount of ascorbic acid in a plant will vary with the season, the extent of sunlight exposure, the maturity and freshness of the plant, the size of the plant as well as the type and part of the plant (Krehl and Winters, 1950; Stevens, 1943; Tressler et al., 1936b). Citrus fruits and juices, green peppers, broccoli, cabbage and strawberries are several foods high in ascorbic acid (Davey et al., 1956; Tressler 1942). Other good sources include cantaloupe, brussel sprouts, asparagus, potatoes and sweet potatoes, tomatoes, spinach and parsley. An average serving (155g) of freshly cooked (boiled) broccoli contains 140 mg of ascorbic acid

(Adams, 1975). This is more than $2\frac{1}{2}$ times the RDA (60 mg) of ascorbic acid for adults (Anonymous, 1979). A cup of raw (100 g) or cooked (135 g) green pepper strips contain 128 and 130 mg respectively of ascorbic acid (Adams, 1975). This supplies about two times the RDA of ascorbic acid for adults.

Losses of ascorbic acid during dehydration may occur in both the blanching and drying steps. During blanching, the vitamin leaches from the vegetable to the cooking water. The drying process results in destruction of the vitamin due to the heat treatment and/or the extended exposure to the air.

For most vegetables that are to be frozen or dried, blanching is a necessary treatment. The purpose of the blanching step is chiefly to inactivate enzymes. The heat treatment should be sufficient to inactivate the enzymes but not severe enough to cause excessive nutrient losses or textural changes. Peroxidase and catalase are two of the most heat resistant enzymes, and their presence in the vegetables after blanching is an indication of inadequacy of the blanch.

Both water and steam blanching result in losses of ascorbic acid. The extent of the losses during blanching is variable. Factors such as the method of blanching, the length of the blanch and the temperatures attained in the product being blanched and the size and shape of pieces all influence the retention of ascorbic acid. Steam blanching results in greater retention than water blanching (Fods et al., 1967; Hollingshead, 1943; Matthews and Hall, 1978; Odland and Eheart, 1975; Tressler et al., 1936b). Holmes et al. (1979) reported as much as 33% of the ascorbic acid in green beans was lost during a water blanch for 3 minutes; however, no comparison was made with steam blanching. In studies with broccoli, the ascorbic acid retained in steam blanched broccoli was significantly higher (57%) than that of water blanched (52%), but the degradation of chlorophyll to form pheophytin was greater (Odland and Eheart, 1975). In addition to the chlorophyll destruction that takes place during blanching, the heat treatments used in dehydration result in further degradation of the pigment (Fischbach and Newburger, 1943). Therefore to maximize color retention in broccoli throughout the drying process, a water blanch may be preferable to a steam blanch. Green peppers are one of the few vegetables that do not require blanching prior to dehydration. In fact, frozen green peppers that have not been subjected to a blanching treatment are superior in flavor, texture and appearance to frozen blanched green peppers after eight months storage (Matthews and Hall, 1978). Also, the unblanched green peppers remained an excellent source of ascorbic acid.

Despite the blanching treatment, ascorbic acid retention is low in dried vegetables. Only traces of ascorbic acid were found in commercially dried, blanched, shredded potatoes (Moyer, 1943; Tressler et al., 1943) while retention of ascorbic acid in commercially dried potato dices was somewhat higher, 18% and 23% (Mallette et al., 1946; Stevens, 1943, respectively). The percent retention of ascorbic acid in commercially dehydrated potato slices and dices in a more recent study was 40% and 38%, respectively (Augustin et al., 1979). The amount of ascorbic acid lost in the blanching process was 30% for the potato slices and 32% in the potato dices. The remaining ascorbic acid was lost in the dehydration step. Ascorbic acid retention will vary in the pared and cut vegetables depending on the amount of cut surface exposed to the water or air (Hewston et al., 1948). Ascorbic acid retention in home dried green beans was only about 2% in both the blanched and unblanched samples (Holmes et al., 1979). Dried tomato puree retained slightly more ascorbic acid (7%) and zucchini squash even more (33%). About one-third of the ascorbic acid loss was attributed to the blanching process. In another study, the ascorbic acid retention in blanched, dehydrated green snap beans was 5% (Farrell and Fellers, 1942).

Vitamin B-6. Vitamin B-6 is widely distributed in foods. A 100 g serving of some raw vegetables may contribute as much as 20% of the RDA for an adult for vitamin B-6. However, losses resulting from processing may drastically reduce the amount of vitamin B-6 contributed by vegetables.

There are three forms of vitamin B-6 in nature, pyridoxine, pyridoxal and pyridoxamine (Figure 3). Pyridoxal and pyridoxamine are the predominant forms of the vitamin in animal tissues and yeasts with only negligible amounts,

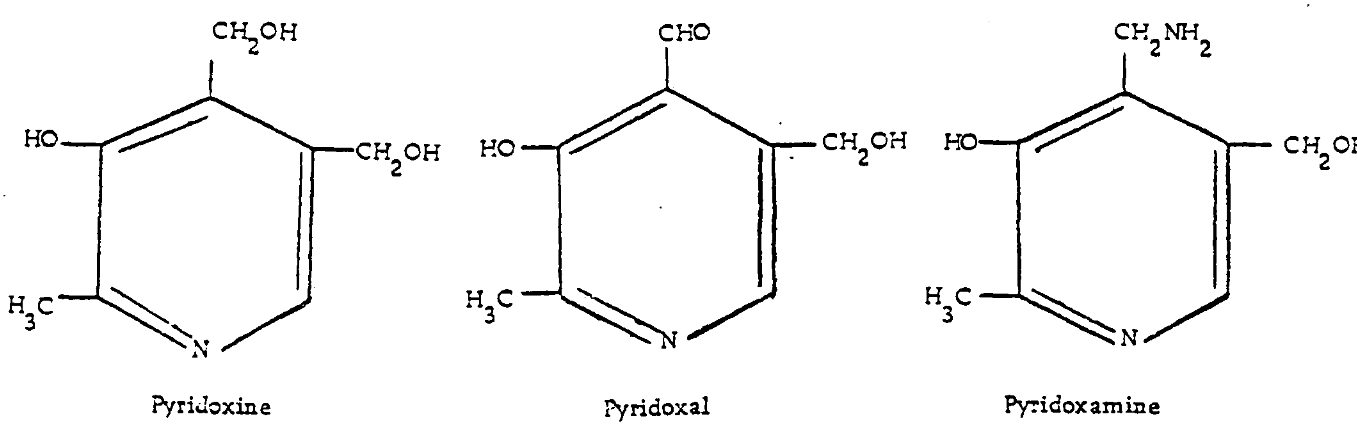

Figure 3. Chemical structure of the three forms of vitamin B-6.

if any, of the pyridoxine form (Rabinowitz and Snell, 1948). The pyridoxine form at levels equal to or greater than the pyridoxal and pyridoxamine forms is found in vegetable materials. In rats, all three forms of vitamin B-6 have equivalent biological activity (National Academy of Sciences, 1974) but their stability during processing is variable. The three vitamers are stable in acidic solutions but may be readily destroyed in neutral and alkaline conditions. The most abundant sources of vitamin B-6 are kidney and muscle tissues with 20-30 mcg/g (Henderson et al., 1941). There is less than 1 mcg/g on a wet weight basis of vitamin B-6 in fruits with the exception of avocados and bananas (Polansky and Murphy, 1966). Between 0.4-6.5 mcg/g of vitamin B-6 are found in nuts.

The total vitamin B-6 in fresh vegetables, determined by microbiological assays, is in the range of 0.5-4.0 mcg/g (Polansky, 1969). Dried vegetables, for the most part, contain considerably more vitamin B-6 (1-7 mcg/g on a dry basis). Partially trimmed raw broccoli contains 1.95 mcg/g of vitamin B-6 (Schroeder, 1971). The total vitamin B-6 in an unchromatographed sample of fresh broccoli reported by Polansky (1969) was 2.28 mcg/g. The vitamin B-6 in broccoli was separated into the individual components by chromatography, and the difference in vitamin B-6 in the chromatographed and unchromatographed sample was not found to be significant. Pyridoxal is the predominant form of the vitamin in broccoli (Polansky, 1969). Green peppers contain 2.20 mcg/g of vitamin B-6 primarily in the pyridoxamine form (Polansky, 1969). A hundred gram sample of either raw broccoli or green peppers may contribute as much as 10% of the RDA (2.2 mg/day for adult male and 2.0 mg/day for adult female) (Anonymous, 1979) of vitamin B-6 for an adult.

Losses of vitamin B-6 during dehydration may occur in the blanching step as well as in the drying procedure. Unlike ascorbic acid, the extent of research in this area is limited. During blanching, vitamin B-6 losses are primarily due to the solubility of the vitamin in water and all three forms of the vitamin are equally soluble. Water blanched garbanzo beans retained significantly less vitamin B-6 (85 to 90%) than steam blanched (92 to 95%) (Daoud et al., 1977). Retention of vitamin B-6 in steamed blanched lima beans (83 to 87%) was also greater than the retention of vitamin B-6 in water blanched (76 to 81%) lima beans (Raab et al., 1973). The greater loss of the vitamin has been attributed to its solubility in water. Holmes et al. (1979) reported 11% of the total B-6 lost during the drying of green beans resulted from the blanching treatment. One would expect the losses of vitamin B-6 due to leaching to be comparable to those losses observed in other water soluble vitamins when exposed to the same blanching technique.

Data on the stability of vitamin B-6 to heat treatments such as those employed in the home dehydration of vegetables are minimal. From the information that is available (Augustin et al., 1979; Holmes et al., 1979), it appears that the losses due to dehydration may be as high as 33% or as low as 8%. Augustin et al. (1979) studied the production of dehydrated potato granules and reported 83% retention of the original vitamin B-6. Examination of the individual steps during production revealed that the greatest losses took place in the blanching and cooling steps and that virtually none of the B-6 was lost in the dehydration step. Dried potato flake production resulted in somewhat less total B-6 retention (62%) and less in each processing step as well. The dehydration caused about 11% of the total loss. Evidently the B-6 is more susceptible to destruction in the potato flake production than in the granule production. In the same studies, the retention of vitamin B-6 in dried potato slices and dices was 72% and 84%, respectively. In each processing step, the percent retention of B-6 was higher in the potato dice production. The dehydration step accounted for 11% of the losses in the potato slice production and only 6% of the losses in the potato dice production. Instant bean powders prepared by conventional methods or a new acid treated process retained 82% and 83% of the total vitamin B-6, respectively (Miller et al., 1973). In studies using other types of products, the retention of vitamin B-6 was variable. The vitamin B-6 remaining in spray-dried milk products ranged from 69 to 89% of the initial vitamin B-6 in milk (Hassinen et al., 1954). A review of the stability of vitamin B-6 in milk to heat treatments such as pasteurization, drying and evaporation has been published by Woodring and Storvick (1960).

The most pertinent studies on vitamin B-6 retention were done by Holmes et al. (1979). Losses of vitamin B-6 in home dried vegetables and berries were between 4 to 41%. Blanched green beans lost the most vitamin B-6 with only 59% remaining after the drying procedure. Tomato puree retained 78.8%; unblanched green beans, 74.7%; zucchini squash, 91.7%; boysenberry leather, 90.5% and raspberry leather had the greatest retention of vitamin B-6 at 96.4%. Approximately 11% of the vitamin was lost in the blanching process. The percent moisture in the unblanched dried green beans was 28%. The blanched green beans contained slightly more moisture after drying (32%). The dried tomato puree, zucchini squash, raspberry leather and boysenberry leathers had 10, 18, 18, and 14% moisture, respectively.

<u>Other water-soluble vitamins and carotene</u>. Retentions of carotene, folacin, niacin, thiamin, riboflavin and pantothenic acid after dehydration have been investigated, but the magnitude of the studies is not nearly as extensive as those for ascorbic acid. In reviewing the literature, carotene retentions in dried vegetables were found to be between 10 and 100% (Tressler, 1942). Holmes et al. (1979) reported only a 5% retention of carotene in blanched and unblanched cut green beans. Stevens (1943) found carotene retention in green beans to be 76% but only 36% was

retained in sliced sweet potatoes. Retention of more than 90% of the carotene in dehydrated rutabagas was observed by Tressler et al., (1943). Total folacin retention in dried zucchini squash, tomato puree and both blanched and unblanched green beans was investigated by Holmes et al. (1979). The retention of folacin ranged from 46% in the blanched green beans to 92% in the zucchini squash. The blanching process employed prior to drying contributed to the retention of folacin possibly by increasing the availability of folacin to the assay organism. Folacin retention in potato granules was 48%, potato flakes, 54% and potato slices and dices, 69% (Augustin et al., 1979). Retention of other B-vitamins (niacin, thiamin, riboflavin and pantothenic acid) in various products after dehydration has been studied. Thiamin is probably the most sensitive of the B-vitamins to heat and niacin the least. Rice and Robinson (1944) examined the retention of the B-vitamins in dehydrated meats. Retention after dehydrating beef was 76% for thiamin, 105% for riboflavin, 92% for niacin and 68% for pantothenic acid. Dehydrated pork retained similar amounts of riboflavin and niacin but only 63% of the thiamin. Pantothenic acid retention was slightly greater in pork (73%). In other studies, the rate of thiamin loss from dehydrated pork during storage was roughly proportional to the moisture content between 0-6% (Rice et al., 1944). Also, the rate of thiamin loss during storage is greater in dehydrated pork and eggs than in dry skim milk or cereals.

<u>Nutrient Retention After Storage</u>. Since most dried vegetables are stored for a period of time before being consumed, it seems appropriate to examine the dried vegetables again at the end of a suitable storage period. Losses during storage may be accelerated if the drying procedures or storage conditions are not optimum. Factors such as insufficient blanching or drying may have a profound effect on the stored product in terms of microbial growth, textural changes, chemical changes and nutrient losses.

In general, the higher the temperature of storage and the moisture content of the dried product, the more rapid the loss of ascorbic acid. At low moisture contents, the ascorbic acid may be destroyed by oxidation. At higher moisture contents, the ascorbic acid participates in non-enzymatic browning reactions resulting in it being unavailable for biological needs. The rapid rate of non-enzymatic browning in intermediate moisture foods (20-50%) during storage results in rapid loss of ascorbic acid (Labuza, 1973). In sweet potatoes dried to 6% moisture and subsequently stored at 40-50°F, there were negligible losses of ascorbic acid after 18 weeks, whereas the same samples stored at 95 to 105°F lost 60% (Mallette et al., 1946). In studies with dried cabbage and cauliflower, 50%

or less of the ascorbic acid was present after 12 weeks of storage at 17°C (Aykroyd, 1943). The effect of storage temperature on dehydrated vegetables is discussed by Goodring (1962). A dehydrated food stored at temperatures between 60 to 70°F will keep for up to 2 years. At 90°F, the dehydrated food is inedible after 6 to 8 months storage. At 100°F and 120°F, the dried food will become inedible in about 3 months or 2 weeks, respectively.

Vitamin B-6 has not been studied as thoroughly as ascorbic acid. Practically no data are available on the extent of vitamin B-6 loss during the storage of dried vegetables regardless of the drying procedures or the storage conditions employed. Most storage studies measuring the retention of vitamin B-6 have been done on commercially canned, frozen or irradiated foods. However, in a study by Bunting (1965), the storage stability of naturally occurring vitamin B-6 and added pyridoxine hydrochloride was 90 to 95% in macaroni and 100% in cornmeal after 1 year at 100°F and 50% relative humidity. Similar retentions of vitamin B-6 in pyridoxine-enriched flour and cornmeal after storage were reported by Cort et al., (1976). Six months storage at room temperature of commercially prepared evaporated milk products resulted in a 30% loss of vitamin B-6 (Davies et al., 1959; Gregory, 1959). The most extensive storage study on vitamin B-6 retention was done on frozen, heat processed and irradiated beef liver, boned chicken, cabbage, green beans, lima beans and sweet potatoes (Richardson et al., 1961). The vitamin B-6 activity, as measured by rat growth studies, was lower in all treatments after 15 months storage. Furthermore, the heat treated and irradiated liver, chicken, cabbage and green beans were 40 to 60% lower in B-6 activity than the frozen samples. Both the lima beans and the sweet potatoes had the same or greater vitamin B-6 activity in all three treatments after the 15 month storage period. The increase in B-6 activity may have been caused by errors in the measurement of the initial activity or the liberation of bound vitamin B-6 during storage.

Effect of Insufficient Drying on Nutrient Retention. In the dehydration of foods it is necessary to lower the moisture content enough to ensure the product will not undergo appreciable changes in color, flavor and nutrient value on subsequent storage. Each dried product has its own characteristic moisture content at which maximum storage stability is achieved. Generally vegetables are dried to 5% moisture; meat, fish and dairy products to 3% or less and cereal products to 11% (Salwin, 1959). The rate a dried product will deteriorate during storage may be hastened by other conditions besides moisture, such as the temperature and relative humidity of the storage atmosphere and the presence or absence of oxygen.

Losses of ascorbic acid in steam blanched dehydrated white potatoes stored at 95 to 105°F were significantly less at 7% moisture than at 13% moisture (Mallette et al., 1946). Ascorbic acid retention in blanched dehydrated cabbage stored in air for 16 weeks was 65% for samples dried to 3.6% moisture (Chase, 1942). Cabbage dried to 8.2% moisture retained 10.1% of the ascorbic acid and samples with 10.2% moisture retained 5.9% of the ascorbic acid. Goodring (1962) also reported that the loss of ascorbic acid in dehydrated foods increased significantly at higher moisture contents. The extent of non-enzymatic browning increased significantly as well. Legault et al. (1947) also found an increase in the rate of non-enzymatic browning in dried white potatoes as the moisture content increased. In other studies, the extent of ascorbic acid destruction in dehydrated orange juice and the rate of non-enzymatic browning were drastically affected by the moisture content (Karel and Nickerson, 1964). The rate of ascorbic acid destruction during storage increased as the moisture content increased and all the water present in the orange crystals, including water in the monomolecular layer, was available for the reactions which cause deterioration of ascorbic acid. Lee and Labuza (1975) found the rate of ascorbic acid destruction in dehydrated model systems increased as the water activity of the system increased. Similar findings were reported by Dennison and Kirk (1978) in their studies on the affect of oxygen on ascorbic acid degradation. To my knowledge, data on the affect of insufficient drying on the retention of vitamin B-6 in dried vegetables is not available. One of the objectives of this study was to fill that gap in the literature.

The Effect of Insufficient Drying on the Quality of Dried Vegetables After Storage. Unless products are dried adequately, they will not retain their original color and flavor during storage at ordinary temperatures. Fading of the natural colors takes place accompanied by darkening of the tissues and changes in aroma and flavor. For example, turnips, cabbage and onions not thoroughly dried lose flavor and darken, ultimately becoming as dark as tobacco (Gore and Mangels, 1921). Spinach will fade and acquire a hay-like flavor if not completely dry. Gore and Mangels (1921) studied the influence of the moisture content on the keeping quality of carrots, turnips, onions, cabbage and spinach. In all cases, the samples stored at higher moisture levels deteriorated more rapidly regardless of the temperature of storage. Carrots containing 11% moisture had obviously faded while those at 7.4% moisture kept well in the same period. Turnips at 11% moisture developed a turnip-like odor and underwent browning in only 33 days. The turnip at 5% moisture had not changed to any degree after 80 days storage. The same general changes were noted in spinach, cabbage and onions. In another study the extent of deterioration in potatoes dried to 13% moisture was greater than the same potatoes dried to 7% moisture after storage at 95 to 105°F (Mallette et al., 1946). Potatoes with 13% moisture became undesirable after one month while those with 7% moisture remained edible for 7 months. Chase (1942) also found the extent of deterioration in dried cabbage during storage to increase as the moisture content of the sample increased. In fact, the storage life of cabbage dried to 3% moisture was twice that of cabbage dried to 5% moisture. Dried pinto beans containing 13% moisture had undergone distinctive changes in flavor and texture after 6 months storage at 77°F (Morris and Wood, 1956). After 12 months at 77°F, they were not palatable. On the other hand, beans below 10% moisture maintained their quality for 2 years. The moisture content of a dried vegetable may also influence the extent of rehydration. Significantly more water is absorbed during rehydration by dehydrated lima beans reduced to lower moisture levels (Nelson et al., 1956).

Retention of Ascorbic Acid and Vitamin B-6 After Cooking. After rehydrating dried vegetables, further preparation is necessary. Usually, they are cooked in a stew or casserole. Additional losses of ascorbic acid and vitamin B-6 may occur due to the cooking. Losses may be caused by heat destruction and/or leaching into the cooking medium if this is discarded. Factors which may affect cooking losses are the length of the cooking period, the maximum temperature reached, the volume of water used and the method of cooking. Additional variables are the freshness of the vegetable, its size and shape and the amount of surface area exposed to the water or oxygen.

Cooking losses of ascorbic acid may be equal to or greater than those which occurred during blanching. Again, the majority of ascorbic acid is lost by leaching into the cooking water, but some losses may result from heat destruction (Krehl and Winters, 1950; Sweeney et al., 1959; Tressler et al., 1936b). Heat destruction of ascorbic acid during cooking is usually minimal. Ascorbic acid losses are dependent on the volume of water used. Smaller amounts of water tend to retain more ascorbic acid (Barnes et al., 1943; Brickman et al., 1942; Eheart and Gott, 1965; Gordon and Noble, 1959a; Krehl and Winters, 1950; Martin et al., 1960; Olliver, 1941; Oser et al., 1943; Sweeney et al., 1959; Van Duyne et al., 1944). When larger volumes of water are used, more of the ascorbic acid is leached into the cooking medium. The percent of ascorbic acid found in the cooking water when equivalent weights of cabbage were cooked in 400 ml, 800 ml and 1600 ml of water was 12%, 24% and 20%, respectively (Van Duyne et al., 1944). About 2 times more ascorbic acid was lost due to leaching when larger volumes of water were used in cooking. Barnes et al. (1943) found 22% more ascorbic acid had leached into the cooking water when 500 ml of water were used to cook frozen broccoli than when 100 ml of water were used. The extent of ascorbic acid retention after cooking in a minimum amount of boiling water, a pressure saucepan, or steaming will vary with the vegetable being examined and no one method is superior (Brickman et al., 1942; Gordon and Noble, 1959a). The data comparing cooking methods, excluding boiling in large volumes of water, and ascorbic acid retention are variable. Microwave cooking retains slightly greater amounts of ascorbic acid than conventional methods, probably due to the shorter cooking periods involved (Ang et al., 1975; Chapman et al., 1960; Gordon and Noble, 1959b). Broccoli cooked in less than 300 ml of boiling water retained between 80 to 91% of the ascorbic acid in the first 5 minutes but further cooking resulted in more losses (Martin et al., 1960). The total retention of ascorbic acid in the cooked broccoli was between 75 to 80%. The rate ascorbic acid leaches into the cooking water is extremely rapid. Practically all of the ascorbic acid that was extracted into the cooking water took place within the first 5 minutes (Olliver, 1941; Sweeney et al., 1959). Gould and Tressler (1936) also found the loss of ascorbic acid to be greatest in the first few minutes of cooking with only slight losses occurring in subsequent heating.

Losses of vitamin B-6 are also due to its solubility in water and its heat lability. Since the pyridoxine form of the vitamin is relatively stable (DeRitter, 1976; Everson et al., 1964), the proportion of pyridoxine to pyridoxal and pyridoxamine as well as the extent of interconversion between the three forms during processing (Gregory and Kirk, 1978; Hodson, 1956) may account for the wide variation in the retention of vitamin B-6 in comparing various types of foods. The effects of cooking and processing on the retention of vitamin B-6 have been published by numerous investigators. Schroeder (1971) reviewed the literature and found the losses of vitamin B-6 in canned vegetables to be between 57 to 77% and in frozen vegetables, 37 to 56%. These values did not include any additional losses that may occur during the home preparation of the foods. Fresh meat samples prepared by roasting or stewing resulted in losses ranging from 20 to 50% (Henderson et al., 1941). The vitamin B-6 present in the meat drippings accounted for only 20% of the observed losses. Commercially processed meats had comparable losses. Turkey breast and thigh muscles roasted from the frozen state, partially thawed state or the thawed state had significantly less vitamin B-6 than the same muscle in the raw state (Engler and Bowers, 1975). The results indicated that the B-6 is either transferred to the drip during cooking or is destroyed by the particular heat treatment employed.

In dehydrated model systems prepared by fortification with the various forms of vitamin B-6, 50 to 70% of the pyridoxine, pyridoxamine and pyridoxal was lost during a 25 minute roast at 180°C. Boiled potatoes retained as much as 80% of the original vitamin B-6 present while baked potatoes had 91% (Page and Hanning, 1963). Approximately 15% of the vitamin B-6 in the raw potato was present in the cooking liquid.

EXPERIMENTAL PROCEDURES

Approximately 14 pounds of broccoli or 11 pounds of green peppers were purchased at a local retail outlet and held overnight at 3°C (38°F). A representative 100 g sample of the prepared broccoli or green peppers was taken to be analyzed for the fresh values of ascorbic acid, vitamin B-6 and moisture. The remaining vegetables were prepared for dehydration.

Preparation of Broccoli for Dehydration

Broccoli (*Brassica cleracea*) was washed, peeled, trimmed and cut to a maximum length of 12 cm and a maximum diameter of 0.5 cm. The method of blanching was boiling water (Miller et al., 1974). A 454 g batch of the prepared broccoli was immersed into approximately 3.5 l of rapidly boiling water and covered. The broccoli was removed two minutes after it entered the water. The blanched broccoli was dipped into a 5% solution of potassium sorbate (Monsanto Company, 1978) and mixed thoroughly so that all pieces of the sample were exposed to the mold inhibitor. The broccoli was spread on paper towels in order to allow excess moisture to drain off.

Ascorbic acid, vitamin B-6 and moisture were also determined on a representative 100 g sample of broccoli that had been blanched and dried to determine the effect, if any, the mold inhibitor had on the retention of ascorbic acid and vitamin B-6. Both the dipped and undipped broccoli retained comparable amounts of ascorbic acid and vitamin B-6 (Table 1). For this preliminary experiment, only half the weight of broccoli used in the other replications was dried. This shortened the drying time to 4½ hours. The average moisture content of the samples was 34.4% for the non-dipped, dried broccoli and 38.9% for the dipped broccoli. These moisture contents correspond to the broccoli samples dried 6-7½ hours (sampling period 1).

Table 1. Ascorbic acid and vitamin B-6 retention in dried broccoli dipped in a mold inhibitor[a] and not dipped in a mold inhibitor.

Sample	Ascorbic Acid				Vitamin B-6			
	Dipped		No Dip		Dipped		No Dip	
	mg/g wet wt	mg/g dry wt	mg/g wet wt	mg/g dry wt	mg/g wet wt	mg/g dry wt	mg/g wet wt	mg/g dry wt
1	4.30	7.04	4.83	7.36	12.2	20.0	12.9	19.7
2	-	-	4.73	7.21	12.4	20.3	11.2	17.1
3	4.83	7.90	4.83	7.36	13.0	21.3	13.4	19.7
Mean	4.56	7.47	4.80	7.31	12.5	20.5	12.5	18.8

[a] potassium sorbate (Monsanto).

Preparation of Green Peppers for Dehydration

Fresh green peppers (*Capsicum frutescen*) were prepared by removing the stems, seeds and white inner membranes.

The remaining flesh was sliced into strips approximately 1/2 cm in width. In 454 g batches, the green peppers were dipped into a 5% solution of potassium sorbate. The excess moisture was removed by spreading the dipped green peppers on paper towels.

Drying Procedure

An electric food dehydrator (Kirk, 1975) was used to dry the vegetables. Heat was provided by six standard 75 watt light bulbs beneath a foil screen. The air inside the dryer was circulated by a 20 cm fan. The temperature in the cabinet was maintained at $60^{\circ}C \pm 1.5^{\circ}C$ by a thermostat built into the dehydrator. An outside thermometer was used to monitor the temperature within the chamber. The drying trays were made from aluminum window screens. The width of all the trays was the same but the length varied from 39 to 50 cm.

The trays were removed from the dryer to be loaded. The dehydrator was preheated to $71^{\circ}C$ ($160^{\circ}F$) for 30 minutes. The trays were loaded so that each batch of prepared samples was evenly distributed on the five trays. On each of the two largest trays about 110 g of vegetables were placed. The three smaller trays each had about 78 g of vegetables to be dried. A total of 3600 g of prepared broccoli or green peppers was dried per replication. The vegetables were placed in three rows lengthwise on all of the trays.

In the case of the broccoli, an alternating flower to stem pattern was employed. Any vacant space between rows was also filled with the vegetables. All trays were filled to capacity at the start of the drying period.

After all trays were loaded, they were placed in the dehydrator. The thermostat was immediately lowered to 60°C (140°F). The temperature of the dehydrator dropped to approximately 38°C (100°F) when it was loaded and returning to temperature (60°C) took between 4-4½ hours. At this time, the door was opened so the trays could be shifted. The trays were turned from front to back and shifted to the next lowest level. For the next hour the door was left open about 3 cm to facilitate air circulation. At the end of the hour, the shelves were moved in a similar fashion, and the door was closed completely. For the remainder of the drying period the door was kept closed except on the half-hour when the trays were being shifted. Thirty to 60 seconds were required to transfer the trays. The temperature inside the dehydrator dropped to about 49°C (120°F). As the vegetables became drier, the time required for the cabinet to return to 60°C became less. No more than 15 minutes were required to reach 60°C in any of the replications.

The design of the dehydrator was such that the longest tray (42 x 50 cm) on the lowest level would not permit the door to be closed completely. For this reason, the trays were not moved to a lower level in the dryer when the 50 cm tray was to be on the lowest level although they were turned from front to back. Instead the trays remained on the same level for an additional half-hour. When the trays were to be shifted again they were moved two levels so that the 50 cm tray on level four was moved to level one bypassing the fifth and lowest level in the dryer. The tray on level five was moved to level two, one went to three, two to four and three to level five.

For each drying time except the last, a 75 g sample was removed from the dehydrator. To be assured of a random selection, the sampling technique illustrated in Figure 4 was employed. The sample size for the last drying time was between 90 and 110 g. After thoroughly mixing the sample from the last drying time, a 75 g sample was removed and the remainder discarded. The desired moisture levels for both the broccoli and green peppers were 35%, 25% and 15%. To achieve these moisture levels, the drying times were varied. The drying times for the broccoli were slightly less than those for the green peppers. The first samples were removed from the dehydrator 6-6 3/4 hours after the start of the drying process. The second samples were removed $6\frac{1}{2}$ to $7\frac{1}{2}$ hours after they entered, and the third samples were removed after 7 to $9\frac{1}{2}$ hours. The first green peppers were removed from the dehydrator $8\frac{1}{4}$ to $8\frac{1}{2}$ hours after drying had begun. The second and third samples were removed $9\frac{1}{4}$ to 10 hours and 13 to 14 hours, respectively.

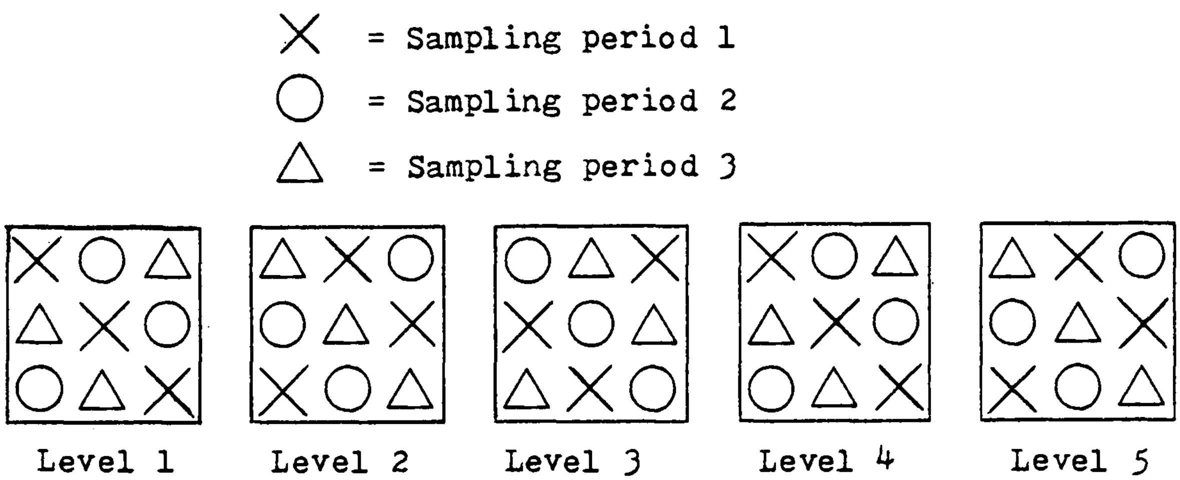

Figure 4. Diagram illustrating sample removal from the dehydrator.

As soon as the sample was removed from the food dehydrator, it was placed into a plastic bag (Fred Meyer Freezer Storage Bags) which was then put into a second plastic bag and labeled. All the samples were allowed to condition for 36 hours at room temperature in the dark. After conditioning, the samples were divided in half. Half of the dried broccoli sample from each drying time was placed in a one quart screw top glass jar. The jars were wrapped to protect the dried vegetables from exposure to light. The green peppers were treated identically except they were stored in pint jars. The dried broccoli was held in an incubator at 37°C for 11 to 13.5 weeks. The dried green peppers were held in the same incubator but only for 8 to 9.5 weeks. After that time, the stored samples were treated the same as the tempered samples which were analyzed for ascorbic acid, vitamin B-6 and moisture.

Nutrient Analysis

Ascorbic acid and vitamin B-6 were determined on the fresh, dried and stored broccoli and the green peppers as well as on the blanched broccoli. For each determination, the samples were assayed in triplicate.

The 100 g samples of fresh or blanched broccoli or fresh green peppers were cut into 1 cm pieces using a stainless steel knife. Once cut, 50 g were placed in an Osterizer blender (Oster Corp., Milwaukee, Wisc.) and blended on the high-mix speed for 3 seconds. The contents of the blender were stirred to remove any sample adhering to the sides of the container and blended for another 3 seconds. The sample was removed and placed on a sheet of wax paper. The second half was blended in an identical way, then both halves were blended together for an additional 3 seconds to uniformly mix the two halves. The sample was placed in an amber glass jar. From the jar, three 10 g samples were removed to glass beakers for the ascorbic acid analysis. Thirty milliliters of meta-phosphoric acid (J. T. Baker Chemical Co., Phillipsburg, N.J.) were added to each beaker to stabilize the ascorbic acid in the sample. The remaining sample was held in the tightly covered amber jar until all the samples to be analyzed for ascorbic acid had been blended, mixed with Norit (Fisher Scientific Co., Pittsburg, PA) and filtered. At this point the ascorbic acid analysis was put aside to make the hydrolysates for the vitamin B-6 analysis and the weighings for the moisture determinations. Between 25 and 35 minutes were required for these steps.

The dried and stored samples were prepared in a slightly different manner. The samples from the first two drying times were cut into 1 cm pieces using stainless steel scissors. This step was not required for the samples from the last drying time because they were sufficiently dried and therefore brittle. Half of each sample to be analyzed (approximately 19 g) was placed in a pint glass blender jar and blended for 6 seconds on the high-liquify speed of an Osterizer blender. The sample was removed and placed on wax paper while the second half was blended identically. Once both halves were blended individually, they were mixed together and blended for another 3 seconds. Three 3 g samples were removed for the ascorbic acid analysis. From this point the fresh and the dried samples were treated identically.

Ascorbic acid was measured using the AOAC microfluorometric method 39.056-39.061 (Horowitz, 1970). The reaction of dehydroascorbic acid with orthophenylenediamine to give a fluorescent quinoxaline is the basis of this assay which measures both ascorbic acid and dehydroascorbic acid.

Total vitamin B-6 was determined using the microbiological method of Toepfer and Polansky (1970). A pyridoxine standard curve was used to calculate the amount of total B-6 in the samples.

The total moisture was determined using the AOAC method 24.003 (Horowitz, 1970). Total solids in each sample were calculated from the moisture content. All data are reported on a dry weight basis. Percent apparent retention of ascorbic acid and vitamin B-6 were calculated using the following formula (Murphy, 1975):

$$\text{Percent apparent retention} = \frac{\text{Nutrient content/g of cooked food (dry wt)}}{\text{Nutrient content/g raw food (dry wt)}} \times 100$$

Statistical Analysis

All values reported are an average of three determinations $\pm$ standard deviations. The data on nutrient retention in broccoli and green peppers after dehydration and storage were analyzed statistically using analysis of variance (Downie and Heath, 1974).

RESULTS AND DISCUSSION

The retention of ascorbic acid and vitamin B-6 in broccoli or green peppers after dehydration and again after storage was determined. The moisture content was also measured in all samples and the values are reported on a dry weight basis.

Drying Times - Moisture Level

The drying times varied slightly in each replication in order for the moisture to remain within a selected range. In spite of varying the drying times, the moisture remaining in broccoli after drying was very inconsistent among replications as compared with green peppers. The sample preparation procedures and blanching treatments were identical and the amount of vegetable, the tray load and the dryer were the same; but the irregularity in piece size and shape and the proportion of stem to flower are variables which could not be controlled and may have contributed to the variation in the moisture content in the replications. For broccoli, the first samples were removed from the dehydrator 6 to 6 3/4 hours after they entered. The moisture content in these samples was between 31 and 45% (Table 2). The second sampling period was between 6½ and 7½ hours. Twenty to 36% of the initial water remained in this broccoli. The third and last sampling period was between 7 and 9½ hours. The lowest moisture in the broccoli for this sampling period was 16% and the highest was 27%.

Green peppers took considerably more time to dry to similar moisture levels than the broccoli did. However, the drying rate is characteristic of each vegetable (Davies et al., 1942; Mrak, 1943). Several factors may account for the slower drying rate in green peppers. The amount of cut surface area was less in green peppers while the initial moisture was an average of 3% greater. The diffusion rate of the water to the surface of the green peppers may also have been less than that in broccoli. The first green peppers were removed from the dryer 8 to 8½ hours after the start of the drying cycle. The moisture content of these samples was between 31 and 33% (Table 3). The second samples were removed after 9 to 10 hours. The moisture content ranged from 22 to 27%. Thirteen to 14 hours after the drying cycle had begun, the last green peppers were removed. The lowest moisture content in these peppers was 21% and the highest was 24%.

The moisture content of the broccoli and green peppers after storage varied slightly from those samples analyzed immediately following the conditioning period (Tables 2 and 3). However, this may reflect sample variation rather than insufficient conditioning prior to moisture analysis. For broccoli, the maximum difference between the average percent moisture in the

Table 2. Average percent moisture in broccoli dried to three moisture levels after dehydration and storage.[a]

Repli- cation	Ini- tial	Blanch- ed	Sampling Period[b] 1 Dried	1 Stored	2 Dried	2 Stored	3 Dried	3 Stored
	%	%	%	%	%	%	%	%
1	92.0	92.5	40.1	42.4	19.9	21.8	16.0	17.0
2	92.3	92.3	31.1	31.1	28.1	29.4	21.2	16.5
3	92.4	91.8	44.6	42.9	36.0	31.2	26.6	21.8
4	90.2	91.9	31.4	27.5	19.5	18.0	16.4	15.2
Mean	91.7	92.1	36.8	36.0	25.9	25.1	20.0	17.6

[a]Storage period was 11 to 13.5 weeks at 37°C.

[b]Sampling period 1, 6 to 6.75 hours; sampling period 2, 6.5 to 7.25 hours; sampling period 3, 7 to 9.5 hours.

Table 3. Average percent moisture in green peppers dried to three moisture levels after dehydration and storage.[a]

Repli- cation	Initial	Sampling Period[b] 1 Dried	1 Stored	2 Dried	2 Stored	3 Dried	3 Stored
	%	%	%	%	%	%	%
1	94.9	32.9	30.6	22.2	25.5	21.3	22.0
2	94.4	30.8	30.3	26.6	24.9	22.7	20.5
3	95.0	31.1	27.5	26.6	25.7	24.0	21.6
4	95.1	31.6	28.8	24.9	25.0	21.2	20.7
Mean	94.8	31.6	29.3	25.1	25.3	22.3	21.2

[a]Storage period was 8 to 9.5 weeks at 37°C.

[b]Sampling period 1, 8 to 8.5 hours; sampling period 2, 9.25 to 10 hours; sampling period 3, 13 to 14 hours of drying.

dried sample and the average percent moisture in the stored sample was 2.4%. The variation in the moisture of the dried and stored green peppers was slightly less at 1.3%.

Ascorbic Acid Retention in Dried Broccoli and Green Peppers

A large reduction in the amount of ascorbic acid in broccoli and green peppers after dehydration was observed. The retention of ascorbic acid in broccoli after blanching was between 59 and 72% or 7.4 to 12.4 mg/g dry weight (Table 4). An average of 9.4 mg/g dry weight or 66% was retained. Retention of ascorbic acid after dehydration varied between 1.49 and 4.62 mg/g dry weight or 18 to 56% of that present after blanching (Table 5). The average retention of ascorbic acid in broccoli was 2.8 mg/g dry weight or 31%. The length of the drying period had no affect (0.05) on the retention of ascorbic acid in broccoli. Evidently, most of the ascorbic acid that was lost in the broccoli was lost in the first 6 hours. Ascorbic acid retention after drying reported in the literature was just as variable. Some studies reported as little as 2% being retained (Holmes et al., 1979) while others as much as 40% (Augustin et al., 1979). Green peppers lost even more ascorbic acid than broccoli after dehydration. The maximum amount of ascorbic acid retained in all green pepper samples was 24%, and the minimum was 6%, with the average being 17%. Between 1.02 and 4.25 mg/g dry weight or an average of 3.03 mg/g dry weight of the

Table 4. Retention of ascorbic acid in mg/g dry weight and percent in broccoli after blanching.

Replication	Fresh Mean	Fresh S.D.	Blanched Mean	Blanched S.D.	%
	mg/g dry wt		mg/g dry wt		
1	14.0	0.12	9.3	0.36	66
2	17.1	0.25	12.4	0.21	72
3	12.9	0.16	8.5	0.22	66
4	12.6	0.10	7.4	0.08	59
Mean	14.2	2.1	9.4	2.2	66

Table 5. Retention of ascorbic acid in broccoli after dehydration. Values reported in mg/g dry weight and percent of the ascorbic acid present after blanching.

Rep.	Sampling Period[a] 1 Mean	1 S.D.	1 %	2 Mean	2 S.D.	2 %	3 Mean	3 S.D.	3 %
	mg/g dry wt			mg/g dry wt			mg/g dry wt		
1	3.07	0.40	33	2.28	0.20	25	2.48	0.18	27
2	2.97	0.14	24	3.52	0.33	28	4.62	0.54	37
3	1.88	0.21	22	1.40	0.20	18	1.96	0.04	23
4	2.30	0.28	31	3.31	0.29	45	4.11	0.04	56
Ave.	2.56	0.56	28	2.65	0.94	29	3.29	1.27	36

[a]Sampling period 1, 6 to 6¾ hours; sampling period 2, 6½ to 7¼ hours; sampling period 3, 7 to 9½ hours of drying.

ascorbic acid present in the fresh green peppers remained in the dried samples (Table 6). Again, the length of the drying period had no affect on retention of ascorbic acid in dried green peppers.

Vitamin B-6 Retention in Dried Broccoli and Green Peppers

Vitamin B-6 was much more stable to dehydration than ascorbic acid, but losses of vitamin B-6 due to blanching of broccoli were greater. The retention of vitamin B-6 in broccoli after blanching ranged from 9.9 to 14.3 mcg/g dry weight or 50 to 59% (Table 7). The maximum loss of vitamin B-6 in all broccoli samples due to dehydration was 22%, and in some samples, none was lost. Vitamin B-6 in the dried broccoli ranged from 8.1 to 13.3 mcg/g dry weight (Table 8). The average retention was 11.5 mcg/g dry weight or 90%. The vitamin B-6 present in green peppers was more susceptible to destruction during dehydration. In green peppers, the maximum B-6 retention was 90% or 35.6 mcg/g dry weight, and the minimum was 58% or 26.9 mcg/g dry weight (Table 9). The average retention in all 3 drying periods was 31.5 mcg/g dry weight or 71%. Retention of vitamin B-6 in either the broccoli or the green peppers was not affected (0.05) by drying time. The vitamin B-6 retention in this study is within the range (8 to 41%) of that reported by other investigators (Augustin et al., 1979; Hassinen et al., 1954; Holmes et al., 1979; Miller et al., 1973) but much

Table 6. Retention of ascorbic acid in green peppers after dehydration. Values reported in mg/g dry weight and percent of the ascorbic acid present in the fresh peppers.

Replication	Fresh		Sampling Period[a] 1			2			3		
	Mean mg/g dry wt	S.D.	Mean mg/g dry wt	S.D.	%	Mean mg/g dry wt	S.D.	%	Mean mg/g dry wt	S.D.	%
1	16.1	0.8	1.02	0.02	6	1.14	0.12	7	1.05	0.11	7
2	15.5	1.2	3.66	0.03	24	3.40	1.18	22	3.80	0.50	25
3	21.8	2.4	3.40	0.23	16	4.25	0.33	19	3.65	0.32	17
4	17.9	0.9	3.88	0.18	22	3.90	0.09	22	3.27	0.34	18
Mean	17.8	2.8	2.99	1.33	17	3.17	1.38	18	2.94	1.28	17

[a]Sampling period 1, 8 to 8½ hours; sampling period 2, 9¼ to 10 hours; sampling period 3, 13 to 14 hours of drying.

Table 7. Retention of vitamin B-6 in mcg/g dry weight and percent in broccoli after blanching.

Replication	Fresh		Blanched		
	Mean	S.D.	Mean	S.D.	%
	mcg/g dry wt		mcg/g dry wt		
1	19.2	1.2	9.9	0.72	52
2	24.3	1.5	14.3	1.4	59
3	28.1	1.4	14.2	0.12	50
4	25.8	1.3	13.1	0.23	52
Mean	24.3	3.8	12.9	2.1	53

Table 8. Retention of vitamin B-6 in broccoli after dehydration. Values reported in mcg/g dry weight and percent of the vitamin B-6 present after blanching.

	Sampling Period[a]								
	1			2			3		
Rep.	Mean	S.D.	%	Mean	S.D.	%	Mean	S.D.	%
	mcg/g dry wt			mcg/g dry wt			mcg/g dry wt		
1	8.1	0.38	82	9.2	0.21	93	10.3	0.26	104
2	12.0	1.07	84	12.7	0.10	89	11.2	0.57	78
3	11.3	0.78	80	12.6	0.35	89	12.1	1.68	85
4	12.6	0.32	96	13.3	0.75	102	12.9	1.05	98
Ave.	11.0	2.0	86	12.0	1.9	93	11.6	1.1	91

[a]Sampling period 1, 6 to 6 3/4 hours; sampling period 2, 6½ to 7¼ hours; sampling period 3, 7 to 9½ hours of drying.

Table 9. Retention of vitamin B-6 in green peppers after dehydration. Values reported in mcg/g dry weight and percent of the vitamin B-6 present in the fresh peppers.

Replication	Fresh		Sampling Period[a] 1			2			3		
	Mean mcg/g dry wt	S.D.	Mean mcg/g dry wt	S.D.	%	Mean mcg/g dry wt	S.D.	%	Mean mcg/g dry wt	S.D.	%
1	46.1	3.93	30.3	1.27	66	30.9	0.44	67	30.5	0.87	66
2	39.3	0.56	33.8	1.12	86	35.6	0.75	90	35.3	0.46	90
3	50.2	1.51	29.0	1.46	58	30.8	2.29	61	31.9	0.62	64
4	42.1	0.83	29.5	1.0	70	30.8	0.71	73	26.9	3.28	64
Mean	44.4	4.1	30.6	2.2	73	32.8	2.6	73	31.2	3.5	71

[a]Sampling period 1, 8 to 8½ hours; sampling period 2, 9¼ to 10 hours; sampling period 3, 13 to 14 hours of drying.

greater than reported by Gregory and Kirk (1978). In the latter study, the drastic conditions of processing resulted in 50 to 70% of the B-6 added to dehydrated model systems being lost. Retention of vitamin B-6 in broccoli was greater than green peppers after each drying period. The fact that the pyridoxal form of the vitamin is more stable to heat (DeRitter, 1976; Everson et al., 1964) and pyridoxal is the predominant form of vitamin B-6 in broccoli (Polansky, 1969), may account for the greater retention during drying. The predominant form of B-6 in green peppers is pyridoxamine.

Ascorbic Acid Retention in Dried Broccoli and Green Peppers After Storage

During storage, retention of ascorbic acid was minimal. The ascorbic acid in all the dried broccoli samples after storage ranged from a low of 6% or 0.182 mg/g dry weight to a high of 33% or 1.35 mg/g dry weight, the average retention being 0.41 mg/g dry weight or 16% (Table 10). The retention of ascorbic acid in the dried green peppers after storage was more variable than in the broccoli. In some of the green pepper samples, there was no measurable amount of ascorbic acid present while others retained as much as 1.79 mg/g dry weight or 47% (Table 11). The average ascorbic acid retention was 0.53 mg/g dry weight or 16%. The extent of drying had no affect (0.05) on the

Table 10. Retention of ascorbic acid in broccoli after storage at 37°C for 11 to 13.5 weeks. Values reported in mg/g dry weight and percent ascorbic acid present after drying which was retained after storage.

	Sampling Period[a]								
	1			2			3		
Rep.	Mean mg/g dry wt	S.D.	%	Mean mg/g dry wt	S.D.	%	Mean mg/g dry wt	S.D.	%
1	0.297	0.087	10	0.241	0.094	11	0.343	0.055	14
2	0.182	0.049	6	0.197	0.060	6	0.711	0.032	15
3	0.346	0.061	18	0.275	0.071	18	0.147	0.020	8
4	0.255	0.111	11	0.581	0.074	18	1.350	0.012	33
Ave.	0.270	0.069	11	0.324	0.175	13	0.638	0.530	18

[a]Sampling period 1, 6 to 6 3/4 hours; sampling period 2, 6½ to 7¼ hours; sampling period 3, 7 to 9½ hours of drying.

Table 11. Retention of ascorbic acid in green peppers after storage at 37°C for 8 to 9.5 weeks. Values reported in mg/g dry weight and percent ascorbic acid present after drying which was retained after storage.

	Sampling Period[a]								
	1			2			3		
Rep.	Mean mg/g dry wt	S.D	%	Mean mg/g dry wt	S.D	%	Mean mg/g dry wt	S.D.	%
1	0	-	-	0.10	0.03	9	0.24	0.43	23
2	0.10	0.03	3	0.24	0.04	7	1.79	0.04	47
3	0.10	0.72	3	0.32	0.09	8	1.21	0.23	33
4	0.22	0.17	6	0.71	0.61	18	1.30	0.01	40
Mean	0.10	0.01	3	0.34	0.26	10	1.14	0.65	36

[a]Sampling period 1, 8 to 8½ hours; sampling period 2, 9¼ to 10 hours; sampling period 3, 13 to 14 hours of drying.

retention of ascorbic acid during storage in either broccoli or green peppers. However, because the amount of ascorbic acid present after dehydration was so small, differences due to the extent of dryness of the samples during storage may not have been detectable. Deterioration of the dried product during storage is dependent on the storage temperature (Aykroyd, 1943; Mallette et al., 1946) and the moisture content (Gore and Mangels, 1921; Labuza, 1973). In this study, the samples were stored at high temperatures (37°C) and at moisture contents that fall on the low side of the intermediate moisture food range (20 to 50%), both of which accelerate changes during storage. Losses of ascorbic acid after storage in intermediate moisture foods is quite rapid (Labuza, 1973). In sufficiently dried cabbage (3.6% moisture) the loss of ascorbic acid after 4 months storage was 35%. At 8.2 and 10.2% moisture, the loss of ascorbic was 90% and 96%, respectively (Chase, 1942).

Vitamin B-6 Retention in Dried Broccoli and Green Peppers After Storage

The extent of vitamin B-6 losses occurring during storage varied with the broccoli and green peppers. Broccoli retained an average of 6.56 mcg/g dry weight or 57% of the vitamin B-6 present after dehydration (Table 12). Retention of vitamin B-6 after storage was 3.59 to 11.5 mcg/g

Table 12. Retention of vitamin B-6 in broccoli after storage at 37°C for 11 to 13.5 weeks. Values reported in mcg/g dry weight and percent vitamin B-6 present after drying which was retained after storage.

	Sampling Period[a]								
	1			2			3		
Rep.	Mean mcg/g dry wt	S.D.	%	Mean mcg/g dry wt	S.D	%	Mean mcg/g dry wt	S.D.	%
1	4.47	0.20	55	4.93	0.12	54	6.30	0.28	61
2	4.93	0.34	41	5.26	0.16	41	8.86	0.26	79
3	3.59	0.16	32	4.17	0.09	33	4.61	0.23	38
4	8.99	0.60	71	11.50	0.07	86	11.10	0.10	86
Mean	5.50	2.3	50	6.46	3.4	54	7.72	2.8	66

[a]Sampling period 1, 6 to 6 3/4 hours; sampling period 2, 6½ to 7¼ hours; sampling period 3, 7 to 9½ hours of drying.

dry weight. Even though there was an upward trend in vitamin B-6 retention in the dried broccoli after storage in the moisture content of the samples decreased, the effect was not significant (0.05). In green peppers, as the moisture content of the samples decreased, the amount of B-6 retained after storage increased. In this case, the moisture content of the dried peppers during storage significantly affected (0.05) the retention of vitamin B-6. Dried green peppers containing the greatest amount of moisture, or those dried the shortest length of time, retained significantly less (0.01) vitamin B-6 during storage than the samples with the lowest moisture contents, or those dried the longest length of time. Samples dried the shortest length of time (sampling period 1) retained 10.0 to 19.7 mcg/g dry weight or 33 to 67% of the vitamin B-6 with the average being 16.5 mcg/g dry weight or 54% (Table 13). Green peppers from the second sampling period retained 19.9 to 28.4 mcg/g dry weight or 64 to 87% with an average of 24.5 mcg/g dry weight or 76% of the vitamin B-6. One of the samples from the third sampling period (20.7% moisture) retained virtually all of the vitamin B-6 during storage. The retention of vitamin B-6 in these pepper samples ranged from a low of 24.2 mcg/g dry weight to a high of 29.6 mcg/g dry weight. The average B-6 retention in these samples was 26.4 mcg/g dry weight or 86%. The vitamin B-6 losses during storage are greater in the broccoli than the green peppers for all 3 drying times. After dehydration more vitamin B-6 was lost in green peppers than in broccoli.

In storage studies on pyridoxine enriched flour and cornmeal, there was no loss of vitamin B-6 in the flour and a 4% loss in cornmeal after 12 weeks storage at 45°C (Cort et al., 1976). Macaroni stored at 100°C for a year lost no vitamin B-6 either (Bunting, 1965). Canned strained lima beans lost 22% of the original B-6 after storage for 270 days at 20 or 30°C (Everson et al., 1964). Gregory (1959) reported that 30% of the vitamin B-6 remaining

Table 13. Retention of vitamin B-6 in green peppers after storage at 37°C for 8 to 9.5 weeks. Values reported in mcg/g dry weight and percent vitamin B-6 present after drying which was retained after storage.

	Sampling Period[a]								
	1			2			3		
Rep	Mean mcg/g dry wt	S.D.	%	Mean mcg/g dry wt	S.D.	%	Mean mcg/g dry wt	S.D.	%
1	10.0	0.55	33	19.9	0.32	64	24.2	1.11	79
2	17.7	2.01	52	28.4	1.05	80	29.6	1.04	84
3	18.6	0.65	64	22.9	1.50	74	25.1	0.12	79
4	19.7	0.56	67	26.7	0.26	87	26.8	0.26	100
Mean	16.5	4.4	54	24.5	3.8	76	26.4	2.4	86

[a]Sampling period 1, 8 to 8½ hours; sampling period 2, 8 3/4 to 10 hours; sampling period 3, 11 to 14 hours of drying.

after the processing of evaporated milk was lost during storage for six months at room temperature. During the processing and storage of the evaporated milk, a decrease in the pyridoxal form of vitamin B-6 was reported as well. After 2 years storage, little pyridoxal was detected in evaporated milk. Hodson (1956) found some of the pyridoxal form being converted to the pyridoxamine form during the processing and storage of evaporated milk. Possibly, the greater losses of vitamin B-6 in all drying times during storage can be explained by changes of the vitamin B-6 to a less stable form during storage.

For broccoli and green peppers, each step in dehydration may result in large losses of ascorbic acid and moderate losses of vitamin B-6. Blanching results in losses of ascorbic acid due to the vitamin leaching into the cooking water and, to a lesser extent, heat destruction (Krehl and Winters, 1950; Sweeney et al., 1959: Tressler et al., 1936b). Vitamin B-6 is primarily lost in blanching by leaching. During dehydration, ascorbic acid and vitamin B-6 are destroyed by heat. Additional losses of ascorbic acid occur due to oxidation. Subsequent storage of the dried vegetables also causes losses of these two vitamins, the causes of which remain uncertain. Directions for drying should be such that they maximize nutrient retention while at the same time producing products of the highest quality.

Implications

In the drying process, the water should be removed as rapidly as possible and in such a way as to preserve cellular structure while preventing undue decomposition by heat and limiting oxidation and the action of enzymes and microorganisms. This will optimize nutrient retention even though some loss of water-soluble and heat-labile nutrients is inevitable. To remove the water, moderate heat and air circulation are employed. However, a knowledge of the characteristics of the products to be dried and the predominant nutrients is also necessary. The resulting dried vegetable, when cooked, should return to approximately the same bulk, appearance and have the same characteristics as the freshly cooked counterpart. In addition, the flavor, color and texture should be essentially the same. Deterioration of a dried vegetable may also occur during storage and is evidenced by browning, structural changes leading to the inability of the vegetable to reconstitute fully, toughness of the cooked product and the loss of nutrients. The loss of nutrients during storage may be equal to or greater than those losses occurring during dehydration. Conditions such as high storage temperature, insufficient drying and inadequate blanching which facilitate browning during storage, also favor other types of deterioration (Gooding, 1962; Hollingshead, 1943).

Unlike blanching, where the directions are exact and the time required to adequately blanch specified for most vegetables, the endpoint in dehydration is subjectively determined. A person that lacks experience in home drying of vegetables may remove the samples prematurely, retaining more moisture in the product than would be desirable. In this study, the retention of ascorbic acid and vitamin B-6 did not differ significantly in samples dried for varying times. Therefore, the losses of ascorbic acid and vitamin B-6 must have occurred between the start of the drying cycle and the first sampling period. In addition, it was also found that the green peppers dried the longest time, thus to a lower moisture content, retained significantly (.05 level) more vitamin B-6 during storage. Broccoli samples dried the longest length of time also retained more vitamin B-6 during storage, but the difference was not significant. So, if a person is not certain whether the vegetable is adequately dried, additional drying should be encouraged.

Dehydration can be an effective means of preventing microbial deterioration and/or minimizing chemical and physical changes. Broccoli and green peppers are usually preserved by freezing or drying since they are not well suited for canning. Home freezing will also cause losses of the water-soluble vitamins such as ascorbic acid and vitamin B-6. Like dehydration, most vegetables to be frozen must be blanched. The blanching treatment used is the same as that employed before dehydration and losses of the water-soluble vitamins due to leaching are equivalent. But, unlike dehydration, the frozen vegetables are not exposed to additional heat or oxygen.

In this study, 66% of the ascorbic acid present in the fresh broccoli was retained after a 2 minute blanch in boiling water. In a study by Fisher and VanDuyne (1952), broccoli to be frozen retained 70% of the ascorbic acid after a 3 minute blanch in boiling water. Retention of ascorbic acid in blanching is influenced by many factors. The size and shape of pieces and the amount of cut surface exposed to the water as well as the type of blanch and the length are some factors which cause variation in nutrient retention.

In frozen and dried products, the steps following blanching are different. In broccoli, 30% of the ascorbic acid was retained after drying and conditioning. Frozen broccoli retained 65% of the initial ascorbic acid after 20 hours in the freezing compartment of a refrigerator (Farrell and Fellers, 1942).

Storage of vegetables results in additional losses of ascorbic acid which are accelerated when conditions of storage are not optimal. In this study, the broccoli samples with the lowest moisture retained 20% of the ascorbic acid that was present after drying. However, the temperature of storage was high. In the frozen broccoli, 68% of the ascorbic acid was retained after 3 months storage at -17.8°C and 62% after 6 months of storage. Farrell and Fellers (1942) measured the ascorbic acid retention in green beans that had been either frozen or dehydrated. After one year of storage, the ascorbic acid retention was 4% in the dehydrated green beans and 53% in the frozen green beans. Both samples had been blanched.

On the other hand, retention of vitamin B-6 in dried vegetables is relatively the same as the retention of vitamin B-6 in frozen vegetables. In this study, most of the B-6 losses occurred as a result of the blanching treatment. The average loss of vitamin B-6 in broccoli due to drying was 11% and in green peppers, 29%. In other studies, the loss of vitamin B-6 in home dried vegetables and fruits was between 4 and 41% with the greatest losses being observed in the blanched green beans (Holmes et al., 1979). Of the vitamin B-6 lost in green beans, only 11% was lost due to the drying process. In this study, storage of dried vegetables resulted in additional losses of vitamin B-6. After storage, the dried broccoli with the lowest moisture retained 66% of the vitamin B-6 that was present after drying. After storage, green peppers containing the least moisture retained 86% of the vitamin B-6 that was present after drying. The storage temperature in this study was high (37°C) so any changes during storage were accelerated.

Vitamin B-6 losses in frozen vegetables were between 37 and 57% with the mean being 37% (Schroeder, 1971). Most losses of vitamin B-6 are due to the vitamin leaching into the blanching water. Storage of frozen foods also results in losses of vitamin B-6. After 15 months storage, the vitamin B-6, expressed as percent activity, in frozen beef liver, boned chicken, cabbage and green beans was 82, 77, 93 and 55, respectively (Richardson et al., 1961).

The chemical nature and stability during processing of ascorbic acid and vitamin B-6 are quite different. An investigation of the affect of shorter drying cycles on the ascorbic acid retention is needed because preliminary findings in this study indicated that the retention of ascorbic acid was 65% greater in broccoli dried 4½ hours than in broccoli dried 6 to 7¼ hours (Table 1). The moisture content in both samples was similar. However, vitamin B-6 retention was comparable in samples from the short drying times and the long drying times. To shorten the drying period in the type of food dryer used, the amount of vegetables dried in each cycle must be reduced. Therefore, to dry equivalent amounts of vegetables, additional drying cycles would be required. Now that energy conservation is essential, a study comparing energy utilization in several short drying cycles with one long drying cycle is necessary. Then, in recommending drying times for vegetables, both nutrient retention and energy utilization should be taken into account. Also, an investigation of the stability of vitamin B-6 in processed foods, including dried vegetables, after storage is needed because the data in the literature are minimal. In this study, the stability of vitamin B-6 in broccoli after dehydration was greater than in green peppers. Since pyridoxal is the predominant form of vitamin B-6 in broccoli and it is not the most stable form of the vitamin to heat, one would not have expected broccoli to retain more vitamin B-6 after dehydration than green peppers where pyridoxamine is the predominant form. On the other hand, the dried green peppers retained more vitamin B-6 than the dried broccoli during storage. A study measuring the individual components of vitamin B-6 after dehydration and again after storage is necessary, and the data collected may help explain the greater losses of vitamin B-6 in broccoli during storage observed in this study.

SUMMARY

Retention of ascorbic acid and vitamin B-6 was measured in broccoli (Brassica oleracea) and green peppers (Capsicum frutescen) that had been subjected to a home dehydration procedure and again after an accelerated storage period at 37°C. Broccoli was purchased in a local food outlet. It was washed, peeled, cut into pieces with a maximum diameter of 0.5 cm and maximum length of 12 cm, water-blanched for 2 minutes, dipped into a mold inhibitor (potassium sorbate) and dried for 6 to 9½ hours. There were 3 sampling periods in each replication. The first sampling was after 6 to 6 3/4 hours. Sampling periods 2 and 3 were between 6½ and 7¼ hours and 7 to 9½ hours, respectively. The peppers were washed, cut into strips with a maximum diameter of 1½ cm, dipped into a mold inhibitor (potassium sorbate) and dried for 8 to 14 hours. The 3 sampling periods were 8 to 8½ hours, 8 3/4 to 10 hours and 13 to 14 hours.

Once dried, both the broccoli and green peppers were allowed to condition for 36 hours at room temperature. At this point, half of each of the broccoli or green peppers from all sampling periods were analyzed for ascorbic acid and vitamin B-6 retention and total moisture. The remaining portion from each drying period was packaged for storage. The length of time the samples were stored

in a 37°C incubator was 11 to 13.5 weeks for the broccoli and 8 to 8.5 weeks for the green peppers. All samples were analyzed in triplicate and reported on a dry weight basis. There were four replications.

The percent moisture in broccoli after conditioning for sampling periods 1, 2 and 3 was 31 to 45%, 20 to 33% and 16 to 27%, respectively. Green peppers from sampling periods 1, 2 and 3 contained 31 to 33%, 22 to 27% and 21 to 24% moisture, respectively. The maximum difference in moisture between the dried sample and the stored sample was 2.4% for the broccoli and 1.3% for the green peppers.

Ascorbic acid retention after drying and storage in broccoli and green peppers was minimal. Since length of the drying period or the moisture content of the dried broccoli or green peppers during storage had no significant affect (0.05) on the retention of ascorbic acid during storage, discussion of ascorbic acid retention will combine values from all 3 sampling periods. Broccoli contained an average of 9.4 mg/g dry weight of ascorbic acid after blanching. Of this, 18 to 56% or an average of 2.8 mg/g dry weight was retained after dehydration. Additional losses during storage were between 67 and 94% or an average retention of ascorbic acid of 0.4 mg/g dry weight. Approximately 3% of the initial ascorbic acid in broccoli was retained after drying and storage. Green peppers contained an average of 17.8 mg/g dry weight. After dehydration between 6 and 24% remained or an average of 3.05 mg/g dry weight. Some samples contained no measurable amount of ascorbic acid after storage and the maximum retention was 47%. The average retention of ascorbic acid after storage in green peppers was 0.53 mg/g dry weight. Green peppers retained approximately 3% of the initial ascorbic acid after dehydration and storage.

The vitamin B-6 in broccoli and green peppers was much more stable to the drying process and storage conditions employed than ascorbic acid. Retention of vitamin B-6 in broccoli or green peppers was not affected (0.05) by the length of the drying period. Therefore, in the discussion on the percent of vitamin B-6 retention after drying, the values from all three sampling periods will be used in the averages that are reported. After blanching, broccoli contained an average of 12.9 mcg/g dry weight of vitamin B-6 or approximately 53% of the B-6 that was present initially. Of that 53%, an average of 90% or 11.5 mcg/g dry weight was retained after dehydration. Additional losses of vitamin B-6 in broccoli occurred during storage. Samples from period 1 retained an average of 5.5 mcg/g dry weight or 50% of the vitamin B-6 that was present after dehydration. Samples from periods 2 and 3 retained an average of 6.5 mcg/g dry weight or 54% and 7.7 mcg/g dry weight or 66%, respectively. An increase in the retention of vitamin B-6 during storage as the moisture content of the sample decreased was observed. However, the effect of length of drying time was not significant (0.05). Green peppers contained an average of 44.4 mcg/g dry weight of vitamin B-6 in the fresh state. An average of 31.5 mcg/g dry weight or 71% was retained after dehydration. The length of the drying period had no effect (0.05) on the retention of vitamin B-6 in dried green peppers. The extent of vitamin B-6 losses in green peppers during storage was less in all 3 sampling periods than losses in broccoli. Green peppers dried the longest length of time, therefore to lower moisture contents, retained significantly more (0.01) vitamin B-6 than those green peppers dried the shortest length of time. Green peppers from the first, second and third sampling periods retained an average of 16.5 mcg/g dry weight or 54% of the vitamin B-6 present after dehydration, 24.5 mcg/g dry weight or 76% and 26.4 mcg/g dry weight or 86%, respectively.

Broccoli and green peppers dried the longest and shortest times retained comparable amounts of ascorbic acid and vitamin B-6. Therefore, additional drying should be encouraged when it is not certain whether the vegetable is adequately dried. Ascorbic acid retention in dried vegetables was much less than the retention of ascorbic acid in frozen vegetables as reported in the literature. However, vitamin B-6 retention was similar in both methods of preservation.

Future studies should examine the effect of shorter drying cycles on ascorbic acid retention and the retention of the individual components of vitamin B-6 after drying and storage to determine if any changes occur.

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APPENDIX

Table 1. Analysis of variance table for retention of ascorbic acid in broccoli not stored and stored and dried three different times.

Source of Variation	df	SS	MS	F[a]
Within	18	9.4	0.52	
Between				
(1) Not stored/stored	1	35.2	35.2	67.7*
(2) Drying times	2	1.4	0.7	1.4
(3) Interaction	2	0.2	0.1	0.2
Total	23	46.2		

[a]Significant at 0.01 level.

Table 2. Analysis of variance table for retention of ascorbic acid in green peppers not stored and stored and dried three different times.

Source of Variation	df	SS	MS	F[a]
Within	18	17.6	0.98	
Between				
(1) Not stored/stored	1	37.7	37.7	38.47*
(2) Drying times	2	1.0	0.5	0.51
(3) Interaction	2	1.9	0.95	0.97
Total	23	58.2		

[a*]Significant at 0.01 level.

Table 3. Analysis of variance table for retention of vitamin B-6 in broccoli not stored and stored and dried three different times.

Source of Variation	df	SS	MS	F[a]
Within	18	101.2	5.6	
Between				
(1) Not stored/stored	1	148.0	148.0	26.4*
(2) Drying times	2	10.3	5.2	0.9
(3) Interaction	2	2.9	1.5	0.3
Total	23	262.4		

[a]*Significant at 0.01 level.

Table 4. Analysis of variance table for retention of vitamin B-6 in green peppers not stored and stored and dried three different times.

Source of Variation	df	SS	MS	F[a]
Within	18	185.2		
Between				
(1) Not stored/stored	1	492.3	492.3	47.9*
(2) Drying time	2	140.5	70.2	6.8*
(3) Interaction	2	90.6	45.3	4.4**
Total	23	908.6		

[a]*Significant at 0.01 level.

[b]**Significant at 0.05 level.