EFFECTS OF PRETREATMENTS AND DRYING CONDITIONS ON COLOR, NUTRIENT RETENTION AND SENSORY CHARACTERISTICS FOR DEHYDRATED OKRA (*Abelmoschus esculentus* (L) MOENCH)

by

DIENEBOU TOURE

B.S., Ecole National Superieure d'Agronomie (ENSA) Abidjan, Ivory Coast, 1982

---

submitted in partial fulfillment of the
requirements for the degree

MASTER OF SCIENCE

in

Food Science
Department of Horticulture
Department of Foods and Nutrition

KANSAS STATE UNIVERSITY

1985

Approved by:

Martha L. Stone and J. K. Greig
Major Professors

TABLE OF CONTENTS

LIST OF TABLES

List of Figures

INTRODUCTION

Despite the increase in the yield of fruits and vegetables due to modern technology, the shortage of food is one of the major problems which most developing countries are facing today. Food losses occur substantially due to the lack of efficient preservation methods (Onayemi and Potter, 1974). Malnutrition is one of the problems our governments are struggling against. Lack of refrigeration and adequate storage facilities are hurdles in the way of supplying fresh vegetables year round. Sun-drying has been used at household levels as a method of preservation.

Today in developed countries, foods are dried by use of electric, hot air dehydrators or ovens. Dehydration is valuable because not only does it help preserve the food from spoiling but it lowers the costs of packaging, storing and transporting by reducing the weight and volume of the products.

Vegetables play an important role in human diet. Their nutritional contribution is to supply vitamins and minerals. Dehydrated vegetables are concentrated in nutrients (Salunkhe et al., 1973). However, some nutrients may be lost during the process of dehydration. Extent of nutrient losses generally depends upon the material preparation prior to dehydration, the dehydration process and the storage conditions of dehydrated products (Villota et al., 1980). Among the nutritional losses that occur in dehydrated products are the loss of protein biological value, fat and water soluble vitamins and minerals (Bluestein and Labuza, 1975).

Okra (Hibiscus esculentus L. or Abelmoschus esculentus) is one of the most popular vegetables consumed in tropical and sub-tropical countries because of its adaptability, dependability, and resistance to hot and humid weather (Martin and Ruberte, 1978). Many studies have been made on protein and oils content of okra seeds (Crossley and Hilditch, 1951; Karakoltsidis and Constantinides, 1975; Savello et al., 1980 and Jones and Earle, 1966). An oil content of 14-19% and a protein content of 21% in okra seeds have been reported by Jones and Earle (1966) and Martin and Ruberte (1978), respectively. Recent research has been conducted by Krutman (1981) to develop alternative dehydration methods for okra.

This study was conducted to establish the effects of not blanching, blanching with boiling water, and blanching with 0.1% sulfur dioxide solution on selected characteristics for dehydrated okra. Drying temperature and duration and storage were also studied. Evaluations made on fresh or dehydrated okra included: moisture content, water activity, color, ascorbic acid and thiamine retention, and sensory characteristics.

LITERATURE REVIEW

All foods which undergo processing are subject to loss of vitamins and minerals to some degree. In general, the processing should be carried out in a manner which minimizes nutrient losses and maximizes safety of the product. Spoilage of plant tissues by microorganisms is enhanced by the presence of a high moisture content.

Dehydration, the removal of water from the tissues to a level that cannot support the growth of microorganisms, is achieved by supplying heat to the food; moisture in the vapor state is removed. In general most bacteria will not grow well if water activity is below 0.9, yeasts will not grow if it is below 0.88, and molds will not grow if it is below 0.8 (Salunkhe, et al., 1973).

Dehydrated foods would be as good as fresh produce if control of microorganisms' growth were the only basis for process evaluation. However, water activity at which the growth of microorganisms is controlled is not low enough to inactivate enzymes responsible for undesirable changes (Troller, 1980). Achieving water activity values at which all enzyme activity ceases is not economically feasible (Schwimmer, 1980). Thus, the use of pretreatments prior to dehydration such as blanching and/or addition of sulfite is done to inactivate enzymes which would contribute to undesirable changes in color, flavor, or nutritive value during subsequent storage of the product.

Pretreatment

Fresh fruit and vegetable tissues contain active enzymes, such as catecholase, tyronase, ascorbinase and polyphenoloxidase, that catalyze the oxidation of phenolic compounds into o-quinones (red to reddish-brown) in the presence of oxygen and when combined with amino acid derivatives form highly colored complexes. Therefore, as fruits or vegetables are prepared for dehydration, undesirable browning can occur unless the cut products are treated to inactivate the enzymes either by heat or addition of sulfur dioxide (Salunkhe et al., 1973).

Blanching. Blanching is used as a preliminary treatment prior to dehydration to inactivate enzymes responsible for the development of objectionable odors and flavors and the loss of ascorbic acid and carotene during storage. Blanching also helps to increase the drying rate, thus, shortens the drying time (Salunkhe et al., 1973). Three methods of blanching exist: steam, boiling water or microwave blanching. Although several authors prefer steam blanching to water blanching (Cruess, 1958), each of these three methods presents some advantages.

Water blanching versus steam blanching have been studied extensively. It seems that steam blanching is more effective than water blanching for the conservation of soluble nutrients. Retzer et al. (1945) studied the effect of steam and hot water blanching on the ascorbic acid content of snap beans and cauliflower; snap beans were found to lose 15% of the vitamin during water blanching and 11% during steam blanching. Dietrich and Heumann (1965) reported that chlorophyll was more stable in water blanched than in steam blanched Brussel sprouts, and that blanching with steam gave a dull colored product.

Quenzer and Burns (1981) studied the effects of microwave, steam and water blanching on freeze-dried spinach, and concluded that microwave blanching was superior to water and steam in ascorbic retention and inferior for beta-carotene. They also concluded that microwave blanching was better than steam but inferior to water for retention of alpha-tocopherol. Eheart (1967) also studied the effects of microwave versus water blanching on nutrients in broccoli. He reported that microwave blanched broccoli was higher than water blanched samples in ascorbic acid and percentage retention of chlorophyll.

Sulfite treatment. Before drying, vegetables are usually reduced to slices, cubes, strips or flakes. Upon an extended period of storage the vegetables tend to change in color, flavor and nutrient content. Therefore, it has become standard practice in the food industry to treat vegetables prior to dehydration with various antioxidants such as butyl hydroxy toluene (BHT), butyl hydroxy anisole (BHA), nordihydroguinaretic acid (NDGA), propyl gallate (PG), and the most commonly used, sulfur dioxide (Pintauro, 1974). Sulfite is used to prevent both enzymatic and non-enzymatic browning of vegetables and to protect ascorbic acid retention (Tannenbaum, 1976).

Nutrient retention. Blanching has been shown to minimize some nutrient losses (Morgan et al., 1945; Salunkhe et al.,1973) reported as high as 80% decrease in the carotene content of unblanched vegetables, while only 5% loss was reported for blanched vegetables. However, the water soluble nutrients such as minerals, ascorbic acid, and the B-vitamins to a lesser extent, may be lost during blanching by leaching into the heating medium or by oxidation of ascorbic acid.

Mineral retention. The loss of mineral substances as reported by Tannenbaum (1976) occurs through trimming unwanted parts of the vegetables and leaching of water soluble materials. Little loss occurs through destruction by chemical reactions.

The minerals that are commonly lost in vegetables according to observations made by Horner in the 1930's and reported by Lee (1958), are potassium and phosphates -- 39% and 20% losses of potassium oxide (K_2O) and phosphorus pentoxide (P_2O_5) in peas blanched for 3 minutes at 100°C (212°F); 40% losses of K_2O in beans blanched for 3 minutes at 82°C (180°F); 16% losses in K_2O, 15% of P_2O_5 in carrots blanched for 7 minutes at 100°C (212°F) and 9% losses of K_2O and P_2O_5 for potatoes blanched for 5 minutes at 100°C (212°F) were observed (Lee, 1958).

Kramer and Smith (1947) reported 12.67% loss of phosphorus in lima beans blanched for 8 minutes at 160°F (71°C), and 40% loss in spinach blanched for 4 minutes at 200°F (93°C). Unlike potassium and phosphorus, calcium is reported to be absorbed by vegetables during blanching depending upon the hardness of the water and the blanching time. Lee and Whitcombe (1945) studied the effects of different types of potable water on nutrients of peas and snap beans and concluded that vegetables blanched in hard water increased significantly in calcium content. Kramer and Smith (1947) reported as high as 58.95% increase of calcium in fancy peas blanched for 9 minutes at 200°F (93°C), 53.78% in spinach blanched for 4 minutes at 200°F (93°C), and 8.92% in lima beans blanched for 8 minutes at 160°F (71°C).

Retention of B-vitamins. As mentioned previously, small amounts of B-vitamins are lost during blanching or sulfiting. Wagner and co-workers (1947) studied the effects of blanching on the retention of ascorbic acid, thiamine, and niacin in vegetables. They reported that for hot water blanching, peas retained 63-105% of their niacin content; green beans 89-109% and lima beans 51-104%. They also reported 66-103%; 90-105% and 42-67% retention of thiamine in peas, green beans and lima beans, respectively.

The amount of B-vitamins retained depends upon the duration of the blanching period, the product and temperature of the blanching water. Guerrant et al., (1947) reported that water-blanched peas retained from 40-90% of their original riboflavin content, while lima beans blanched in water for 8 minutes at 200^{o}F (93^{o}C) lost 43% of their original riboflavin and spinach lost as high as 73% of its initial riboflavin content as the result of being water-blanched for 7 minutes at 200^{o}F (93^{o}C). Also, Guerrant et al., (1947) reported that the retention of niacin and especially thiamine in vegetables during blanching is time/temperature dependent. They reported a 44% loss of niacin in lima beans blanched for 8 minutes at 200^{o}F (93^{o}C).

Thiamine is the B-vitamin that has been reported to be the least stable and sensitive to sulfite (Bluestein and Labuza, 1975; Tannenbaum, 1976). Mallette et al. (1946) found that about 45% of the initial thiamine content is lost in sulfite-blanched cabbage while only 14.86% is lost in steam-blanched cabbage. Thiamine sensitivity to sulfite is explained by the fact that thiamine undergoes a series of degradative reactions involving a nucleophilic displacement at the methylene carbon joining the two ring systems (Figure 1, Appendix). Thus, in the presence of strong nucleophiles such as sulfite (HSO_3) thiamine is destroyed (Tannenbaum, 1976).

Ascorbic acid retention. Of all the vitamins present in a food system, the greatest loss occurs in ascorbic acid during pretreatment prior to dehydration as a result of leaching or oxidation (Bluestein and Labuza, 1975; Tannenbaum, 1976).

Stevens (1943) found that ascorbic acid losses during blanching varied with the product. He reported that rutabagas and carrots lost only 10-20% whereas, peas and white potatoes lost about 60%. Guerrant (1947) reported 81 mg ascorbic acid retained per 100g of dry matter by sweet peas, 62 by whole green beans and 46 mg/100g of dry matter by lima beans all blanched under the same conditions [water blanching for 3 minutes at 180°F (82°C)].

Because of its solubility in water and its sensitivity to heat, ascorbic acid is easily lost during blanching (Salunkhe et al., 1973). However, blanching is reported to help in the retention of ascorbic acid during dehydration and storage because it (blanching) inactivates the oxidative enzymes.

The effect of blanching is more extensive during the storage of the dried vegetables than in the dehydration process. Holmes et al. (1979) reported that dried green beans retained only 2% of their ascorbic acid whether or not they were blanched. Similar observations were made earlier by Morgan and co-workers (1945). They found that blanched or unblanched snap beans, after dehydration retained only 20-30% of their initial ascorbic acid; however, during storage, the residual amount of ascorbic acid in the unblanched products is lost while the blanched products lose little of their residual ascorbic acid.

Morgan et al. (1945) reported that from blanching to dehydration, spinach lost 84 to 91% of its ascorbic acid content as compared to the unblanched spinach which lost 70% of its ascorbic acid during the dehydration process. Unblanched spinach continued to lose ascorbic acid during storage while the blanched product suffered little degradation.

Color retention. Color is an important aspect that helps determine the acceptability of a food product. Often the value of raw food materials, especially fruits and vegetables, is judged as to value by their color (Clydesdale and Francis, 1975; Dutton et al., 1943). Color of green vegetables is due primarily to the presence of chlorophyll pigments. Unfortunately, processing causes deterioration of the chlorophyll pigments, especially blanching which causes the conversion of chlorophyll to pheophytin and results in a dulling and browning of the green (Clydesdale and Francis, 1975; Dutton et al., 1943). Dutton et al. (1943) reported that darkening and graying of color occurs in dehydrated spinach as a result of blanching.

Dehydration

The dehydration process causes fewer losses of nutrients than pretreatment or storage conditions. Niacin and riboflavin have been reported to be fairly stable to heat and oxidation; therefore, they are not affected by drying (Tannenbaum, 1976).

The vitamins most affected by dehydration are ascorbic acid and thiamine. Apparently, the loss of these vitamins depends upon the food system, the pretreatment applied and the conditions of dehydration (time and temperature). Stevens (1943) studied the conditions affecting the nutritive values of dehydrated vegetables and reported that onions and peas did not lose ascorbic acid during drying, but that corn and sweet potatoes lost over 60%. Morgan et al, (1945) found that snap beans retained only 20 to 30% of their ascorbic acid originally present while blanched spinach retained only 9 to 26% and unblanched spinach 30%.

Holmes et al. (1979) also found that dried tomato puree retained 7% of its ascorbic acid but higher retention was achieved in dried zucchini squash (33%) and raspberries where up to 74% was retained. They concluded that the low retention of ascorbic acid in tomato puree may be caused by the longer drying time (6.5 hours) when compared to the drying time of 4 to 4.5 hours for squash and raspberries. In artifically dehydrated or sun-dried vegetables, thiamine content reduction is less in blanched tissue than in unblanched (Morgan et al., 1945). Salunkhe et al. (1973) reported that a 15% loss of ascorbic acid is typical in blanched tissues and 75% in unblanched tissues for fruits and vegetables.

Pavcek (1946) studied the effect of sulfite on ascorbic acid and thiamine retention; he found that while the use of sulfite enhanced the retention of ascorbic acid in cabbage (351 mg/100g in sulfited product versus 189 mg/100g in unsulfited product) it was detrimental to thiamine retention; 0.41 mg/100g of thiamine were found in unsulfited cabbage while only 0.13 mg/100g were found in sulfited product.

Storage

Shelf life of foods is based on changes in nutritional quality during storage as well as their microbiological quality (Kirk et al., 1977). Initial quality of the raw material and changes that occur during processing and storage determine the quality of dehydrated foods (Villota et al., 1980). According to Tressler (1956) most freshly dehydrated vegetables are comparable in color and flavor to the original vegetable. However, during storage, color, flavor and nutrients may be lost as a result of the storage conditions (temperature, presence of light and oxygen), and the moisture content or water activity of the dehydrated product (Tressler, 1956; Salunkhe et al., 1973; Kirk et al., 1977; Villota et al., 1980).

Lee and Labuza (1975) studied the destruction of ascorbic acid as a function of water activity in a desorption and absorption system. They found after 48 hours that the fraction of ascorbic acid remaining in the system with water activity equal to 0.32 was 6.51 and 1.32 for the system with water activity equal to 0.84. They concluded that the destruction rates increase with increasing water activity.

Dutton et al. (1943) reported that dehydrated spinach stored at high moisture levels lost its green color, and implied that this impairment of color may be due to the conversion of chlorophyll to pheophytin. Mallette et al. (1946) studied the storage stability of ascorbic acid of commercially dehydrated potatoes. They found that 50% of the ascorbic acid content is lost during blanching and half of the remaining ascorbic acid is lost during dehydration. They studied storage changes in dehydrated potatoes containing two moisture levels and found that ascorbic acid was more stable at the lower moisture level (7%) at all storage temperatures than the product containing a medium amount of moisture (13%).

Pretreatments such as blanching and sulfiting prior to dehydration are means of preventing ascorbic acid loss, change of color and development of off flavors during storage. Mallette et al. (1946) reported that the loss of ascorbic acid and the development of abnormal color and odor in sulfite-blanched cabbage were less pronounced even at a high storage temperature (29^{o} - $40^{o}C$). They also reported that in steam-blanched cabbage (where about 50% of the ascorbic acid was lost during blanching and processing), the ascorbic acid content remained constant for nearly a year.

Sensory characteristics. Among the factors that limit the acceptability of dehydrated vegetables are the loss of flavor and/or the development of off-flavors and off-odors that occur during drying and storage at room or higher temperatures (Salunkhe et al., 1973). Products in which the flavor constituents are volatile oils are prone to severe flavor deterioration. According to Villota et al. (1980) flavor deterioration in dehydrated products is attributed to volatile losses, oxidation and non-enzymatic browning. Development of off-flavors and off-odors is related also to pretreatment, methods of drying, handling and storage conditions (Villota et al., 1980).

Blanching as a method of pretreatment to inactivate the enzymes that may cause development of off-flavors and off-odors, has been recommended. However, some researchers (Mallette et al., 1946; Foda et al., 1967) reported finding off-odors that they characterized as hay-like aromas in blanched vegetables.

Okra flavor is important in determining its acceptability. Woodroof and Shelor (1958) reported that okra flavor characterized as "green" vegetable and its mucilaginous character were closely related. They also reported that the seeds contained more of these flavor components than the pod wall.

MATERIALS AND METHODS

Six treatments for drying okra were studied. Unblanched okra was dried at 1) 125^{o}F (52^{o}C) for 14 hours, 2) 145^{o}F (63^{o}C) for 10 hours; okra blanched in boiling water were dried at 3) 125^{o}F (52^{o}C) for 14 hours; 4) 145^{o}F (63^{o}C) for 10 hours and okra blanched in boiling water containing 0.1% sulfur dioxide (SO_2) at 5) 125^{o}F (52^{o}C) for 14 hours; 6) 145^{o}F (63^{o}C) for 10 hours.

Fresh okra was evaluated for color, ascorbic acid and thiamine content. After dehydration the dried okra was evaluated for ascorbic acid and thiamine content, color, moisture and water activity before and after six weeks of storage. Sensory characteristics were evaluated after six weeks of storage and rehydration. Data from four replications were subjected to analysis of variance.

Pretreatment, Drying and Storage Condition

Locally grown fresh okra pods (Abelmoschus esculentus Cv Lee) were obtained from the Kansas State University Horticulture farm. The fresh pods were sized (7.5-8.75 cm) washed, and one of the following treatments was applied; 1) without blanching; 2) okra pods blanched in boiling water for three minutes in quantities of 1kg/5 l water; 3) okra pods blanched in boiling water containing an equivalent of 0.1% SO_2 in quantities of 1kg/5 l solution.

For blanching in boiling water, 5 l of water were used for each kg of okra pods. Whole okra pods were placed in the blanching kettle with boiling water, covered, and boiled for 3 min. Blanched pods were cooled in running tap water for the same amount of time that they had been exposed to heat.

For blanching in SO_2, 5 l of water also were used for each kg of okra pods, except that 8.55 g of sodium sulfite were added to the boiling water just prior to addition of okra.

After each treatment okra pods were trimmed and cut into 2 cm cylindrical slices. An electric dehydrator with nine shelves (Excalibur Model ED 301) was used for dehydration. Okra slices (250g) were spread in a single layer on each tray and dried as previously described. Dehydrated okra slices were packaged and sealed in "Seal-a-Meal" bags and stored in a dark place at room temperature (22-25^{o}C) for six weeks.

Evaluation and Measurements

Ascorbic acid. Total ascorbic acid was measured by the fluorometric method (AOAC, 1980) which includes reduced and dehydroascorbic acid. Samples were prepared by lending 5 gm of fresh okra or 2 gm of dehydrated okra in 100 ml extracting acid (3% metaphosphoric/8% acetic acid) for 1 min in a Waring blender. Fluorescence was determined with a Coleman Photofluoremeter (Model 12c). Data were reported as mg/100g wet weight, mg/100g dry weight, and % retention ($\frac{\text{fresh X dry}}{100}$).

Thiamine. Thiamine also was determined by the fluorometric method (Freed, 1966). Ten grams of fresh okra or 1 gm dried okra samples were prepared by blending for 1 min in 0.1N HCl. Fluorescence was determined on a Coleman photofluorometer (Model 12C). Data were reported as mg/100g wet dry weight, and % retention ($\frac{\text{fresh X dry}}{100}$).

Color. Color was monitored with the HunterLab spectorphotometer (Model D54P-5). Fresh okra (20 gm) was blended for 3 min in 200 ml water. Dried okra slices (5 gm) were placed in 200 ml water for 30 minutes and then blended for 3 min in Waring blender. Slurries were allowed to stand for 30 minutes for the foam to dissipate. Optically clear cells (5.6 cm diameter, 3.8 cm depth) were filled with samples for presentation to the spectrophotometer. HunterLab L, a, and b values were measured.

Water activity. Water activity was measured using the Beckman thermocouple psychrometer sample changer (Model Sc-10A). Samples (0.5 gm) were ground into plastic bags to avoid moisture uptake.

Moisture. Percent moisture was determined for 10 gm samples using the Brabender semi-automatic moisture tester. Samples were dried until constant readings were obtained.

Sensory analysis. After six weeks of storage, a professionally trained taste panel composed of five members evaluated the samples for intensity of aroma ("cooked green vegetable" and hay-like) and flavor ("cooked green vetetable", hay-like, bitter, sweet, sour and mouth-drying characteristics). Okra samples (20 gm) were placed in 150 ml boiling water, simmered for 30 minutes, and served at room temperature in covered 50 ml beakers. A semi-structured intensity scale was used (see Figure 3). Intensity scores for each characteristic were determined by measuring the distance of line from No (0 cm) to Extreme (14 cm).

Analysis of Data

Moisture content, water activity, ascorbic acid, thiamine, color and sensory characteristics were subjected to analysis of variance using a randomized block design.

Source of variance	df
Block (Rep)	3
treatment (Trt)	5
Rep x Trt (Error a)	15
Storage time (St)	1
Trt x St	5
St x Rep + Trt x St x Rep (Error b)	18
Total	47

Least square means were compared to determine treatment effects. When F-values were significant, probability of differences were calculated to determine the level of significance.

RESULTS AND DISCUSSION

Data for percentage moisture, total ascorbic acid and thiamine content, and color for fresh okra are reported in Table 6, Appendix. Moisture content, water activity, ascorbic acid and thiamine content, and color of dehydrated okra were determined before and after storage; sensory analysis of rehydrated okra was conducted after 6 weeks' storage. Data for all replications are presented in Table 7-14, Appendix.

Moisture Content and Water Activity

Moisture content and water activity of dried okra slices are listed in Table 1. Pretreatment (not blanching, blanching in boiling water and blanching in 0.1% sulfur dioxide solution) and drying conditions had no significant effect on the moisture content immediately after dehydration, contrary to results found by Sugihara and Cruess (1942) and Moyer et al. (1959). Sugihara and Cruess studied the effect of blanching on the dehydration rates of vegetables. They concluded that blanching in most cases caused an increase in the rate of drying. Moyer et al. (1959) studied the interaction between blanching and drying rates of peas. They also concluded that drying rate increased when peas were blanched, especially in peas that were steam blanched. Drying temperature and duration had no effect on the water activity within pretreatments. However, blanching had a significant effect ($p<0.05$). Unblanched samples had a lower water activity (A_w=0.31) than samples blanched in water (A_w=0.49) or those blanched in 0.1% sulfur dioxide solution (A_w=0.48). Storage had no significant effect ($p<0.05$) on moisture content nor on water activity of blanched samples. Only unblanched samples which had lower initial water activity underwent a significant increase ($p<0.05$) in

Table 1. Effects of pretreatments and drying conditions on means[a] for moisture content and water activity (Aw) of dried okra before and after storage.

	% Moisture		Water Activity	
	0 Wk	6 Wk	0 Wk	6 Wk
Unblanched				
$125^{o}F/14$ hr	19.96 d	20.28 d	0.309 d	0.428 d
$145^{o}F/10$ hr	18.16 d	19.10 e	0.318 d	0.448 d
Blanched[b]				
$125^{o}F/14$ hr	18.45 d	18.70 e	0.478 e	0.492 e
$145^{o}F/10$ hr	18.29 d	18.25 e	0.502 e	0.486 e
Blanched in SO_2[c]				
$125^{o}F/14$ hr	18.43 d	18.58 e	0.512 e	0.508 e
$145^{o}F/10$ hr	18.68 d	18.55 e	0.455 e	0.494 e

[a]Means with the same letter in the same column are not siginficantly different ($p < 0.05$).

[b]Blanched in boiling water for 3 minutes.

[c]Blanched in boiling 0.1% SO_2 solution for 3 minutes.

water activity during storage.

Ascorbic Acid

Table 2 shows the ascorbic acid content of dehydrated okra before and after storage. Before storage, unblanched okra and okra blanched in 0.1% sulfur dioxide solution had higher percentage retention of ascorbic acid ($p<0.05$) than okra blanched in boiling water. Similar observations were made by Morgan and co-workers (1945) who found that before storage, spinach that had been blanched prior to dehydration retained 9 to 16% of its ascorbic acid content, whereas, unblanched spinach retained up to 30% of its original ascorbic acid content.

No significant difference ($p<0.05$) was found between the amount of ascorbic acid retained by unblanched okra and okra blanched in 0.1% sulfur dioxide solution before storage. Drying temperature and duration had no significant effect ($p<0.05$) on the ascorbic acid retention of okra before storage.

As mentioned previously the effects of blanching and use of sulfur dioxide as pretreatments prior to dehydration are more noticeable after storage. Okra blanched in boiling water and 0.1% sulfur dioxide solution underwent no significant changes in their ascorbic acid level. However, the unblanched samples (which had the same ascorbic acid content as okra blanched in 0.1% sulfur dioxide solution before storage) underwent the greatest losses during storage.

Morgan and co-workers (1945) reported that blanched spinach retained less ascorbic acid than the unblanched spinach. But during storage the unblanched spinach continued losing its ascorbic acid, whereas the blanched product suffered few additional losses. After storage the highest ascorbic acid level was exhibited by okra blanched in 0.1% sulfur dioxide solution. This is in agreement with Krutman (1981) who reported that okra blanched in 0.1% sulfur dioxide solution and cabinet-dried had the highest ascorbic acid content when compared with other treatments. Okra blanched in boiling water and unblanched okra exhibited the same level of ascorbic acid after storage, despite the fact that unblanched okra had a higher level of ascorbic acid before storage.

Table 2. Effects of pretreatments and drying conditions on mean values[a] for ascorbic acid of dried okra before and after storage.

	Unblanched		Blanched[b]		Blanched in SO_2[c]	
	125°F/14hr	145°F/10hr	125°F/14hr	145°F/10hr	125°F/14hr	145°F/10hr
			Ascorbic Acid (mg/100g wet wt)			
0 Week	78.59 d	79.56 d	55.25 e	61.41 e	82.97 d	85.32 d
6 Week	44.74 d	46.09 d	41.16 e	43.81 de	71.63 f	73.94 f
			(mg/100g dry wt)			
0 Week	98.15 d	97.30 d	67.65 e	75.02 e	101.72 d	105.02 d
6 Week	55.09 d	57.18 d	50.62 e	53.55 de	88.00 f	90.91 f
			(% retention)			
0 Week	36.30 d	35.51 d	24.86 e	27.64 e	36.89 d	38.30 d
6 Week	19.56 d	20.28 d	18.49 e	19.44 de	31.44 f	32.68 f

[a]Means with the same letter in the row are not significantly different ($p < 0.05$)

[b]Blanched in boiling water for 3 minutes

[c]Blanched in boiling 0.1% SO_2 solution for 3 minutes

Thiamine

Thiamine content of dehydrated okra slices before and after storage are listed in Table 3. Unblanched okra and okra blanched in boiling water showed no loss of thiamine after dehydration when compared to fresh samples. However, okra blanched in 0.1% sulfur dioxide solution exhibited significantly less thiamine than fresh samples. About 20-31% of the original thiamine content of the okra was lost after dehydration as a result of treatment with sulfur dioxide. Other researchers (Mallette et al., 1946; Pavcek , 1946) have reported the effects of sulfite on dehydrated cabbage. They found that sulfite-blanched cabbage contained considerably less thiamine than the unsulfited cabbage.

Drying temperature and duration within pretreatments had no significant effect ($p < 0.05$) on the retention of thiamine. Upon six weeks of storage the samples underwent no significant change ($p < 0.05$) in their thiamine level. Samples blanched in sulfur dioxide remained lower in thiamine than those unblanched or blanched in boiling water.

Color

HunterLab L, a-and b-values of fresh and dehydrated okra before and after storage are listed in Table 4. A decrease in the HunterLab "L" values means an increase in darkening, an increase in the "a" values corresponds to a shift from green towards red and a decrease in the "b" values means a shift from yellow to blue.

"L" values were higher in okra samples blanched in boiling water or in 0.1% sulfur dioxide solution than in unblanched samples. These samples were lighter because of the inhibition of enzymatic browning by heat treatment and/or by addition of sulfur dioxide. The same samples were

Table 3. Effects of pretreatments and drying conditions on mean values[a] for thiamine of dried okra before and after storage.

	Unblanched		Blanched[b]		Blanched in SO_2[c]	
	$125^oF/14hr$	$145^oF/10hr$	$125^oF/14hr$	$145^oF/10hr$	$125^oF/14hr$	$145^oF/10hr$
			Thiamine (mg/100g wet wt)			
0 Week	0.983d	0.974d	0.945d	1.030d	0.762e	0.794e
6 Week	0.858d	0.858d	0.919d	0.923d	0.655e	0.671e
			(mg/100g dry wt)			
0 Week	1.220d	1.190d	1.160d	1.260d	0.934e	0.935e
6 Week	1.080d	1.060d	1.130d	1.129d	0.805e	0.824e
			(% retention)			
0 Week	104.38d	101.53d	98.78d	107.61d	79.87e	80.31e
6 Week	91.95d	90.17d	96.20d	96.08d	68.62e	70.37e

[a]Means with the letter in the same row are not significantly different ($p < 0.05$)

[b]Blanched in boiling water for 3 minutes

[c]Blanched in boiling 0.1% SO_2 solution for 3 minutes

greener and more yellow ($p < 0.05$) than unblanched samples. Krutman (1981) made similar observations on cabinet-dried okra. When compared to the fresh samples, only unblanched okra dried at 145°F for ten hours produced "L" values similar to the fresh okra ($p < 0.05$). Other treatments produced significantly higher "L" values than the fresh okra indicating that they were lighter than the fresh samples.

Statistical analysis showed the HunterLab "a" and "b" values for all treatments were significantly different from the fresh except for unblanched okra dried at 125°F for 14 hours. Unblanched okra dried at 145°F for 10 hours had higher "a" but lower "b" values than the fresh meaning that this sample was less yellow and less green than the fresh sample. Blanched okra had lower "a" and higher "b" values meaning that they were a yellower green than the fresh sample. Drying temperature and duration had no significant effect ($p < 0.05$) on color changes for blanched (blanched in boiling water or blanched in 0.1% SO_2) dried okra.

No significant darkening or lightening ($p < 0.05$) occurred in any samples within six weeks of storage. Nevertheless, all samples increased ($p < 0.05$) in the HunterLab "a" values, but no significant change ($p < 0.05$) in the HunterLab "b" value occurred, meaning that the samples were not as green as they were prior to storage. However, blanched samples were yellower (significantly higher "b" values) but as green as the fresh sample (no significant difference in the "a" value at $p < 0.05$).

Table 4. Effects of pretreatments and drying conditions on means[a] HunterLab L, a and b values of dried okra

	HunterLab L - value		HunterLab a - value		HunterLab b - value	
	0 Wk	6 Wk	0 Wk	6 Wk	0 Wk	6 Wk
Fresh	40.00 f		-7.85 f		14.31	
Unblanched						
$125^{o}F/14hr$	41.70 d	40.01d	-6.82d	-5.14d	14.28df	13.77d
$145^{o}F/10hr$	39.88df	41.49d	-5.79d	-5.28d	13.15d	14.36d
Blanched[b]						
$125^{o}F/14hr$	46.44e	45.24e	-9.26e	-7.14e	17.94e	15.83e
$145^{o}F/10hr$	47.07e	45.71e	-8.79e	-7.41e	17.03e	16.62e
Blanched in SO_2[c]						
$125^{o}F/14hr$	46.98e	46.47e	-9.26e	-7.33e	18.10e	17.16e
$145^{o}F/10hr$	47.28e	46.49e	-8.81e	-6.47e	18.08e	17.07e

[a]Means with the same letter in the same column are not significantly different (p 0.05)

[b]Blanched in boiling water for 3 minutes

[c]Blanched in boiling 0.1% SO_2 solution for 3 minutes

Sensory Characteristics

Means for aroma and flavor of cooked okra are listed in Table 5. The unblanched okra samples showed the lowest values ($p<0.05$) for the "cooked green vegetable" aroma characteristics as well as for the "cooked green vegetable" flavor, and they exhibited the highest values ($p<0.05$) for the hay-like aroma and flavor. Enzymes, yet unidentified, have been reported to be responsible for the development of off-flavors and off-aromas such as hay-like in dehydrated food products (Schwimmer, 1980). Blanching has been recommended to prevent the development of these off-flavors and off-aromas. Therefore, inhibition of potential enzymes present in okra by heat and/or sulfur dioxide treatment might have occurred in okra samples that have been blanched in boiling water and 0.1% sulfur dioxide.

Pretreatments and drying conditions had no significant effects ($p<0.05$) on bitterness, sourness or mouth drying of cooked okra. However, blanched okra samples were sweeter ($p<0.05$) than unblanched okra samples.

CONCLUSIONS

Blanching of okra pods in 0.1% sulfur dioxide solution under the conditions of this study resulted in

1. relatively higher ascorbic acid retention;
2. protection of the characteristic flavor of okra identified as "cooked green vegetable";
3. protection against excessive development of hay-like aroma and flavor;
4. lighter, greener, and more yellow okra samples;
5. a substantial loss of thiamine.

Blanching in boiling water yielded similar results except that lower ascorbic acid retention occurred, but better thiamine retention was achieved.

Table 5. Effects of pretreatments and drying conditions on a means for aroma and flavor for cooked okra after 6 weeks storage.

	Unblanched		Blanched[b]		Blanched in SO_2[c]	
	125°F/14hr	145°F/10hr	125°F/14hr	145°F/10hr	125°F/14hr	145°F/10hr
Aroma						
Cooked green vegetable	2.14 d	2.21 d	5.02 e	4.30 e	5.08 e	4.90 e
Hay-like	5.68 d	5.30 d	0.92 e	1.54 e	1.06 e	1.26 e
Flavor						
Cooked green vegetable	2.68 d	2.72 d	5.19 e	4.44 e	5.35 e	5.16 e
Hay-like	4.52 d	5.10 d	0.91 e	1.21 e	1.07 e	1.30 e
Bitter	1.81 d	2.06 d	1.31 d	2.02 d	1.71 d	1.75 d
Sweet	1.17 d	1.26 d	3.05 e	2.10 f	2.70 f	2.21 ef
Sour	1.88 d	1.98 d	1.76 d	2.00 d	1.83 d	2.03 d
Mouth-drying	1.90 d	2.11 d	1.88 d	2.12 d	1.95 d	1.94 d

[a]Means with the same letter in the same row are not significantly different ($P < 0.05$).

[b]Blanched in boiling water for 3 minutes.

[c]Blanched in boiling 0.1% SO_2 solution for 3 minutes.

RECOMMENDATIONS

1. Blanching is an effective pretreatment for dehydrated okra for retention of physical attributes, nutritional quality, and sensory characteristics.
2. Sulfur dioxide should be used in blanching water for vegetables where thiamine content is initially low or not a nutritional concern.

REFERENCES

AOAC. 1980. "Official methods of analysis," 13th ed. Association of Official Analytical Chemists, Washington, D.C.

Bluestein, P. M., and Labuza, T. P. 1975. Effects of moisture removal on nutrients. In "Nutritional evaluation of food processing," 2nd ed., eds. R. S. Harris and E. Karmas. Avi Publishing Co., Westport, CT.

Clydesdale, F. M., and Francis, F. J. 1975. Pigments. In "Principles of food science, Part 1, food chemistry." ed. O. R. Fennema. Marcel Dekker, Inc., NY.

Crossley, A., and Hilditch, T. P. 1951. The fatty acids and glycerides of okra seeds and oil. J. Sci. Fd. Agric. 2(6):251.

Cruess, W. F. 1958. Commercial fruit and vegetable products, 4th ed. McGraw-Hill Book Company, Inc., NY.

Dietrich, W. C., and Heumann, H. J. 1965. Blanching Brussel sprouts. Food Technol. 19:1174.

Dutton, H. J., Bailey, G. F., and Kohake, E. 1943. Dehydrated spinach. Changes in color and pigments during processing and storage. Ind. Eng. Chem. 35:1173.

Eheart, M. S. 1967. Effect of microwave vs water-blanching on nutrients in broccoli. J. Amer. Dietet. Assoc. 50:207.

Foda, Y. H., El-waraki, A., and Zaid, M. A. 1967. Effect of dehydration, freeze-drying and packaging on the quality of green beans. Food Technol. 21(7):83

Freed, M. 1966. "Methods of vitamins assay," 3rd ed. Interscience Publishers, NY.

Guerrant, N. B., Vavich, M. G., Fardig, O. B., and Ellenberger, H. A. 1947. Effect of duration and temperature of blanch or vitamin retention by certain vegetables. Ind. Eng. Chem. 39:1000.

Holmes, Z. A., Miller, L., Edwards, M., and Benson, E. 1979. Vitamin retention during home drying of vegetables and fruits. Home Economics Research Journal 7(4):258.

Jones, Q., and Earle, F. R. 1966. Chemical analysis of seeds. II. Oil and protein content of 759 species. Econ. Bot. 20:127.

Karakoltsidis, P. A., and Constantinides, S. M. 1975. Okra seed: a new protein source. J. Agric. Food Chem. 23:1204.

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

Kramer, A., and Smith, M. H. 1947. Effect of duration and temperature of blanch on proximate and mineral composition of certain vegetables. Ind. Eng. Chem. 39:1007.

Krutman, A. 1981. Development of alternative dehydration methods for okra. Ph.D. dissertation, University of Georgia, Athens, GA.

Lee, F. A. 1958. The blanching process. Adv. in Fd. Res., Vol. 9, pp. 63-109. eds. E. M. Mrak and G. F. Stencard. Academic Press, Inc., Publishers, NY.

Lee, F. A., and Whitcombe, J. 1945. Blanching of vegetables for freezing. Effect of different types of potable water on nutrients of peas and snap beans. Food Research 10:465.

Lee, S. H., and Labuza, T. P. 1975. Destruction of ascorbic acid as a function of water activity. J. Fd. Sci. 40:370.

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

Martin, F. W., and Ruberte, R. 1978. Vegetables for the hot humid tropics. Part 2. Okra _Abelmochus esculentus._ USDA Mayaguez Institute of Tropical Agriculture, University of Puerto Rico.

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

Moyer, J. C., Pallesen, H. R., and Schallenberger, R. S. 1959. The interaction between blanching and drying rates of peas. Food Technol. 13: 581.

Onayemi, O., and Potter, N. M. 1974. Preparation and storage properties of drum dried white yam (_Dioscorea rotundata_ Poir) Flakes. J. Fd. Sci. 39:559.

Pavcek, P. L. 1946. Nutritive value of dehydrated vegetables and fruits. Ind. Eng. Chem. 38:853

Pintauro, N. D. 1974. Food additives to extend shelf life. Food Technol. Reviews No. 17. Noyes Data Corporation. Park Ridge, NJ.

Quenzer, H. R., and Burns, E. E. 1981. Effects of microwaves, steam and water blanching on freeze-dried spinach. J. Fd. Sci. 46:410.

Retzer, J. L., Van Duyne, F. O., Chase, J. T., and Simpson, J. I. 1945. Effect of steam and hot-water blanching on ascorbic acid content of snap beans and cauliflower. Food Res. 10:518.

Salunkhe, D. K., Do, J. Y., and Bolin, H. R. 1973. Developments in technology and nutritive value of dehydrated fruits, vegetables and their products. CRC Critical Reviews in Food Technology 4:153.

Savello, P. A., Martin, F. W. and Hill, J. M. 1980. Nutritional composition of okra seed meal. J. Agric. Food Chem. 28:1163.

Schroeter, L. C. 1966. "Sulfur dioxide: applications in foods, beverages, and pharmaceuticals," p. 195. Pergamon Press, N.Y.

Schwimmer, S. 1980. Influence of water activity on enzyme reactivity and stability. Food Technol. 34(5):64.

Stevens, H. P. 1943. Preliminary study of conditions affecting the nutritive values of dehydrated vegetables. J. Amer. Dietet. Assoc. 19:832.

Sugihara, J., and Cruess, W. V. 1942. Effect of blanching on the dehydration rates of vegetables. Fruit Products J. 21:139.

Tannenbaum, S. R. 1976. Vitamins and minerals. In "Principles of Food Science. Part 1, Food Chemistry," ed. O. R. Fennema. Marcel Dekker, Inc., NY.

Tressler, D. K. 1956. New developments in the dehydration of fruits and vegetables. Food Technol. 10(3):119.

Troller, J. A. 1980. Influence of water activity on microorganisms in foods. Food Technol. 34(5):76.

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

Wagner, J. R., Strong, F. M., and Elvehjem, C. A. 1947. Effects of blanching on the retention of ascorbic acid, thiamine and niacin in vegetables. Ind. Eng. Chem. 39:990.

Woodroof, J. G. and Shelor, E. 1958. Okra for processing. Georgia Agric. Expt. Sta., University of Georgia, College of Agriculture, Bull. N.S. 56.

ACKNOWLEDGEMENTS

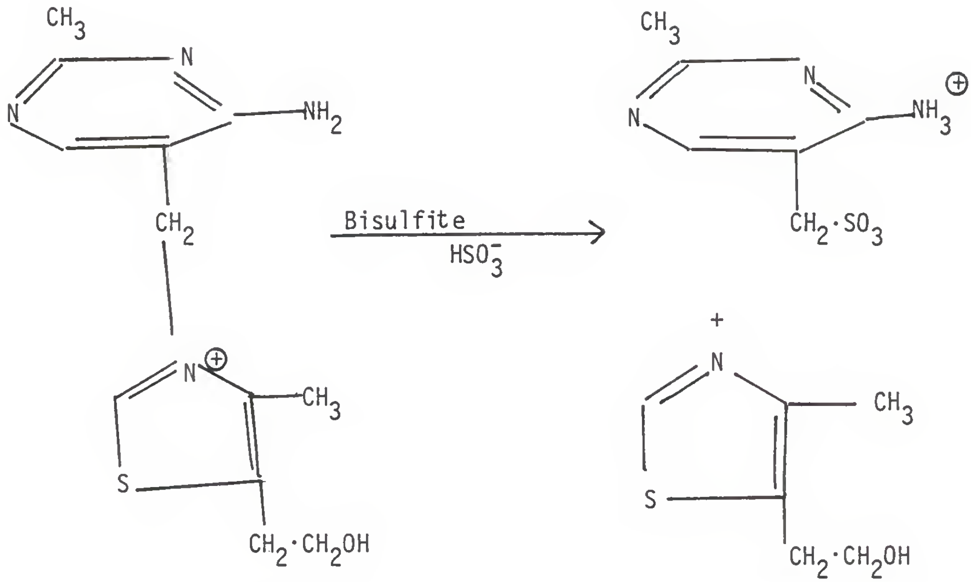
I wish to express my appreciation to my major professors, Dr. Martha B. Stone and Dr. James K. Greig for their guidance, patience and understanding throughout my stay at Kansas State University. I also wish to express my appreciation to Dr. Daniel Y. C. Fung for serving on my advisory committee.

I am grateful to the African American Institute and the Kansas State University Graduate School for their financial support for my graduate studies.

Special thanks are extended to my family, especially to my mother, Mahoua Coulibaly and my late father, Tidiani Toure, for believing, trusting and supporting me all these years.

APPENDIX

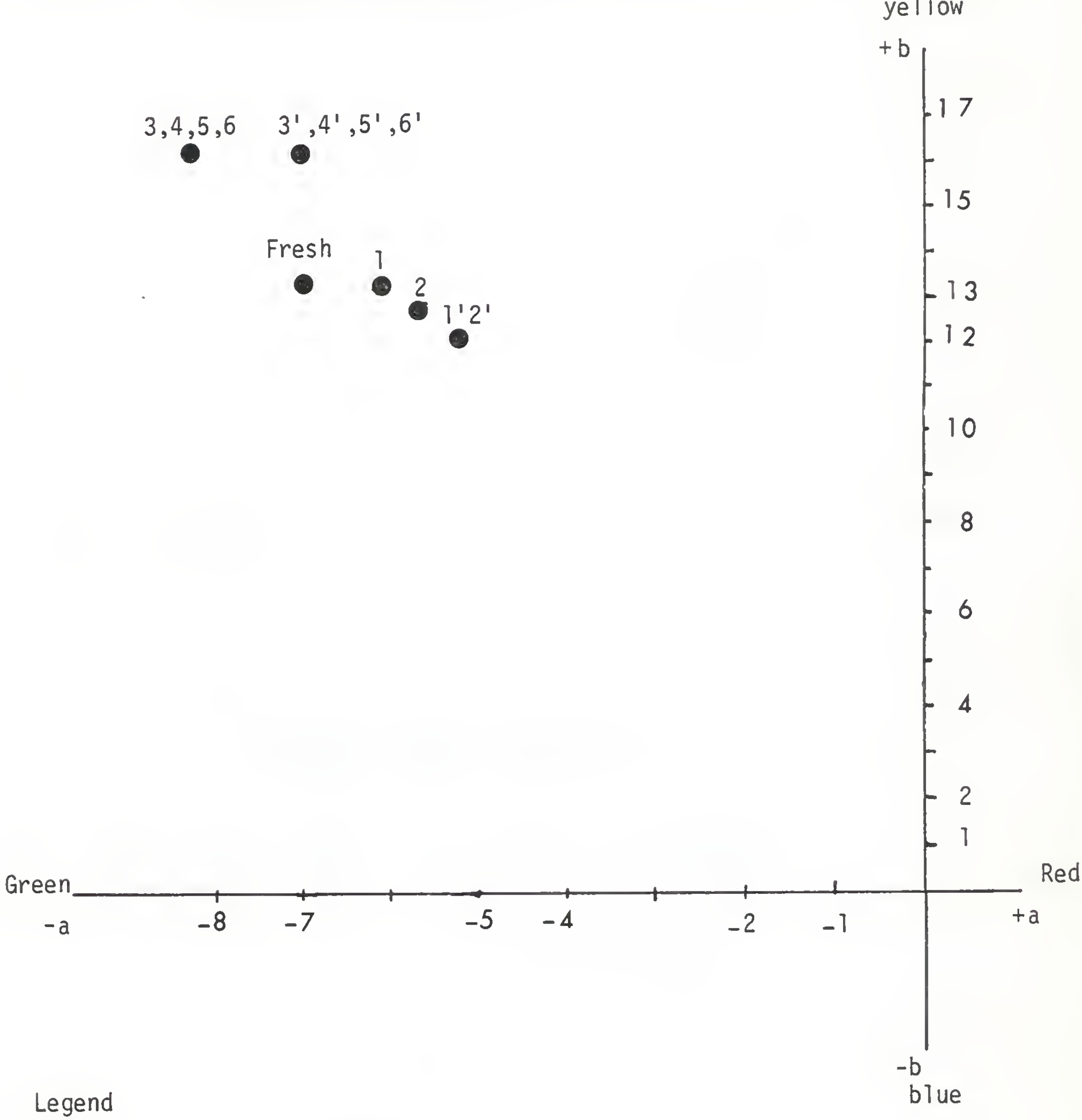
Figure 1. Effect of sulfite on thiamine.



Thiamine (vitamin B_1)   Inactive fragments

Source: Schroeter, Louis C. 1966. "Sulfur dioxide: Applications in foods, beverages, and pharmaceuticals," p. 195. Pergamon Press, N.Y.

Figure 2. Representation of fresh and dried okra samples in the Hunter-Lab a,b diagram.



Legend

	0wk	6wk
Unblanched		
$125^{o}F/14$ hr	1	1'
$145^{o}F/10$ hr	2	2'
Blanched in water		
$125^{o}F/14$ hr	3	3'
$145^{o}F/10$ hr	4	4'
Blanched in SO_2		
$125^{o}F/14$ hr	5	5'
$145^{o}F/10$ hr	6	6'

Figure 3. Score card for evaluation of rehydrated okra

NAME________________________ DATE________________________

Place a perpendicular line across the point which best describes your evaluation for the characteristics listed. Label each mark with the sample code number.

AROMA

Cooked green vegetable

|__________________|__________________|

No Moderately Extremely

Hay-like

|__________________|__________________|

No Moderately Extremely

FLAVOR

Cooked green vegetable

|__________________|__________________|

No Moderately Extremely

Hay-like

|__________________|__________________|

No Moderately Extremely

Bitter

|__________________|__________________|

No Moderately Extremely

Sweet

|__________________|__________________|

No Moderately Extremely

Sour

|__________________|__________________|

No Moderately Extremely

Mouth drying

|__________________|__________________|

No Moderately Extremely

Table 6. Moisture, ascorbic acid and thiamine content and HunterLab L, a-and b-values of fresh okra

% Moisure	90.27
Ascorbic Acid	
mg/100 g	27.08
mg/100 g of dry matter	280.11
Thiamine	
mg/100 g	0.114
mg/100 g of dry matter	1.170
Color	
L	40.00
a	-7.85
b	14.31

Table 7. Moisture content and water activity of dried okra before and after storage

	Block 1		Block 2		Block 3		Block 4		Mean	Mean
	% Moisture	Aw	% Moisture	A.w	% Moisture	Aw	% Moisture	Aw	% Moisture	Aw
Fresh	90.27		89.85		90.94		90.01		90.27	
Unblanched										
125°F/14 hr										
0 wk	19.20	0.394	19.60	0.232	20.70	0.286	20.20	0.325	19.93	0.309
6 wk	18.60	0.352	21.50	0.349	20.50	0.423	20.50	0.589	20.28	0.428
145°/10 hr										
0 wk	21.05	0.278	17.80	0.359	15.30	0.340	18.50	0.293	18.16	0.318
6 wk	20.60	0.347	19.60	0.460	18.20	0.508	18.00	0.475	19.10	0.448
Blanched										
125°F/14 hr										
0 wk	18.85	0.535	19.65	0.436	17.10	0.444	18.20	0.496	18.45	0.478
6 wk	18.00	0.455	19.80	0.506	18.40	0.508	18.60	0.499	18.70	0.492
145°/10 hr										
0 wk	18.50	0.505	19.00	0.543	17.00	0.523	18.65	0.435	18.29	0.502
6 wk	18.50	0.458	18.70	0.493	17.80	0.505	18.00	0.489	18.25	0.486
Blanched in SO_2										
125°F/14 hr										
0 wk	18.50	0.503	18.80	0.481	18.00	0.557	18.40	0.505	18.43	0.512
6 wk	18.50	0.467	18.60	0.490	18.20	0.503	19.00	0.471	18.58	0.508
145°F/10 hr										
0 wk	20.40	0.550	18.50	0.406	17.70	0.436	18.10	0.428	18.68	0.455
6 wk	20.30	0.474	17.40	0.500	18.00	0.518	18.50	0.485	18.55	0.494

Table 8. Total ascorbic acid content of fresh and dried okra before and after storage

	Block 1			Block 2			Block 3			Block 4		
	mg/100g wet wt	mg/100g dry wt	% Retention	mg/100g wet wt	mg/100g dry wt	% Retention	mg/100g wet wt	mg/100g dry wt	% Retention	mg/100g wet wt	mg/100g dry wt	% Retention
Fresh	32.36	347.68		23.90	235.35		24.17	264.44		27.27	272.97	
Unblanched												
$125^0F/14hr$												
0 wk	73.26	90.67	26.74	91.46	113.82	48.36	79.17	99.84	35.75	70.45	88.28	31.34
6 wk	66.33	81.49	23.44	27.27	34.74	14.76	44.44	55.90	21.14	40.91	51.46	18.85
$145^0F/10hr$												
0 wk	83.72	106.04	31.27	83.12	101.12	42.97	81.63	96.45	36.45	69.77	85.60	31.36
6 wk	66.33	83.59	24.04	45.46	56.54	24.02	40.74	49.80	18.83	31.82	38.80	14.22
Blanched												
$125^0F/14hr$												
0 wk	48.72	60.04	17.71	50.00	62.19	26.42	67.71	81.68	30.89	54.44	66.69	24.43
6 wk	38.78	47.29	13.60	38.64	48.18	20.47	46.30	56.74	21.46	40.91	50.25	18.41
$145^0F/10$ hr												
0 wk	52.33	64.20	18.93	55.85	68.94	29.29	81.63	98.34	37.19	55.81	68.60	25.13
6 wk	44.68	54.82	15.77	38.64	47.53	20.20	55.56	67.52	25.53	36.36	44.34	16.24
Blanched in SO_2												
$125^0F/14hr$												
0 wk	94.87	116.40	34.32	80.00	98.52	41.86	72.92	88.92	33.63	84.09	103.05	37.75
6 wk	91.49	112.26	32.29	68.18	83.76	35.59	51.85	63.39	23.97	75.00	92.59	33.92
$145^0F/14hr$												
0 wk	92.78	116.56	34.37	93.33	114.52	48.66	71.43	86.78	32.72	83.72	102.22	37.45
6 wk	87.24	109.46	31.48	74.24	89.88	38.19	59.26	72.27	27.33	75.00	92.02	33.71

Table 9. Thiamine content of fresh and dried okra before and after storage

	Block 1			Block 2			Block 3			Block 4		
	mg/100g wet wt	mg/100g dry wt	% Retention	mg/100g wet wt	mg/100g dry wt	% Retention	mg/100g wet wt	mg/100g dry wt	% Retention	mg/100g wet wt	mg/100g dry wt	% Retention
Fresh	0.107	1.130		0.120	1.180		0.104	1.140		0.123	1.240	
Unblanched												
$125^{o}F$/14hr												
0 wk	0.918	1.140	100.88	1.000	1.240	105.08	1.049	1.290	113.15	0.964	1.220	98.39
6 wk	0.829	1.018	90.09	0.800	1.019	86.36	0.850	1.069	93.77	0.960	1.210	97.58
$145^{o}F$/10hr												
0 wk	0.934	1.180	104.42	0.986	1.200	101.69	0.965	1.140	100.00	1.010	1.240	100.00
6 wk	0.732	0.922	81.59	0.900	1.119	94.86	0.800	0.978	85.79	1.000	1.220	98.39
Blanched												
$125^{o}F$/14hr												
0 wk	0.906	1.120	98.82	0.788	0.980	83.05	0.927	1.120	98.25	1.160	1.420	115.00
6 wk	0.927	1.130	100.00	0.650	0.810	68.64	1.000	1.230	107.50	1.100	1.350	108.87
$145^{o}F$/10hr												
0 wk	1.095	1.340	118.58	1.072	1.320	111.86	0.943	1.140	100.00	1.010	1.240	100.00
6 wk	0.683	0.838	74.16	1.000	1.230	104.24	1.000	1.217	106.71	1.010	1.230	99.19
Blanched in SO_2												
$125^{o}F$/14hr												
0 wk	0.688	0.844	76.72	0.788	0.970	82.20	0.634	0.773	63.80	0.938	1.150	92.74
6 wk	0.683	0.838	74.16	0.700	0.860	72.88	0.550	0.672	58.95	0.688	0.849	68.47
$145^{o}F$/10hr												
0 wk	0.869	0.898	81.63	0.831	1.020	86.42	0.736	0.894	78.25	0.741	0.929	74.92
6 wk	0.683	0.857	75.84	0.800	0.969	82.08	0.600	0.732	64.21	0.600	0.736	59.35

Table 10. HunterLab L, a-and b-values of fresh and dried okra before and after storage

	Block 1			Block 2			Block 3			Block 4		
	L	a	b	L	a	b	L	a	b	L	a	b
Fresh	39.79	-8.17	14.12	42.24	-7.63	15.68	38.77	-7.91	14.21	39.20	-7.65	13.23
Unblanched												
$125^{o}F/14hr$												
0 wk	42.49	-7.16	14.62	43.98	-8.29	16.24	40.56	-6.65	13.92	39.78	-5.19	12.33
6 wk	39.25	-5.45	13.95	40.77	-5.11	13.72	43.86	-6.06	15.41	36.14	-3.94	12.00
$145^{o}F/10hr$												
0 wk	41.04	-6.59	13.58	40.22	-6.17	13.54	39.39	-5.44	13.37	38.87	-4.97	12.11
6 wk	40.77	-4.85	13.66	41.73	-4.78	14.44	41.71	-5.85	15.05	41.73	-5.64	14.28
Blanched												
$125^{o}F/14hr$												
0 wk	47.16	-8.21	17.56	45.41	-9.74	17.87	46.16	-9.88	18.51	47.01	-9.22	17.82
6 wk	43.69	-5.47	14.93	46.62	-8.52	18.01	46.51	-8.12	17.05	44.13	-6.46	13.33
$145^{o}F/10hr$												
0 wk	47.77	-7.91	16.96	45.89	-8.17	16.66	47.37	-9.99	17.81	47.20	-9.10	16.70
6 wk	43.39	-5.83	14.88	46.19	-8.03	17.03	47.63	-9.28	18.66	45.64	-6.51	15.91
Blanched in SO_2												
$125^{o}F/14hr$												
0 wk	49.53	-8.58	17.65	45.38	-9.95	18.56	47.17	-9.38	18.85	45.85	-9.11	17.35
6 wk	46.82	-6.50	16.96	48.98	-8.79	18.39	45.78	-7.52	17.41	44.28	-6.52	15.88
$145^{o}F/10hr$												
0 wk	46.64	-8.36	16.62	47.38	-9.19	19.51	48.75	-8.73	18.97	46.35	-8.93	17.23
6 wk	44.02	-5.05	14.18	46.52	-8.14	18.29	48.79	-7.53	19.73	46.61	-5.17	16.08

Table 11. Means for aroma and flavor of rehydrated and heated okra after 6 weeks' storage (Block 1)

	Unblanched		Blanched		Blanched in SO_2	
	$125^{o}F/14hr$	$145^{o}F/10hr$	$125^{o}F/14hr$	$145^{o}F/10hr$	$125^{o}F/14hr$	$145^{o}F/10hr$
Aroma						
cooked green vegetables	2.4	3.52	4.72	3.50	4.94	4.60
hay-like	5.66	4.72	1.22	2.32	1.32	1.82
Flavor						
cooked green vegetables	2.9	.56	5.18	4.02	5.38	5.16
hay-like	3.94	5.5	1.22	2.00	0.84	1.80
bitter	0.66	2.36	1.66	2.48	1.54	2.28
sweet	1.38	1.02	3.70	1.72	4.00	2.20
sour	1.18	1.88	2.04	2.44	1.76	2.58
mouth drying	1.98	2.76	2.18	2.34	1.96	2.56

Table 12. Means for aroma and flavor of rehydrated and heated okra after 6 weeks' storage (Block 2)

	Unblanched		Blanched		Blanched in SO_2	
	$125^{O}F/14hr$	$145^{O}F/10hr$	$125^{O}F/14hr$	$145^{O}F/10hr$	$125^{O}F/14hr$	$145^{O}F/10hr$
Aroma						
cooked green vegetables	1.13	2.78	5.73	4.65	5.23	5.50
hay-like	6.43	5.18	0.80	1.15	0.98	1.05
Flavor						
cooked green vegetables	1.73	5.50	6.13	5.90	5.93	5.33
hay-like	5.33	4.20	0.78	0.70	0.75	1.43
bitter	2.08	2.18	0.95	2.88	1.70	2.03
sweet	0.75	1.35	3.60	2.18	2.30	1.63
sour	2.23	1.53	0.95	1.65	1.53	1.15
mouth drying	2.50	2.03	1.90	2.60	2.48	2.90

Table 13. Means for aroma and flavor of rehydrated and heated okra after 6 weeks storage (Block 3)

	Unblanched		Blanched		Blanched in SO_2	
	$125^{o}F/14hr$	$145^{o}F/10hr$	$125^{o}F/14hr$	$145^{o}F/10hr$	$125^{o}F/14hr$	$145^{o}F/10hr$
Aroma						
cooked green vegetables	2.40	2.14	5.10	4.98	5.98	5.02
hay-like	6.38	4.60	0.72	1.62	0.88	1.60
Flavor						
cooked green vegetables	3.56	2.98	4.36	3.92	6.02	5.00
hay-like	5.82	4.86	0.78	1.14	1.16	1.16
bitter	2.86	1.44	1.06	1.10	1.86	1.42
sweet	1.40	1.42	2.80	1.78	2.68	2.18
sour	2.84	2.36	2.42	2.36	2.44	2.70
mouth drying	2.04	1.96	1.74	1.88	1.38	1.26

Table 14. Means for aroma and flavor of rehydrated and heated okra after 6 weeks storage (Block 4).

	Unblanched		Blanched		Blanched in SO_2	
	125°F/14hr	145°F/10hr	125°F/14 hr	145°F/10hr	125°F/14hr	145°F/10hr
Aroma						
cooked green vegetables	2.64	0.40	4.52	4.06	4.20	4.48
hat-like	4.26	6.70	0.94	1.06	1.06	0.58
Flavor						
cooked green vegetables	2.52	0.82	5.10	3.90	4.08	5.16
hay-like	3.00	5.82	0.84	1.00	1.54	0.82
bitter	1.62	2.24	1.58	1.62	1.73	1.26
sweet	1.16	1.26	2.08	2.72	1.80	2.82
sour	1.26	2.16	1.62	1.56	1.60	1.68
mouth drying	1.08	1.70	1.68	1.64	1.98	1.04

EFFECTS OF PRETREATMENTS AND DRYING CONDITIONS ON COLOR, NUTRIENT RETENTION AND SENSORY CHARACTERISTICS FOR DEHYDRATED OKRA (*Abelmoschus esculentus* (L) MOENCH)

by

DIENEBOU TOURE

B.S., Ecole National Superieure d'Agronomie (ENSA) Abidjan, Ivory Coast , 1982

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the
requirements for the degree

MASTER OF SCIENCE

in

Food Science

Department of Horticulture
Department of Foods and Nutrition

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1985

Moisture content, water activity, color, ascorbic acid and thiamine retention of okra not blanched, blanched in boiling water and blanched in a boiling 0.1% sulfur dioxide solution and dried at $125^{O}F$ ($52^{O}C$) for 14 hours and at $145^{O}F$ ($63^{O}C$) for 10 hours were evaluated before and after 6 weeks' storage at room temperature. Before storage unblanched okra, whether dried at $125^{O}F$ for 14 hours or dried at $145^{O}F$ for 10 hours, retained as much ascorbic acid as okra samples blanched in 0.1% sulfur dioxide solution. Okra samples blanched in boiling water had the lowest level of ascorbic acid immediately after dehydration. During storage excessive loss of ascorbic acid occurred in unblanched samples. No significant difference ($p<0.05$) was found between the ascorbic level of unblanched samples and that of okra blanched in boiling water. Samples blanched in 0.1% sulfur dioxide solution retained the highest ascorbic acid level ($p<0.05$); but the same samples exhibited significantly lower thiamine values than the fresh okra samples. All pretreatment variables and drying conditions produced samples lighter than fresh okra except for unblanched okra dried at $145^{O}F$ for 10 hours which showed no significant difference ($p<0.05$) between its "L" value and the "L" value of the fresh sample. Okra samples blanched in boiling water or in 0.1% sulfur dioxide solution were a yellower green than either fresh or unblanched okra samples before storage. After storage they still remained yellower but decreased in greenness until they reached HunterLab "a" values similar to that of fresh okra sample. Unblanched samples, except those dried at $125^{O}F$ for 14 hours, were less green and less yellow than fresh sample before storage. After storage they decreased in greenness but increased in yellowness until HunterLab "b" values were similar to those produced in fresh okra. Blanching in boiling water or in 0.1% sulfur dioxide solution produced okra with more "cooked green vegetable" and less hay-like aroma and flavor than okra dried without blanching ($p<0.05$).