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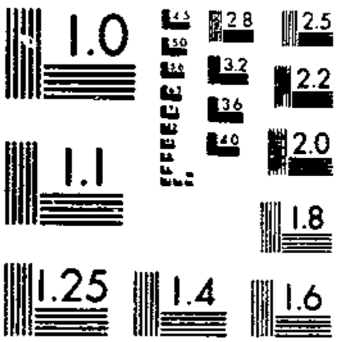

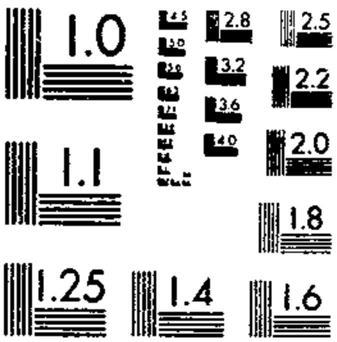

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Flavor, Texture, Color, and Ascorbic Acid Content of Home-Dehydrated Vegetables and Fruits

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UNITED STATES
DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

Flavor, Texture, Color, and Ascorbic Acid Content of Home-Dehydrated Vegetables and Fruits

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GENERAL SUMMARY

Factors affecting quality, ascorbic acid content, and cost of processing certain home-dehydrated vegetables and fruits were investigated with a view to improving home-dehydration methods. Special emphasis was placed on the methods of pretreatment, dehydration temperatures, and storage. Reconstitution and preparation of the dehydrated food for the table were also investigated. Quality and in some cases ascorbic acid content of the products were the criteria used in evaluating the success of the procedures.

Comparison of precooking methods revealed that carrots and spinach, which were selected as typical root and leafy vegetables, can be precooked in a small amount of water or in steam with equally good results from the standpoint of palatability and ascorbic acid retention during dehydration. Precooking in a small amount of water was most economical of time and fuel. Precooking in a large amount of water was extremely detrimental to ascorbic acid value and palatability, and was expensive in time and fuel consumption.

Comparison of different lengths of steaming time was made to determine what degree of doneness in the precooking of broccoli, carrots, and spinach resulted in the most desirable product when the dehydrated food was prepared for the table.

Precooking in steam half the time required to cook tender was sufficient to inactivate the enzymes in broccoli and carrots, and to soften the food sufficiently to insure complete reconstitution without overcooking after dehydration.

In keeping quality, the vegetables that were half cooked before dehydration compared favorably with those fully cooked. Leafy green

[1] Acknowledgment is made to the following colleagues who contributed to these investigations: Colleen C. Hambleton on the preliminary dehydration studies; Lenore Sater Thye on dehydration equipment; Dawn H. Tuttle on the preparation and quality studies; Kay E. Stein and Joan A. Lorr on the chemistry, enzyme, and nutritive value studies; Florence McDonough Rice and staff on recipe development.

vegetables must be precooked slightly more than half time to wilt the leaves, but less than full time to avoid matting on the drier trays.

Ascorbic acid determination made on broccoli indicated that the shorter precooking time resulted in slightly better retention of this vitamin. The broccoli precooked half time before dehydration contained 453 mg. per 100 gm. when dried, and that precooked the longer time contained 415 mg. per 100 gm.

Pretreatment of light-colored fruits and vegetables such as apples and cauliflower with 1 percent solution of sodium sulfite or bisulfite improved the quality of the dehydrated product by preventing development of strong flavors and darkening of the color. The retention of ascorbic acid in dehydrated cauliflower was almost doubled by a bisulfite dip.

Pretreatment of green vegetables with 0.5 percent solution of sodium bisulfite or a 0.1 percent solution of sodium bicarbonate helped to preserve the bright-green color, crisp texture, and natural flavor during dehydration and storage.

The selection of optimum drying temperatures depended upon several factors: Kind of food, moisture content before and after dehydration, quality of the product, cost in fuel, and time required for drying. For broccoli, dehydration in a preheated drier set at 135° F. gave the best results. For carrots, a preheated drier set first at 170° and lowered after 3 hours to 150° proved best. For spinach, 190° for the first 3 hours and 150° thereafter was the most economical of fuel and time, and did not adversely affect the quality.

Storage studies revealed that dehydrated broccoli with a moisture content of 8 percent can be stored for 9 months at 75° without appreciable loss in color, flavor, and texture. Approximately a quarter of the ascorbic acid content of the fresh broccoli was retained after dehydration and 9 months' storage at 75°. Since raw broccoli has a high ascorbic acid content, dehydrated broccoli is still a fairly good source of vitamin C. The quality and ascorbic acid value of dehydrated broccoli stored at 110° deteriorated very rapidly. After 3 months the product was inedible.

Studies of the ascorbic acid content of dehydrated vegetables after reconstitution were carried out with cauliflower and spinach. Cooked dehydrated cauliflower was found to be a fair source of ascorbic acid, whereas cooked dehydrated spinach was a poor source of this vitamin.

Directions for cooking and serving dehydrated vegetables were developed.

PURPOSE AND SCOPE OF WORK

An investigation of home dehydration was undertaken by the Bureau of Human Nutrition and Home Economics in the fall of 1941 as a food conservation measure. At that time many families found it impossible to obtain pressure cookers for processing low-acid foods. In order to prevent waste of garden produce, it was necessary to provide homemakers with directions for the home dehydration of these products. The entrance of this country into the war intensified the need for supplementing canning and freezing activities.

Existing directions for home drying were investigated, and modified procedures for typical vegetables and fruits were developed in an effort to improve the palatability, keeping quality, and nutritive value of home-dehydrated products. Agricultural experiment stations in California, New York, and Texas cooperated in these studies. As a result of this work, the Bureau published a bulletin on drying foods at home, and also directions for building and using different types of dehydrators (*36, 37, 40*).[2]

A report on home-drying methods and their effects on the palatability, cooking quality, and nutritive value of foods, given by Batchelder (*3*) at the annual meeting of the American Public Health Association in October 1942, summarized the research findings of the Bureau up to that time.

In 1943 the Bureau published directions for oven drying (*39*) based on results of research in the Bureau's laboratories and by the cooperating institutions. The publication included the steps in the drying process from selection and preparation of food for the drier, through packaging, storage, and utilization. A later publication (*41*) went into more detail on the preparation of these foods for the table. Reports of the cooperative work in New York and California have appeared in technical journals (*14, 15, 25, 26, 32, 34*).

These 1941–43 studies brought out many of the problems of home dehydration and provided a basis of practical experience for further work. Results are summarized by food products in the Appendix, page 54. The findings and a review of the literature revealed the need for improvement in the palatability and nutritive value of dehydrated vegetables and fruits. In many instances the quality of home-dehydrated food was only fair and losses of ascorbic acid were extensive. During dehydration and subsequent storage, some dehydrated vegetables and fruits lost their characteristic fresh flavor and natural color and often developed a haylike odor and woody texture.

To find ways to improve the flavor, texture, color, and nutritive value of dried food, the research on home-dehydration methods reported here was undertaken. The objective of this study was to obtain information which would make possible better home-dehydrated products. The findings have been applied to provide answers to practical problems of extension workers, teachers, and homemakers who have turned to the Bureau for help. The details of the research are being put into permanent form in this publication to make them available to research workers concerned with dehydration problems and to others interested in the background for the procedures recommended for practical use.

Factors investigated in this study included methods of pretreatment, dehydration temperatures, storage, reconstitution, and uses. The vegetables and fruits studied under each of these headings were selected on the basis of their sensitivity to the variable being investigated and their availability.

[2] Italic numbers in parentheses refer to Literature Cited, p. 51.

Because vegetables and fruits are important sources of ascorbic acid, conservation of this nutrient is highly desirable. Therefore, in this study ascorbic acid content was determined at several stages of home dehydration. This determination had an additional value as a possible indicator of the extent of leaching and destruction by heat and oxidation of other labile constituents which contribute to the nutritive value and flavor of the food. Relationships between ascorbic acid values, palatability, and color as affected by chemical pretreatment and storage were studied.

Since the scope of the nutritional value studies was necessarily limited, it was not possible to check experimentally other nutrients less susceptible to heat and oxidation which would probably suffer less change.

Careful attention was paid to inactivating enzymes and to obtaining low moisture content, since it has been found in research related to commercial practice that these factors are especially important in retention of quality in dehydrated food during storage (*35*).

Storage studies were included in many cases for purposes of evaluating experimental methods as, for example, in the study of precooking time and chemical pretreatment. Reconstitution and preparation of the dehydrated food for the table was also investigated. Consideration was given to the cost and convenience of the processing methods.

GENERAL PROCEDURES

The vegetables and fruits were purchased in bushel quantities from the wholesale and retail markets in Washington, D. C. They were stored at 40° F. until used 1, 2, or 3 days later. In some cases variety was identified by the Bureau of Plant Industry, Soils, and Agricultural Engineering. Known varieties included Nantes carrots, Savoy spinach, Calabresse broccoli, and Stayman Winesap apples.

The following standard procedures were used except where the experiment called for a variation of these procedures.

PREPARATION, PRECOOKING, AND COOKING OF FOOD.—Directions for washing, trimming, cutting, and precooking the various foods prior to dehydration are given in table 1. The vegetables were either cooked until tender or three-fourths of this time as determined in preliminary experiments. The standard for doneness was established as that point where the vegetable is tender but still firm. Cooking time varied with the quality and maturity of the vegetables used.

A gas range with a pressure regulator on the flow of gas and a meter to measure the quantity of gas consumed was used throughout the study. In precooking, 1 quart of water was brought to a boil in a steamer over the full heat of the burner. The vegetables were then placed in the top part of the steamer.

All food was drained for 1 minute after precooking, cooled, and weighed. Records were kept of the weight changes in the food from the raw to the dehydrated state.

TABLE 1.—*Standard procedures for preparation of foods*

Food	Preparation of raw food	Weight of prepared raw food (grams)	Precooking in steamer
Apples	Wash once in tap water, once in distilled water, pare, core, slice ¼ inch thick.	-------	
Beans, green snap.	Wash twice in tap water, once in distilled water, remove stem and tip ends, cut julienne style.	454	Three-fourths of time to cook tender.
Broccoli	Strip leaves, wash twice in tap water, soak in 1 percent salt solution 5 minutes, wash twice in distilled water, peel stalks, cut into 3-inch lengths, and slice ⅛ inch thick.	454	Do.
Carrots	Wash twice in tap water, once in distilled water, peel, trim, dip in distilled water, shred in mechanical shredder, sort, mix.	680	Until tender.
Cauliflower	Remove leaves, wash twice in tap water, soak in 1 percent salt solution 5 minutes if insects are present, wash twice in distilled water, remove core, separate buds, and slice ⅛ inch thick.	454	Three-fourths of time to cook tender.
Spinach	Clip stems from leaves, discard torn, wilted, and immature leaves, wash gently five times in tap water, twice in distilled water.	454	Until tender.

Cooling the food after precooking was necessary in order to know the weight relationships throughout the various stages of processing. For ascorbic acid determination it was desirable to cool the food rapidly so that the losses under experimental conditions would be as small as possible. In a preliminary study, cooling precooked food by spreading it on large enameled trays was compared with cooling in a covered glass saucepan in an ice bath.

The ascorbic acid content of carrots cooled on large enameled trays was 13.22 mg. per 100 gm. dry weight and only 7.40 mg. for those cooled in closed containers in an ice bath. Twenty-three minutes were required for cooling on trays and 53 minutes in saucepans in an ice bath. The shorter cooling time was probably the main reason for the greater ascorbic acid content. Another advantage of cooling on trays is that evaporation can take place to initiate the drying process.

SAMPLING.—Samples for ascorbic acid, enzyme, moisture, color, and palatability determinations were taken at each stage in the process—raw, precooked, dehydrated, and stored.

For the raw sample, except in the case of broccoli, the prepared product was well mixed and portions taken at random for the various determinations. In order to maintain the natural proportion of bud to stem in broccoli, these parts were weighed separately and a sample composited from them. Subdivision for chemical analysis took care of such variation as differences in color and size of leaves.

Studies were made to find a satisfactory method of sampling carrots and to learn the effect of shredding and holding on ascorbic acid content. Carrots were quartered; one quarter was tested without further cutting, and the other three quarters shredded. One-third of the shredded sample was used for immediate determination of ascorbic acid content, one-third for determination after 1 hour of holding at room temperature, and the remaining one-third used for determination after 2 hours of holding at room temperature. Variations in ascorbic acid content of several different samplings were also studied to determine the size of sample necessary. Results indicated that practically all the loss of ascorbic acid on shredding took place almost immediately so that differences between the first and last carrots shredded were negligible.

In sampling precooked food, identical amounts were taken at random from each of several steamers or kettles used in the cooking process. A separate lot of broccoli was cooked for the chemical determinations.

With the exception of broccoli, the dry food from all drier trays was well mixed before sampling. In the case of broccoli, the contents of each tray were kept separate. When the yield from several days' drying was needed to make a large enough sample, the dried food was held at 0° F. in airtight containers until the entire sample could be mixed. To assure good mixing for moisture, enzyme, and ascorbic acid determinations, the dried samples were crushed thoroughly immediately before determinations were begun.

DEHYDRATION.—The dehydrator used in this experimental work was an electric type manufactured commercially for use in home dehydration. It was selected because of its even heating system. Drying was done on four trays made with wooden frames and wire bottoms, totaling 9 square feet in area. To keep the food from coming in contact with the metal of the trays, a single thickness of cheesecloth was spread over each tray.

Heat for drying was furnished by a set of five solid heating panels slightly smaller in area than the trays. The trays fitted like drawers between the heating panels. A fan in the lower part of the drier below the trays circulated air through the drier by blowing it against the side wall which slanted in such a manner as to direct the air across the trays.

In all experiments except the one in which temperature of drying was investigated, the thermostat was set to maintain a temperature of 150° F. with a temperature differential as allowed by the action of the thermostat. The temperature was measured by thermocouples attached to a recording potentiometer. One thermocouple was placed over the edge of the tray nearest to and on a level with the thermostat. Other thermocouples were located over the middle left and right sides of the top tray, and over the middle right side of each of the other trays.

Energy consumption of the drier was determined by keeping a record of the current used. Kilowatt-hours were measured by an integrating kilowatt-hour meter, read at the beginning and end of each experiment. The input of wattage to the drier was controlled at a constant rate by a manually operated voltage control.

Drier trays were loaded as evenly as possible with cooled, precooked food. Spinach leaves were spread out carefully to allow maximum area for evaporation, and each entire tray load turned over after half the drying period. Two cooking lots of broccoli were loaded on each tray to maintain the proportion of stem to bud, whereas with other foods a predetermined load was used: Spinach, 0.5 to 0.75 pound per square foot; carrots, 0.83 pound per square foot; apples, 1.5 pounds per square foot; cauliflower, 1 pound per square foot; snap beans, 0.5 to 1 pound per square foot. At the end of each hour of drying the trays were weighed and positions rotated, that is, the bottom tray was moved to the top and each of the others was placed in the position just below the one it formerly occupied.

Completion of drying was determined by weight loss. The food was weighed every hour during the first part of the drying time and every half hour during the last part. When the food had lost no more than 2 gm. during a half-hour period, drying was considered complete. In most cases drying required approximately 6 hours; apples required 7½ to 8 hours.

Drying ratios were calculated as the weight of the cooled, precooked vegetable which made up the drier load divided by the weight of the dried food.

STORAGE.—All samples for storage studies were placed in glass jars with glass lids held in place by metal screw bands and sealed with rubber rings and paraffin. These were stored at 0°, 70°, and/or 110° F. for 3, 6, and/or 9 months, depending on the purposes of the experiment.

RECONSTITUTION.—The amount of water used and the length of soaking and/or cooking time for reconstitution of dried foods varied according to precooking time and drying ratio for each food (table 2). On the basis of experience in the preliminary dehydration studies, an allowance of two to three parts by weight was made for evaporation during cooking. Whenever the character of the food permitted, soaking was eliminated in order to simplify the process as much as possible. Food was cooked in covered 2-quart enameled pans in quantity to yield four ½-cup servings. Spinach was stirred at 2-minute intervals. After soaking and/or cooking, the reconstituted food was drained 1 minute, then weighed to determine the rehydration capacity. The rehydration ratio was calculated by dividing the drained weight of the reconstituted sample by the weight of the dry sample. This ratio indicated the degree of effectiveness of rehydration, as calculated by Davis and Howard (*13*).

TABLE 2.—*Standard methods of reconstituting vegetables and fruits in quantities to provide four ½-cup servings*

Food	Weight of dry food	Volume of dry food	Volume of distilled water	Temperature of soaking water at start	Soaking time	Cooking time
	Grams	*Cups*	*Milliliters*	° *C.*	*Minutes*	*Minutes*
Apples	75	2	474			20
Beans, green snap	40	2	520			30
Broccoli:						
Precooked one-half time	40	2	440	29	30	15
Precooked three-fourths time	40	2	440	29	30	12
Carrots (shredded):						
Precooked until tender	40	⅓	400			15–18
Precooked one-half time	40	⅓	520			30
Cauliflower	40	1	560	100	30	8
Spinach	45	2	450			6

PALATABILITY DETERMINATIONS.—Table quality of each food before and after dehydration and storage was evaluated by a panel of three experienced food judges who had been selected for their sensitivity of taste and smell. Each one had an average or lower than average threshold for the four primary tastes and was able to discriminate between samples containing varying concentrations of the primary tastes. The selected panel members had also demonstrated an ability to smell 14 odorous substances important in food flavoring or commonly used in testing olfactory sensitivity. The procedures used for conducting the taste and smell tests have been described by the Bureau of Human Nutrition and Home Economics (*38*).

The quality characteristics measured by the panel included plumpness, color, aroma, flavor, and texture. The scale of values ranged from 1 for the poorest quality to 5 for the highest quality.

A study of the interrelationship of each quality characteristic and the score of the product as rated by the panel revealed that flavor and texture were the most important factors in determining acceptability. The correlation coefficient for flavor and acceptability of several different foods was 0.81 and for texture and acceptability, 0.76. Since aroma directly influences flavor, the two may be considered together. Plumpness and color, which determine the appearance of the product, seemed to be as important in actual enjoyment of food as texture or flavor alone.

Hence, in arriving at a system for weighting the individual quality characteristics to obtain a single score which would describe the product as a whole, each quality was weighted as follows: Texture, 6; flavor, 6; aroma, 2; plumpness, 3; color, 3. Each quality factor is thus reflected in the weighted score in much the same way as in the general acceptability score by each judge.

In this manner the weighting is done consistently and is not dependent upon the individual's opinion of the relative importance of each of the quality characteristics. Actually, however, the correlation between the judge's acceptability score and the weighted over-all score was very high, with a coefficient of 0.92. It was felt, therefore, that the relative weighting of each quality was fair and representative of the quality observed by the individual judges.

The highest total score possible was 100; hence samples could be compared on a percentage basis. The scores were interpreted as follows: 90 to 100, very good; 70 to 89, good; 50 to 69, fair; 30 to 49, poor; 0 to 29, very poor.

Before unknown samples were presented for scoring, the panel was trained to recognize the various quality characteristics in standard samples. Samples representing a range of flavors and textures were introduced in the training period. The unknown samples were served one at a time for scoring according to mental standards established in the training period. In this way the rating of the samples was placed on an objective basis, independent of the individual's like or dislike for the product.

COLOR ANALYSIS.—The Munsell color system was used in making color notations of hue, value, and chroma at each step of the processing. *Hue* is the quality by which color is classified as red, yellow, green, blue, or purple. The hue notation is expressed by letters, as Y for yellow, or by numbers in terms of 10 or 100 steps in the color circuit. *Value* refers to lightness and darkness as compared with white, grays, or black. The Munsell scale of grays extends from 0, black, to 10, white. *Chroma* refers to saturation or degree of difference from a gray of the same value. The notation is numerical with 0 at gray, extending outward from the neutrals toward 10 or more for the strong colors.

The color measurements were made by matching the food with Munsell color charts, using the Kelly mask method described by Nickerson (*27*). Several readings were made on whole pieces of the food and the results averaged for the various parts, as for example stem and bud of broccoli. The illumination for color grading consisted of 1,200-watt incandescent lamps with a glass filter specially designed to correct the yellow light of incandescent tungsten to as near a daylight distribution as possible. In some instances the color of the cooking liquid was determined by comparison with specially prepared color standards.

CHEMICAL DETERMINATIONS.—Ascorbic acid was determined by the method of Bessey and King, titration with 2:6-dichlorophenolindophenol (*5*), as modified by Harris and Olliver (*16*). Analysis of dehydroascorbic acid was made by the Bessey method (*4*) and determination of reductones by the method of Mapson (*24*). Ascorbic acid in the presence of sulfur dioxide was determined by the method of Levy (*18*).

The method of Prater, Johnson, Pool, and MacKinney (*29*), with slight changes at the suggestion of MacKinney,[3] was used for determining sulfur dioxide. Moisture determinations were made by the oven method and, in some cases, by the more rapid xylene distillation method (*2*). Catalase and peroxidase were determined by the meth-

[3] Personal communication.

ods described by the Bureau of Agricultural and Industrial Chemistry (*35*).

METHOD OF PRECOOKING

For precooking foods for dehydration in the home, directions in the literature range from steaming to immersion in very large quantities of boiling water. Reports on the nutritive losses are meager. According to Cruess and Mrak (*10*), retention is greater when precooking is done in steam or in small amounts of water. Allen, Barker, and Mapson (*1*) suggest immersion in large quantities of water, claiming that repeated blanchings in the same water build up the solid content of the water to a point of equilibrium with the soluble solid content of the vegetable, and thus reduce the losses of soluble constituents.

Four precooking methods were selected for comparison in terms of enzyme inactivation, cost and convenience, yield, quality, and ascorbic acid value in the precooked and dehydrated products. The four methods studied were: Precooking in an aluminum steamer of standard household type; precooking in a steamer improvised by placing a home-made cloth bag containing the food on a wooden rack over a small amount of water in a covered enameled preserving kettle (*39*); precooking in a small amount of water in a covered enameled saucepan; and precooking by immersion in a large amount of boiling water in which three lots were previously cooked, using a large uncovered enameled kettle.

Spinach and carrots were selected as typical leafy and root vegetables. Preliminary experiments were made to determine the time required to cook each vegetable tender by each method.

Shredded carrots, weighed into 680-gm. lots, were cooked 17 minutes in the standard steamer, 18 minutes in the improvised steamer, 18 minutes in a small amount of water (118 ml.), and 15 minutes in a large amount of water (5,688 ml.).

Whole washed spinach leaves were weighed into lots of 454 gm. and cooked 5 minutes in both the standard and improvised steamers, and 4 minutes in a small amount of boiling water. In each process the spinach was turned once during cooking. Precooking spinach in a large amount of water was omitted because of the large losses previously observed in carrots.

CARROTS

ENZYME ACTIVITY.—Catalase and peroxidase enzymes were negative in all precooked and dehydrated samples, regardless of the method of precooking.

COST AND CONVENIENCE.—In comparing the relative cost of precooking carrots by the four methods, total time was considered. With the heat on full, 1 minute was required to bring the small amount of water to a boil, 6 minutes to bring 1 quart of water to a rolling boil for precooking by steam, and 50 minutes to bring the large amount of water to a boil for the first cooking and 12 minutes for each serial cooking.

Cooking time for carrots was counted from the time the samples were placed in the steamer or from the time the water returned to a boil.

The water boiled again in 2 minutes after carrots were added to the small amount of water, and in 8 minutes after they were added to the large amount of water (table 3). It is obvious that time and fuel consumed would be greatest for the latter method.

TABLE 3.—*Time and fuel consumed in precooking vegetables by various methods*

Vegetable	Method of precooking	Time to heat water	Time to bring back to boil	Cooking time	Total time required	Gas consumed
		Minutes	*Minutes*	*Minutes*	*Minutes*	*Cubic feet*
Carrots	Standard steamer	6	------	17	23	------
	Improvised steamer	6	------	18	24	------
	Small amount of water [1]	1	2	18	21	------
	Large amount of water: [2]					
	First cooking	50	8	15	73	------
	Each serial cooking	12	8	15	35	------
Spinach	Standard steamer	6	------	5	11	3.08
	Improvised steamer	6	------	5	11	3.03
	Small amount of water [1]	1	2	4	7	1.43

[1] 118 ml. water. [2] 5,688 ml. water.

YIELD.—After 6 hours' drying the carrots that had been precooked in steam and in a small amount of water had approximately the same drying ratios (7.77 to 7.95), whereas carrots precooked in a large amount of water had a drying ratio almost twice as high (15.46), as shown in table 4. In the latter case 15.46 pounds of raw prepared food were required to produce 1 pound of dehydrated material. The

TABLE 4.—*Drying data for carrots and spinach precooked in different ways*

Vegetable	Method of precooking	Moisture content of dry product	Drying ratio (wet load/dry load)	Yield of dry product
		Percent		*Percent of wet load*
Carrots	Standard steamer	5.97	7.95	12.58
	Improvised steamer	6.40	7.84	12.81
	Small amount of water [1]	5.88	7.77	12.92
	Large amount of water [2]	3.80	15.46	6.47
Spinach	Standard steamer	4.28	12.34	8.28
	Improvised steamer	4.57	10.60	9.51
	Small amount of water [1]	4.33	10.10	9.41

[1] 118 ml. water. [2] 5,688 ml. water.

TABLE 5.—*Effect of method of precooking on table quality of dehydrated vegetables*

Vegetable and stage of processing	Method of precooking	Moisture (percent)	Rehydration ratio	Quality rating [1]					Acceptability rating [2]
				Plumpness	Color	Aroma	Texture	Flavor	
Carrots: Before dehydration	Aluminum steamer	88. 1	--------	5. 0	4. 9	4. 8	4. 9	4. 7	97
	Improvised steamer	87. 6	--------	5. 0	5. 0	4. 0	4. 9	4. 1	92
	Small amount of water [3]	87. 5	--------	4. 9	5. 0	4. 9	4. 8	4. 8	97
	Large amount of water [4]	93. 7	--------	4. 8	4. 4	3. 3	4. 3	2. 7	76
After dehydration	Aluminum steamer	6. 6	5. 69	4. 0	4. 7	3. 9	4. 2	3. 8	82
	Improvised steamer	6. 4	5. 70	3. 9	4. 6	4. 1	4. 2	4. 1	83
	Small amount of water [3]	6. 1	5. 58	3. 8	4. 7	3. 9	3. 8	4. 1	80
	Large amount of water [4]	3. 8	10. 60	3. 8	3. 7	2. 8	4. 2	2. 0	66
Spinach: Before dehydration	Aluminum steamer	91. 3	--------	4. 9	5. 0	4. 8	4. 6	4. 6	94
	Improvised steamer	91. 0	--------	5. 0	5. 0	4. 6	4. 4	4. 5	92
	Small amount of water [3]	91. 3	--------	4. 9	4. 9	4. 7	4. 6	4. 7	95
After dehydration	Aluminum steamer	3. 4	6. 39	3. 8	3. 7	3. 4	3. 8	3. 4	72
	Improvised steamer	4. 2	6. 39	3. 8	3. 7	3. 4	3. 8	3. 5	73
	Small amount of water [3]	3. 8	6. 15	3. 8	3. 8	3. 3	3. 8	3. 4	73

[1] Average of 6 ratings on triplicate runs of carrots, 3 ratings on triplicate runs of spinach; 5 is maximum, 1 is minimum score.
[2] Rating scale: 90 to 100, very good; 70 to 89, good; 50 to 69, fair; 30 to 49, poor; 0 to 29, very poor.
[3] 118 ml. water.
[4] 5,688 ml. water.

yield of dry product was only 6.47 percent as compared to yields of 12.58, 12.81, and 12.92 percent for the standard steamer, improvised steamer, and small amount of water, respectively. Apparently considerable soluble carrot constituents were lost in the precooking water.

QUALITY.—Precooking until tender in steam or in a small amount of water in a covered saucepan gave products of practically the same table quality. As evaluated by the tasting panel, texture was the only characteristic that varied with the different methods of precooking (table 5).

When shredded carrots were precooked in a small amount of water, the texture was slightly uneven, probably because of the different rates of cooking in steam at the top of the pan and in water at the bottom. After these products were dehydrated and reconstituted, the same relative effects of precooking method on palatability were observed. In general acceptability, all the carrots rated good except those precooked in a large quantity of water. That method resulted in an inferior product. The flavor rating was low, owing to the loss of soluble sugars and minerals by solution in the large amounts of water. The color was affected only slightly.

No storage studies were made in this experiment. However, since all enzymes had been inactivated by all methods of precooking and the moisture contents of the dry material were similar, it may be justifiable to assume that the keeping quality would not differ for the various methods of precooking.

TABLE 6.—*Effect of method of precooking on ascorbic acid content of dehydrated vegetables*

Vegetable	Number of samples	Method of precooking	Ascorbic acid: Content per 100 gm. dry weight: Raw	Pre-cooked	De-hy-drat-ed	Retention: Raw to pre-cooked	Pre-cooked to dehy-drated	Raw to dehy-drat-ed
			Milli-grams	*Milli-grams*	*Milli-grams*	*Per-cent*	*Per-cent*	*Per-cent*
Carrots	3	Standard steamer	24	14	2	58	14	9
	3	Improvised steamer	24	15	2	63	13	9
	3	Small amount of water.[1]	24	8	0	33	0	0
	1	Large amount of water.[2]	24	0	0	0	------	0
Spinach	3	Standard steamer	405	298	47	74	16	12
	3	Improvised steamer	405	290	42	72	14	10
	3	Small amount of water.[1]	405	284	55	70	19	14

[1] 118 ml. water. [2] 5,688 ml. water.

Ascorbic Acid Content.—Shredded carrots precooked by steaming retained a higher percentage of ascorbic acid than those precooked in small amounts of water (table 6). Cooking in a large amount of water resulted in complete loss of the vitamin. Determinations on the dehydrated products were of no value for comparative purposes, since the retention of both ascorbic and dehydroascorbic acid was practically nil in all the dehydrated samples, probably owing to the low ascorbic acid content of carrots.

SPINACH

Enzyme Activity.—Catalase and peroxidase enzymes were negative in all precooked and dehydrated samples.

Cost and Convenience.—The total time, including heating-up time, required to precook spinach was 7 minutes in a small amount of water and 11 minutes in either the standard steamer or the improvised steamer (table 3, p. 11).

Fuel as well as time was saved by precooking in a small amount of water. Fuel consumption averaged 3.08 cubic feet of gas for each lot cooked in the standard steamer, 3.03 cubic feet for each lot cooked in the improvised steamer, and 1.43 cubic feet for cooking in a small amount of water.

Yield.—Because of the high water content of fresh spinach, the yield of the dry product was less than for carrots (table 4). The differences due to the precooking method employed were slight; the yields ranged from 8.28 percent for spinach precooked in a standard steamer to 9.51 percent for that precooked in an improvised steamer. For spinach precooked in a small amount of water the yield was 9.41 percent.

Quality.—Spinach, precooked by the different methods, rated fairly good in general acceptability (table 5). On the whole, the dehydrated product approached fresh spinach in texture and did not lose its character and identity as a leafy vegetable. It lost some of its freshness of flavor and became darker in color. The objective measurement by the Munsell system indicated that dehydrated spinach precooked in a small amount of water was slightly darker and duller than the steamed samples.

Ascorbic Acid Content.—Ascorbic acid retention during the precooking of spinach in steam and in a small amount of water was fairly high (table 6). The spinach precooked in the standard steamer and improvised steamer retained 74 and 72 percent, respectively, and that precooked in the small amount of water retained 70 percent. In the dehydrated spinach, ascorbic acid retention was low for all precooking methods, ranging from 10 to 14 percent of the raw value, and showed no superiority of one method over the others.

SUMMARY OF EFFECT OF PRECOOKING METHODS

The effect of precooking carrots and spinach until tender in a small amount of water was compared with the effect of steaming them until tender in a standard and an improvised steamer. Carrots precooked in a small amount of water were somewhat uneven in texture; otherwise, the three methods appeared to result in products of about the same palatability rating after dehydration. The carrots in all cases rated good in over-all acceptability and spinach fairly good.

Precooking carrots in a large amount of water was extremely detrimental to ascorbic acid and palatability and was expensive of time and fuel. Precooking in a small amount of water was most economical of time and fuel. From the standpoint of ascorbic acid retention during dehydration, no superiority of one method over another was indicated.

PRECOOKING TIME

Partial or complete inactivation of catalase and peroxidase is considered essential to assure the keeping quality of dehydrated vegetables during storage. Precooking food the proper length of time is known to inactivate these enzymes. In order to give the homemaker practical directions for precooking foods, most of the Bureau's early work had been set up on the basis of cooking until tender. It was recognized, however, that overcooking is then likely to result when the dehydrated food is prepared for the table. On the other hand, if certain foods are precooked insufficiently, they cannot be properly reconstituted after dehydration. It is desirable to know the minimum amount of time required to produce favorable results. If a time less than that required to cook tender could be established for each food, time and fuel would be saved in preparation, and the danger of overcooking during reconstitution would be minimized. The ease of handling the precooked food needs also to be considered.

In a study of length of precooking time required, broccoli, carrots, and spinach were used to represent different types of vegetables including stalks, flowers, roots, and leafy vegetables. The vegetables were prepared as described in table 1, page 5.

Broccoli was precooked one-half and three-fourths of the time required to cook it tender, or 5 and 7½ minutes, respectively. Shredded carrots were precooked one-half the time necessary to cook tender (8½ minutes) to compare with those cooked until tender (17 minutes). Spinach was precooked 3, 4, 5, and 6 minutes. It was sufficiently done to serve at the table in 6 minutes. A standard steamer was used for all precooking because of the ease with which the equipment could be handled for loading, cooking, and weighing, and the reproducibility of results in triplicate drying.

Representative samples of dehydrated carrots and broccoli were stored at 75° F. for 3, 6, and 9 months as a final criterion of the effect of the precooking time. Samples were stored at 0° as controls. No dehydrated spinach was available for storage.

The vegetables were reconstituted as described in table 2, page 8. The reconstitution time was inversely proportional to the precooking time. Cooking times for reconstitution of spinach were 5, 6, 7, and 8 minutes for samples precooked 6, 5, 4, and 3 minutes, respectively.

Table quality was the chief criterion for the comparison of precooking times. Ascorbic acid determinations were also made on broccoli.

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BROCCOLI

ENZYME ACTIVITY.—The enzymes catalase and peroxidase were inactivated in most samples of broccoli after precooking and no activity was observed in the studies carried out after dehydration and subsequent storage.

QUALITY.—There was no appreciable difference in the quality of the freshly dehydrated broccoli precooked different lengths of time (table 7). The broccoli reconstituted quite well, rating good in the characteristic of plumpness and having rehydration ratios of 6.01 and 5.66 when precooked one-half and three-fourths of the time required to cook the vegetable completely tender. The texture was also rated good by the panel of judges.

TABLE 7.—*Effect of precooking time on table quality of dehydrated broccoli before and after storage at 75° F.*[1]

Precooking time		Storage time	Moisture	Rehydration ratio	Quality rating[2]					Acceptability rating[3]
Percent of total	Minutes				Plumpness	Color	Aroma	Texture	Flavor	
		Mo.	*Pct.*							
Fresh					5.0	4.8	5.0	5.0	4.8	98
50	5.0	0	11.0	6.01	4.3	4.3	3.7	4.2	3.8	81
75	7.5	0	11.4	5.66	4.0	3.8	3.5	4.0	3.5	75
50	5.0	3		5.81	3.8	3.3	3.5	3.3	3.3	68
75	7.5	3		5.85	3.8	3.2	3.5	3.3	3.2	67
50	5.0	6		5.79	3.7	2.8	2.5	3.7	2.8	64
75	7.5	6		5.85	3.7	3.2	2.7	3.8	2.7	65
50	5.0	9		5.71	3.3	2.5	2.2	3.3	2.5	57
75	7.5	9		5.65	3.3	2.7	2.2	3.2	2.5	56

[1] Controls stored at 0° F. remained essentially unchanged.
[2] Average of 3 ratings: 5 is maximum, 1 is minimum score.
[3] Rating scale: 90 to 100, very good; 70 to 89, good; 50 to 69, fair; 30 to 49, poor; 0 to 29, very poor.

In color, the dehydrated broccoli precooked half time was slightly better than that precooked the longer time. According to the Munsell color system, the shorter precooking time resulted in the retention of more green color in the stalk in the dry condition. This difference was less noticeable after reconstitution since the broccoli precooked half time must be cooked a few minutes longer during reconstitution to reach the same stage of doneness as that precooked three-fourths time.

The flavor of dehydrated broccoli precooked one-half or three-fourths time was fairly good. It was characteristic of broccoli, but was somewhat lacking in freshness and resembled that of a slightly overcooked product. However, for optimum texture and plumpness, the reconstitution time could not be shortened. In the opinion of several visitors who were not as critical as the panel, the dehydrated cooked broccoli could not be distinguished from the fresh broccoli to which they were accustomed. However, it was the opinion of the panel that the dehydrated product, compared with properly cooked fresh broccoli, could be improved. Studies on chemical pretreatment reported on page 28 consider this quality problem further.

The keeping quality of broccoli precooked half time before dehydration was the same as that precooked three-fourths time. Because the 11-percent moisture content was slightly higher than desirable, the dehydrated broccoli deteriorated slowly in storage at 75° F. There was no change in quality of samples stored at 0°. Color, aroma, and flavor were the characteristics most affected by storage. Color became less and less green, with red hues predominating after 9 months at 75°. The broccoli acquired undesirably strong characteristics of aroma and flavor, described as stale, burnt, and caramel. Since there was no difference in the keeping quality of broccoli precooked different lengths of time, the moisture content rather than enzyme action was considered responsible for the changes in quality.

Ascorbic Acid Content.—Comparison of ascorbic acid retention in broccoli precooked half and three-fourths time, shows the shorter time to be slightly better at the precooked and dehydrated stages. Notwithstanding a loss of approximately one-half the original ascorbic acid content during dehydration, the freshly dehydrated broccoli was still a good source of this vitamin, since the ascorbic acid value of the raw broccoli was high (table 8). Broccoli precooked half time before dehydration contained 453 mg. ascorbic acid per 100 gm. when dried, and that precooked the longer time contained 415 mg. per 100 gm.

Table 8.—*Effect of precooking time on ascorbic acid content of dehydrated broccoli*

Precooking time		Ascorbic acid					
		Content per 100 gm. dry weight			Retention		
Percent of total	Minutes	Raw	Pre-cooked	Dehy-drated	Raw to pre-cooked	Pre-cooked to dehy-drated	Raw to dehy-drated
		Mg.	*Mg.*	*Mg.*	*Pct.*	*Pct.*	*Pct.*
50	5.0	849	760	453	90	60	53
75	7.5	849	740	415	87	56	49

In the preparation of the dehydrated vegetable for the table, 15 minutes cooking was necessary for the broccoli that had been precooked half time as compared with 12 minutes for that precooked three-fourths time. Therefore, it is likely that the final vitamin C values at the time the food was consumed were the same.

CARROTS

ENZYME ACTIVITY.—All enzymes were inactivated in carrots precooked half or full time, and no activity was observed after dehydration and storage.

QUALITY.—Precooking carrots 50 percent of the total time required to cook tender gave a better quality dehydrated product than precooking full time (table 9).

TABLE 9.—*Effect of precooking time on table quality of dehydrated carrots before and after storage at 75° F.*[1]

Precooking time		Storage time	Moisture	Rehydration ratio	Quality rating[2]					Acceptability rating[3]
Percent of total	Minutes				Plumpness	Color	Aroma	Texture	Flavor	
		Mo.	*Pct.*							
Fresh	-----	----	88. 0	-----	5. 0	4. 6	4. 6	4. 9	4. 5	95
50	8. 5	0	5. 4	6. 68	4. 7	4. 9	4. 0	4. 4	4. 1	88
100	17. 0	0	6. 0	5. 69	4. 0	4. 9	3. 9	4. 2	3. 8	82
50	8. 5	3	-----	6. 60	4. 6	4. 3	3. 6	4. 5	3. 8	83
100	17. 0	3	-----	5. 62	3. 5	4. 3	3. 3	3. 5	3. 7	73
50	8. 5	6	-----	6. 72	4. 5	3. 2	3. 5	4. 2	4. 0	80
100	17. 0	6	-----	5. 31	4. 0	4. 0	3. 5	4. 2	4. 0	80
50	8. 5	9	-----	6. 50	4. 6	3. 2	2. 7	4. 7	3. 2	76
100[4]	17. 0	9	-----	5. 42	4. 3	4. 3	2. 5	4. 0	3. 5	76

[1] Controls stored at 0° F. remained essentially unchanged.
[2] Average of 6 ratings; 5 is maximum, 1 is minimum score.
[3] Rating scale: 90 to 100, very good; 70 to 89, good; 50 to 69, fair; 30 to 49, poor; 0 to 29, very poor.
[4] Precooked in a small amount of water; all others precooked in steam.

A crisp, natural texture, with a high degree of plumpness, was characteristic of carrots precooked half time, whereas the fully cooked carrots had a soft, limp texture and a lower score for plumpness. The cellular structure of the carrots cooked the longer time was collapsed and therefore the carrots were incapable of taking up as much water as those precooked a shorter time. This is reflected in the rehydration ratios, which are higher for the half-time precook. Crafts (*7*) has shown that the loss of intercellular air during blanching and dehydration is responsible for the collapse of cellular structure.

Other quality characteristics were less affected by the length of precooking time.

The color of both freshly dehydrated samples rated very good and the flavor good. During storage for 9 months at 75° F. the carrots gradually changed in color from orange to yellowish orange. The amount of precooking determined the speed of this reaction; carrots precooked full time did not fade as rapidly as those precooked only 50 percent of the total time required to reach the tender point.

Aroma and flavor gradually deteriorated during storage at 75° without differentiation between samples precooked half and full time. After 9 months the aroma in both cases was stale and weak; the flavor was slightly stale but was still mild and sweet. The texture did not change. The over-all acceptability rating was 76, or fairly good for both precooking times at the end of the 9 months' storage period.

SPINACH

A short experiment without storage studies was performed to determine the proper precooking time for dehydrated spinach. Steaming 1 pound of spinach for 6 minutes produced a product that was difficult to load evenly on the dehydrator trays because the leaves were too tender. Steaming the spinach 3 or 4 minutes scarcely wilted the leaves, so that in some cases the spinach was being dehydrated raw. Five minutes steaming yielded spinach that was not too tender to handle in loading the trays, and that could be cooked sufficiently during reconstitution without overcooking. Spinach reconstituted for palatability immediately after dehydration rated the same regardless of the length of time of precooking (table 10). However, it has been reported in the literature that unblanched vegetables do not keep well in storage. Choice of steaming time would therefore depend on evenness of cooking and ease of handling in loading the trays.

TABLE 10.—*Effect of precooking time on table quality of dehydrated spinach*

Precooking time		Moisture	Rehydration ratio	Quality rating [1]					Acceptability rating [2]
Percent of total	Minutes			Plumpness	Color	Aroma	Texture	Flavor	
		Percent							
Fresh				4.9	5.0	4.8	4.6	4.6	94
50	3	3.6	6.19	4.2	4.0	3.2	4.2	3.5	77
66	4	3.0	6.32	4.0	4.2	3.3	4.2	3.7	78
83	5	4.2	6.40	4.3	4.3	3.7	3.8	3.3	76
100	6	3.0	6.33	4.2	4.3	3.7	4.0	3.5	78

[1] Average of 3 ratings; 5 is maximum, 1 is minimum score.
[2] Rating scale: 90 to 100, very good; 70 to 89, good; 50 to 69, fair; 30 to 49, poor; 0 to 29, very poor.

SUMMARY OF EFFECT OF PRECOOKING TIME

Comparisons of different lengths of steaming time were made to determine what degree of doneness in the precooking of broccoli, carrots, and spinach resulted in the most desirable product after the dehydrated food was prepared for the table. In retaining quality of dehydrated broccoli and carrots through 9 months of storage at 75° F., precooking in steam for half the time required to cook tender proved to be as effective as precooking fully or for three-fourths of that time. The texture of carrots precooked the shorter time was superior to that of carrots precooked for a longer time, but color retention was better with the longer precooking time. Even the shortest precooking period studied (one-half of full cooking time) was sufficient to inactivate both catalase and peroxidase enzyme systems in the precooked material as well as in the stored dehydrated broccoli and carrots.

Since both time and fuel were saved in the shorter preparation period and since equally good or better products were obtained, it is recommended that broccoli and carrots be precooked half the time required to cook tender. Spinach must be precooked slightly more than half time to wilt the leaves but less than full time to avoid matting on drier trays. Five minutes was found to be the optimum steaming time for broccoli, 8½ minutes for carrots, and 5 minutes for spinach used in this experiment.

Ascorbic acid determinations made on broccoli indicated that the shorter precooking time resulted in slightly better retention of this vitamin in the dehydrated product.

CHEMICAL PRETREATMENT

Early in World War II American, British, Canadian, and Australian investigators started sulfiting vegetables for dehydration and have published many reports indicating that sulfited vegetables were superior to unsulfited ones under adverse storage conditions.

In commercial practice in this country the use of certain chemical treatments has been found effective in preventing deteriorative changes during dehydration and in adding to the storage life of the products. Greater uniformity of color and better appearance result, with a greater factor of safety in drying (*9*). Higher finishing temperatures are possible during drying and consequently shorter drying times are needed.

Treatment with sodium sulfite, sodium bisulfite, or potassium metabisulfite in solution has been recommended by several investigators (*8, 11, 17, 19, 20, 42*). Caldwell and others (*6*) found that dipping raw snap beans in cold sodium bicarbonate solution aided retention of vitamin C and improved the general ratings because it resulted in superiority in color. However, use of sodium bicarbonate solution for blanching beans or dipping after blanching caused alteration of flavor and reduction of food value.

Possible application of these findings to home dehydration was the purpose of one phase of this investigation—the use of certain chemical compounds for treating fruits and vegetables before dehydration as a means of improving the color, palatability, and ascorbic acid value of the dried products. The keeping quality of sulfited and dehydrated food packaged and stored at 75° F. was also determined as a final criterion of the success of the pretreatment.

Studies were made of the action on apples and cauliflower of various chemicals, including sodium sulfite, sodium bisulfite, sodium thiosulfate, thiocarbamide, and citric acid. The tissues of these foods discolor rapidly, and dehydrated cauliflower and apples without pretreatment are yellowish brown in color. This browning is hastened by enzymes present in the food unless the enzymes can be inactivated before the damage is done.

The color of green vegetables is also adversely affected by the dehydration process, changing from bright green to olive green. For the study of methods of preserving the green color during dehydration and subsequent storage, broccoli and snap beans were chosen as representative of the green vegetables. Chemical pretreatment included different concentrations of sodium bicarbonate and sodium sulfite in solution.

CAULIFLOWER

Steamed cauliflower, prepared as described in table 1, page 5, was pretreated as follows: (1) Dipped for 15 seconds in 0.25 or 0.5 percent sodium sulfite solution; (2) dipped for 15 seconds in 0.5 or 1.0 percent sodium sulfite solution; (3) dipped for 5 minutes in 2.0 percent citric acid solution. Raw cauliflower was dipped for 2 minutes in a 2.0 percent citric acid solution. Plain steamed samples were dehydrated as controls for these studies. Representative samples were stored at 0°, 75°, and 110° F. for 3 and 6 months.

Catalase and peroxidase enzyme systems were inactivated in the precooked and dehydrated stages of all cauliflower samples. The cooking times used were apparently long enough to prevent destruction of the quality by any activity of these enzymes. Steaming alone, however, was not sufficient to preserve all desirable qualities of dehydrated cauliflower.

Pretreatment of steamed cauliflower with solutions of sodium sulfite was effective in improving the quality of the dehydrated product (table 11 and fig. 1). Dipping the steamed cauliflower in a 0.5 percent solution of sodium sulfite was more satisfactory than dipping in 0.25 percent solution. Although the flavor of the sample dipped in the weaker solution was preferred immediately after dehydration because of the lower concentration of sulfur dioxide, this superiority was not maintained throughout storage. After 3 months at 75° F. cauliflower pretreated with 0.5 percent sodium sulfite did not have a haylike or stale flavor as did the untreated samples and those dipped in the weaker solution.

Sodium bisulfite also proved effective in preserving the quality of dehydrated cauliflower. Cauliflower pretreated with 0.5 or 1.0 percent sodium bisulfite dropped only 7 percent in acceptability after storage for 6 months at 75°, still being rated fairly good. The sample dipped in 1.0 percent sodium bisulfite rated higher in plumpness, color, and aroma than that dipped in the weaker solution, but lower in texture and flavor. The sulfur flavor was noticeable, and the natural cauliflower flavor was weak in the samples dipped in the 1.0 percent solution. Only 811 p.p.m. of sulfur dioxide were present in the dry, stored sample pretreated with 0.5 percent sodium bisulfite, compared with 2,087 p.p.m. in the sample pretreated with 1.0 percent sodium bisulfite.

Pretreatment with citric acid was unsuccessful. It did not prevent darkening of the color and the samples were undesirably sour in flavor.

TABLE 11.—*Effect of various chemical pretreatments on table quality of dehydrated cauliflower before and after storage* [1]

Stage of processing	Pretreatment [2]		Moisture	Sulfur dioxide in dry sample	Rehydration ratio	Quality rating [3]					Acceptability rating [4]
	Kind	Time in chemical solution				Plumpness	Color	Aroma	Texture	Flavor	
			Pct.	*P. p. m.*							
Before dehydration	None		92.4			5.0	4.8	4.8	4.9	4.7	97
After dehydration	None		11.5		6.12	4.1	2.7	3.0	4.1	3.1	69
	0.25 pct. sodium sulfite	15 sec	6.0		6.11	3.8	3.5	3.2	4.2	3.7	75
	0.5 pct. sodium sulfite	15 sec	12.2		6.12	4.3	4.5	3.2	4.3	3.3	79
	0.5 pct. sodium bisulfite	15 sec	13.1	1,840	7.26	4.2	4.8	2.7	4.5	3.4	80
	1.0 pct. sodium bisulfite	15 sec	12.2	4,174	7.01	4.6	4.9	2.5	4.5	3.3	80
	2.0 pct. citric acid	15 sec	12.6		5.85	4.0	3.0	2.8	4.0	2.8	67
	2.0 pct. citric acid	5 min	14.3		5.54	3.8	2.5	2.2	3.5	1.8	55
	2.0 pct. citric acid	2 min [5]	10.4		5.55	4.2	3.5	3.5	4.2	3.2	75
Dehydrated, stored 3 months at 75° F.	None		11.3		5.92	3.7	2.3	2.5	4.0	2.8	64
	0.25 pct. sodium sulfite	15 sec	11.4	816	6.16	3.3	3.0	3.0	4.0	3.3	69
	0.5 pct. sodium sulfite	15 sec	9.3	1,425	6.26	3.7	3.7	2.7	4.0	3.3	71
Dehydrated, stored 6 months at 75° F.	None		13.5		6.00	2.5	1.5	3.0	3.3	1.8	49
	0.5 pct. sodium bisulfite	15 sec	14.3	841	6.74	3.6	3.1	3.1	4.2	3.6	73
	1.0 pct. sodium bisulfite	15 sec	14.3	2,087	6.54	3.9	3.7	3.3	4.0	3.3	73
Dehydrated, stored 3 months at 110° F.	None		11.8		2.94	2.8	1.0	1.3	2.2	1.0	33
	0.25 pct. sodium sulfite	15 sec	10.1	746	3.02	2.2	1.0	1.0	1.8	1.0	28
	0.5 pct. sodium sulfite	15 sec	11.9	1,166	3.06	2.8	1.0	1.3	1.3	1.0	31

[1] Controls stored at 0° F. remained unchanged.
[2] All cauliflower was steamed three-fourths of the time necessary to cook tender.
[3] Average of 3 ratings; 5 is maximum, 1 is minimum score.
[4] Rating scale: 90 to 100, very good; 70 to 89, good; 50 to 69, fair; 30 to 49, poor, 0 to 29, very poor.
[5] Chemically treated before steaming.

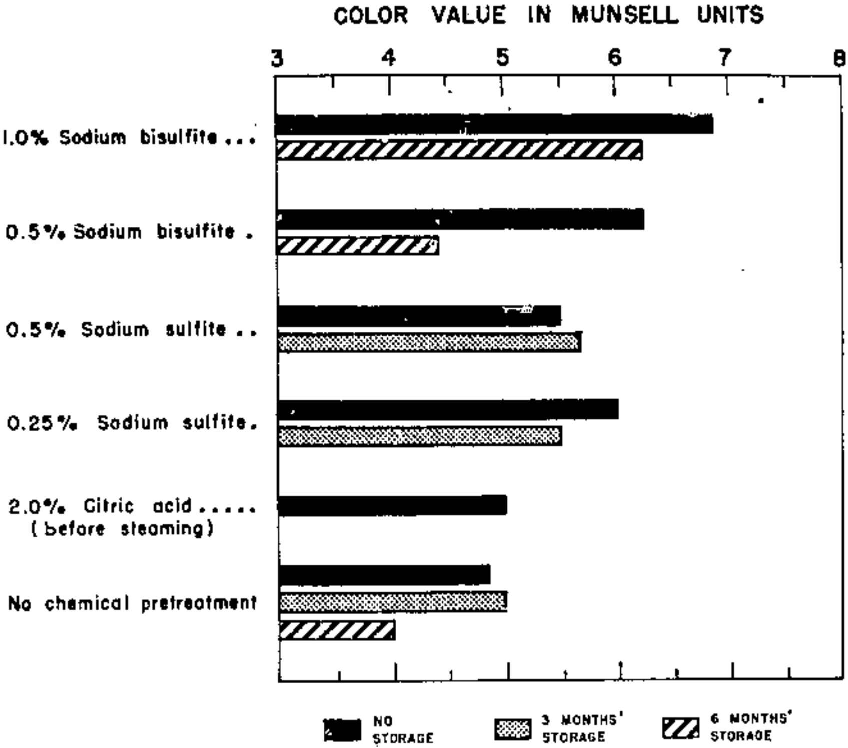

FIGURE 1.—Effect of various chemical pretreatments after steaming on the color of dehydrated cauliflower immediately after dehydration and after storage at 75° F. for 3 and 6 months.

Cauliflower stored at 110° for 3 months was rated low in every quality factor and very poor in acceptability, regardless of pretreatment. Although there were 1,166 p. p. m. sulfur dioxide in the sample pretreated with 0.5 percent sodium sulfite, the color was dark and all characteristics poor, indicating that the damaging influence of the storage temperature overbalanced the protective influence of the sulfite. The rehydration ratios of samples stored at 110° were very low. The texture was powdery and had the characteristics of charred food.

ASCORBIC ACID CONTENT.—A few studies of nutritive value were made on cauliflower. As shown in table 12, the cauliflower dipped in 0.5 or 1 percent sodium bisulfite solution before dehydration retained more ascorbic acid than that untreated except for steaming. Immediately after dehydration the over-all retentions were 406, 410, and 251 mg. per 100 gm. dry weight, respectively. There was less retention of ascorbic acid in cauliflower treated with citric acid and dehydrated, than in cauliflower steamed and dehydrated without any chemical pretreatment. After storage for 6 months at 75° F., however, samples of dehydrated cauliflower that had been pretreated with 0.5 and 1 percent sodium bisulfite retained 174 and 229 mg. ascorbic acid, respectively, as compared with only 89 mg. in the untreated sample.

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Table 12.—*Effect of various chemical pretreatments on the ascorbic acid content of dehydrated cauliflower*

Age of sample	Pretreatment [1]		Number of samples	Ascorbic acid				
				Content per 100 gm. dry weight		Retention		
	Kind	Time in chemical solution after steaming		Raw untreated	Dehydrated	Raw to precooked	Precooked to dry	Raw to dry
				Mg.	*Mg.*	*Pct.*	*Pct.*	*Pct.*
Immediately after dehydration.	None		4	819	251	88	35	31
	0.5 percent sodium bisulfite	15 sec	2	806	406	81	62	50
	1.0 percent sodium bisulfite	15 sec	2	989	410	81	52	42
	2.0 percent citric acid	15 sec	1	632	198	83	37	31
	2.0 percent citric acid	5 min	1	787	219	57	49	28
	2.0 percent citric acid	2 min.[2]	1	893	213	81	29	24
Dehydrated, stored 6 months at 75° F.	None		2	930	89		10	10
	0.5 percent sodium bisulfite	15 sec	2	806	174		27	22
	1.0 percent sodium bisulfite	15 sec	2	989	229		29	23

[1] All cauliflower was steamed three-fourths of the time necessary to cook tender.
[2] Chemically treated before steaming.

The laboratory was not set up to determine dehydroascorbic acid and reductones when the samples were freshly dehydrated, and for that reason, those factors are not taken into account in making the above comparisons. When the dehydroascorbic acid and the interfering substances were evaluated on later samples, however, the comparison of the three pretreated samples and the control remained the same. The percentages of the calculated values on the stored samples that represent antiscorbutic material were as follows:

1.0 percent sodium bisulfite treated, stored at 75° F., 111 percent.
0.5 percent sodium bisulfite treated, stored at 0° F., 97 percent.
0.5 percent sodium bisulfite treated, stored at 75° F., 77 percent.
Control, steamed, stored at 75° F., 59 percent.

Dehydroascorbic acid in the 1 percent sodium bisulfite treated sample represents 10 percent of the total vitamin. At the same time, no reductones were formed. The sample treated with 0.5 percent sodium bisulfite and stored at 0° contained nearly 7 percent of the vitamin in the oxidized form but also contained an appreciable amount of reductones which constituted 9 percent of the titration value. The 0.5 percent sodium bisulfite treated samples stored at 75° and the control contained practically no dehydroascorbic acid, but reductones increased the titration values 16 percent and 30 percent, respectively. Apparently the presence of reducing substances such as sodium bisulfite, as well as low temperatures, protects the dehydroascorbic acid from being irreversibly oxidized and at the same time helps to prevent the formation of reductones.

Relationship Between Ascorbic Acid, Palatability, and Color.—The correlation of ascorbic acid and color (hue) of dehydrated cauliflower was calculated and the coefficient was found to be 0.88. High ascorbic acid content was found in the samples that were greenish in color. Cauliflower having a yellow or yellow to reddish color was low in vitamin C. There was likewise a high correlation between ascorbic acid and palatability, the coefficient being 0.89. Palatability and color were even more closely related, with a correlation coefficient of 0.93. Factors that affected palatability and color of the dehydrated cauliflower likewise influenced ascorbic acid. The sulfites had a protective effect on vitamin C content as well as on color and flavor.

APPLES

Raw sliced apples were dipped in 0.05 percent thiocarbamide solution, or in 1.0 percent solution of sodium sulfite, sodium bisulfite, or sodium thiosulfate for 15 minutes. One lot of apples was precooked by steaming for 5 minutes. As a control, apples were dried with no pretreatment. Length of drying time was 7½ to 8 hours. All samples were stored at 75° F., and removed at monthly intervals for color readings, and at 3, 6, and 9 months for palatability testing.

Sodium sulfite and sodium bisulfite were the most effective pretreatments for the retention of the light color, natural flavor, and crisp texture of apples during dehydration and subsequent storage (table 13 and fig. 2). Sodium thiosulfate helped to preserve the color of the apples but a very undesirable flavor resulted, making the

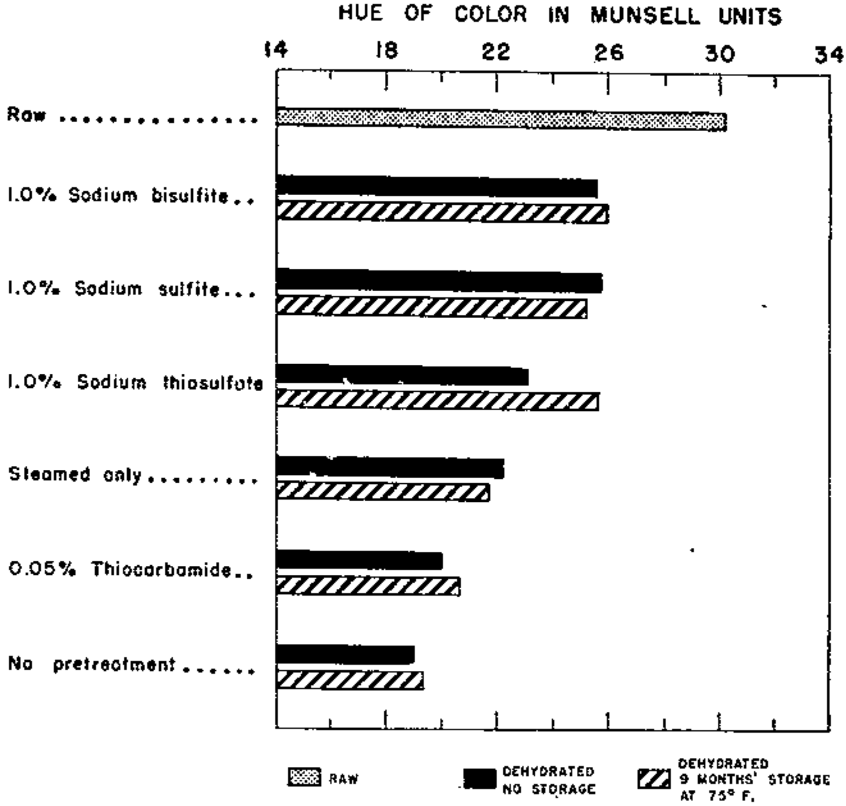

FIGURE 2.—Effect of various pretreatments on the color of dehydrated apples.

apples inedible. Thiocarbamide in a 0.05 percent solution was not a very effective pretreatment. Dehydrated apples precooked in steam, another method of inactivating the enzymes which cause discoloration, retained their color fairly well but cooked to a sauce when reconstituted; however, they became more firm with longer storage. The flavor of the steamed samples and untreated controls was not as good as that of the apples dipped in 1 percent solution of sodium sulfite or sodium bisulfite. The stale flavor that developed in the untreated and steamed apples was not evident in the sulfited apples.

After 9 months' storage, dehydrated apples treated with sodium sulfite were found to contain 69 p.p.m. of sulfur dioxide and those treated with sodium bisulfite contained 122 p.p.m. The small quantity of sulfur dioxide present in the reconstituted apples was scarcely perceptible to the taste and was not considered objectionable by the tasting panel.

None of the apples changed very markedly in color during storage. The color of those treated with sodium bisulfite, sodium sulfite, or sodium thiosulfate was still good after 9 months at 75°. Apples treated with thiocarbamide, steamed samples, and untreated raw apples had a poor color and a brownish hue.

TABLE 13.—*Effect of pretreatment on table quality of dehydrated apples before and after storage at 75° F.*[1]

Pretreatment	Storage time	Moisture	Sulfur dioxide in dry sample	Rehydration ratio	Quality rating[2]					Acceptability rating[3]
					Plumpness	Color	Aroma	Texture	Flavor	
	Months	*Percent*	*P.p.m.*							
Before dehydration	0	84.9	----	----	5	4.8	5	4.7	4.8	96
No pretreatment	0	8.6	----	3.95	4.3	2.2	4.0	4.8	3.8	80
	3	----	----	3.19	3.8	2.0	3.2	3.2	3.2	63
	6	----	----	3.06	3.1	1.5	3.0	3.1	2.4	53
	9	----	----	3.16	3.8	1.8	3.2	3.7	2.8	62
Steamed	0	8.9	----	4.19	3.8	2.3	3.8	1.8	3.3	57
	3	----	----	3.95	3.0	2.5	3.7	2.3	2.8	55
	6	----	----	4.10	3.6	3.0	3.2	2.8	3.0	61
	9	----	----	3.83	2.9	3.0	3.8	3.3	3.2	65
0.05 percent thiocarbamide	0	5.9	----	3.40	3.5	2.7	2.8	3.5	2.8	62
	3	----	----	3.29	4.0	1.8	3.5	3.5	3.2	65
	6	----	----	3.17	3.4	2.0	3.4	3.3	2.7	60
	9	----	----	3.08	3.5	2.0	2.9	3.3	2.8	59
1.0 percent sodium sulfite	0	6.8	----	3.57	4.7	4.9	4.4	4.9	4.2	92
	3	----	----	3.23	4.1	4.1	4.5	4.4	4.0	84
	6	----	----	3.20	4.1	3.8	4.1	4.1	4.0	80
	9	----	69	3.21	4.4	4.5	4.0	4.3	4.2	86
1.0 percent sodium bisulfite	0	6.0	----	3.59	4.7	4.9	4.5	4.9	4.0	91
	3	----	----	3.00	4.2	3.8	4.1	4.2	4.0	82
	6	----	----	2.95	3.6	4.0	3.9	3.8	4.0	78
	9	----	122	2.99	4.2	3.9	4.3	4.3	3.9	82
1.0 percent sodium thiosulfate	0	6.5	----	3.92	4.0	4.8	2.2	3.7	1.9	64
	3	----	----	3.72	3.8	3.8	2.3	3.5	1.7	59
	6	----	----	3.87	4.0	4.4	1.5	3.2	1.0	53
	9	----	----	3.71	3.5	4.3	2.0	3.0	1.0	51

[1] Controls stored at 0° F. remained unchanged.
[2] Average of 3 ratings; 5 is maximum, 1 is minimum score.
[3] Rating scale: 90 to 100, very good; 70 to 89, good; 50 to 69, fair; 30 to 49, poor; 0 to 29, very poor.

The moisture content of the pretreated dried apples was approximately 6 percent, whereas the untreated samples retained about 9 percent moisture. Pretreatment seemed to make possible more efficient removal of the water and at the same time it helped to retain the natural crisp texture of fresh apples. The untreated and steamed apples did not come back to the original texture as well as those that had been sulfited before dehydration.

BROCCOLI

Broccoli, prepared and steamed by standard methods (table 1, p. 5), was dipped in 0.5 percent solution of sodium sulfite for 15 seconds or in 0.5 percent sodium bicarbonate solution for 1 minute. Broccoli was also precooked in boiling 0.1 percent sodium bicarbonate solution for a period approximately one-half that for steaming. Untreated samples were used as controls. For ascorbic acid determinations, samples were prepared without the soaking in salt solution called for by the standard procedure, as well as with soaking, so that the effect of the salt might be studied. Some of the samples were stored for 3 months at 0°, 75°, and 110° F., and some for 6 and 9 months at 75°.

Comparison of the over-all quality ratings for broccoli immediately after dehydration showed very little difference in the effectiveness of the various pretreatments (table 14). The sulfited sample, however, was slightly inferior to the others in flavor because of the sulfur flavor acquired in the pretreatment. Pretreatment with sodium bicarbonate did not injure the flavor of the freshly dehydrated samples.

Both treated and untreated samples had fairly good texture. Treatment with sodium bicarbonate and sodium sulfite improved the texture of the reconstituted product, the shape of the stalk and bud closely resembling that of fresh broccoli.

The rehydration ratios indicated that all samples rehydrated well in the short cooking period. Longer cooking brought out the strong, overcooked flavors, characteristic of vegetables containing sulfur, and produced an undesirably soft texture quite unlike the crisp texture of freshly cooked broccoli.

The color of the sample precooked in sodium bicarbonate solution, and of the sample dipped in a sodium sulfite solution after precooking was superior to that of the untreated samples (fig. 3).

Dipping the precooked food in 0.5 percent sodium sulfite or precooking in 0.1 percent sodium bicarbonate solution best preserved initial color, flavor, and texture through storage at 75°. The latter method was more effective than dipping in 0.5 percent solution of sodium bicarbonate, and boiling in plain water was better than steaming. All of the broccoli stored at 110°, regardless of pretreatment, had a very low rating. The rehydration capacity was particularly low, and all quality factors were rated very poor. The texture was mealy rather than crisp and the color changed from green to dark brown.

TABLE 14.—*Effect of various pretreatments on table quality of dehydrated broccoli before and after storage at 75° and 110° F.*[1]

Age of sample and pretreatment	Moisture (percent)	Rehydration ratio	Quality rating[2]					Acceptability rating[3]
			Plumpness	Color	Aroma	Texture	Flavor	
Before dehydration:								
Steamed	93.3		5.0	4.8	4.7	4.7	4.5	94
Boiled in water	91.7	------	5.0	4.8	5.0	4.8	4.2	93
Boiled in 0.1 percent sodium bicarbonate	92.0	-------	5.0	4.8	4.8	4.3	4.2	90
Immediately after dehydration:								
Steamed	10.1	6.12	3.8	3.2	3.3	3.7	3.5	71
Boiled in water	8.7	6.96	3.7	3.8	4.1	3.7	3.8	76
Boiled in 0.1 percent sodium bicarbonate	8.2	6.43	4.1	4.3	4.0	3.7	3.7	77
Steamed, then dipped in 0.5 percent sodium bicarbonate	9.8	6.04	3.8	3.1	3.4	3.8	3.8	73
Steamed, then dipped in 0.5 percent sodium sulfite	9.6	6.52	4.1	4.0	3.5	4.0	3.4	76
Stored 3 months at 75° F.:								
Steamed	7.2	5.76	3.0	3.2	2.9	3.3	2.9	61
Boiled in water	9.1	6.11	3.5	3.8	3.3	3.4	3.2	68
Boiled in 0.1 percent sodium bicarbonate	9.2	5.46	3.2	4.4	3.4	3.3	3.5	71
Steamed, then dipped in 0.5 percent sodium bicarbonate	6.0	5.21	2.8	3.2	2.5	3.0	2.8	58
Steamed, then dipped in 0.5 percent sodium sulfite	7.7	6.20	3.3	3.8	3.1	3.6	3.4	69
Stored 3 months at 110° F.:								
Steamed	6.8	3.78	1.3	1.0	1.0	1.0	1.0	21
Boiled in water	9.4	3.70	1.7	1.3	1.3	1.0	1.0	24
Boiled in 0.1 percent sodium bicarbonate	-------	3.62	1.3	1.3	1.0	1.0	1.0	22
Steamed, then dipped in 0.5 percent sodium sulfite	9.9	3.89	1.3	1.0	1.0	1.0	1.0	21

[1] Controls stored at 0° F. remained unchanged.
[2] Average of 3 ratings on duplicate samples; 5 is maximum, 1 is minimum score.
[3] Rating scale: 90 to 100, very good; 70 to 89, good; 50 to 69, fair; 30 to 49, poor; 0 to 29, very poor.

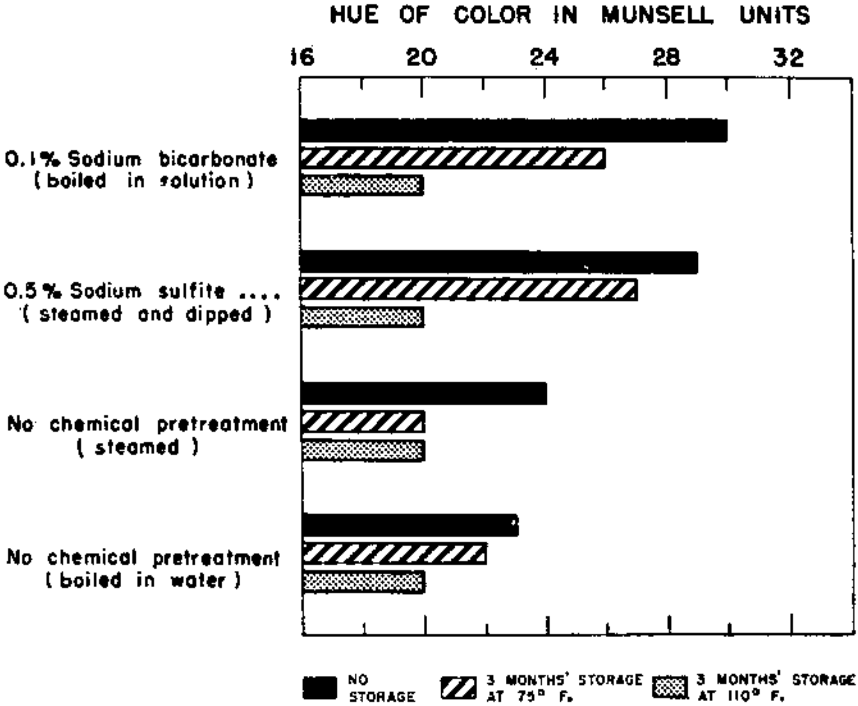

FIGURE 3.—Effect of various pretreatments on the color of dehydrated broccoli immediately after dehydration and after storage for 3 months at 75° and 110° F.

ASCORBIC ACID CONTENT.—Some workers consider that under favorable conditions of concentration, pH, temperature, and the concentration of certain other substances present, sodium chloride could act as a protective influence on ascorbic acid in foodstuffs (*22*).

In this study of broccoli, results of ascorbic acid determinations showed that after dehydration the broccoli that had been soaked in salt solution had retained 53 percent of the ascorbic acid present in the raw vegetable, whereas that not soaked retained 50 percent. After 3 months' storage at 75° and at 110° F., retention was 45 and 11 percent, respectively, for the soaked broccoli and 41 and 10 percent for the unsoaked. Since the samples stored at 110° were inedible after 3 months' storage, they were not held for further study. After 6 months' storage at 75° the broccoli that had been soaked in salt solution and that not soaked contained 31 and 34 percent, respectively, of the raw ascorbic acid content. After 9 months' storage, retention was 31 and 30 percent.

No dehydroascorbic acid was present in the 6 and 9 months' storage samples. Reductones, however, constituted from 31 to 43 percent of the titration values. When true vitamin C values were calculated for dehydrated broccoli stored 9 months, retention of the nutrient was 19 percent for the sample soaked in salt solution and 18 percent for that not soaked.

It is apparent that in this particular experiment, soaking broccoli in salt solution before dehydration did not affect ascorbic acid retention during dehydration and storage.

SNAP BEANS

Green snap beans were precooked by the standard method in steam or in boiling 0.1 percent solution of sodium bicarbonate. The steamed sample was dipped in 0.5 percent solution of sodium sulfite for 5 seconds. Untreated samples were used as controls.

Chemical pretreatment of green snap beans favorably affected the quality of the dehydrated product (table 15). Snap beans dipped in sodium sulfite after steaming and beans precooked in sodium bicarbonate solution rated 9 points higher than those dehydrated with no pretreatment other than steaming. Snap beans boiled in sodium bicarbonate solution rated slightly higher in color, aroma, and flavor than those given a sulfite dip, whereas the sulfited beans had better texture. Though the use of sodium bicarbonate shortens the time of precooking, careful timing is necessary to prevent break-down of the cell structure from overcooking. Color readings of snap beans at the precooked and reconstituted stages indicated that the green pigment was retained most successfully in the treated samples. Additional research including studies of storage and the effect on the vitamin content is needed before recommendations concerning the use of these pretreatments can be made.

SUMMARY OF CHEMICAL PRETREATMENTS STUDY

Quality of the dehydrated product was improved by dipping light-colored fruits and vegetables such as apples and cauliflower in solutions of sodium sulfite and sodium bisulfite before dehydration. Dipping in thiosulfate solution prevented darkening of dehydrated apples, but the flavor was definitely impaired by the chemical. Both sodium sulfite and sodium bicarbonate were effective in improving the quality of dehydrated green vegetables such as broccoli and snap beans. The small quantity of sulfur dioxide present in the sulfited food was scarcely perceptible to the taste.

Determinations of nutritive value were made on dehydrated cauliflower and broccoli. It was found that a sulfite dip almost doubled the retention of ascorbic acid in dehydrated cauliflower. Citric acid, on the other hand, was detrimental to both table quality and ascorbic acid content. Soaking broccoli in salt solution before dehydration did not affect ascorbic acid retention during dehydration and storage.

DEHYDRATION TEMPERATURE

There has been considerable controversy over the relative merits of drying food at one fixed temperature and of starting with a high temperature and lowering the temperature as drying proceeds. Vegetables will stand high temperature without scorching or other damage while they are high in moisture during initial stages of drying. On the other hand, most vegetables are very sensitive to heat when they are dry or nearly dry, as shown by the work of Mangels and Gore (*21*).

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TABLE 15.—*Effect of chemical pretreatment on table quality of dehydrated snap beans*

Pretreatment	Moisture (percent)	Rehydration ratio	Quality rating [1]					Acceptability rating [2]
			Plumpness	Color	Aroma	Texture	Flavor	
Before dehydration:								
Steamed			5.0	4.5	4.8	4.4	4.6	92
Boiled in 0.1 percent sodium bicarbonate			5.0	5.0	5.0	4.3	4.7	94
Immediately after dehydration:								
Steamed	8.4	5.56	4.2	3.0	3.2	3.2	3.2	66
Boiled in 0.1 percent sodium bicarbonate	8.3	5.90	4.0	4.2	3.8	3.5	3.7	75
Steamed, then dipped in 0.5 percent sodium sulfite	10.4	5.51	4.2	3.7	3.7	3.8	3.5	75

[1] Average of 3 ratings; 5 is maximum, 1 is minimum score.
[2] Rating scale: 90 to 100, very good; 70 to 89, good; 50 to 69, fair; 30 to 49, poor; 0 to 29, very poor.

Tressler (33) reported that the temperatures within any dehydrator should be adjusted so that the product temperature does not exceed the critical temperature determined for the particular stage of dryness and the character of the food being dried. Powers (28) warned that case hardening, the formation of a hard, dry surface layer on the food at high temperatures, may greatly prolong the drying period. The dry layer prevents the easy escape of moisture from the innermost cells.

It was the purpose of this investigation to determine the critical dehydration temperatures for broccoli, spinach, and carrots, and to compare the results of drying at the temperature obtained by a single stationary setting of the thermostat with the results of drying at temperatures obtained by two settings of an adjustable thermostat.

BROCCOLI

Broccoli (Calabresse variety) for this experiment was soaked 5 minutes in 5 percent salt solution to eliminate insects. The standard method of preparation and precooking was then used (table 1, p. 5).

Initial dehydration temperatures of 190°, 170°, 150°, and 135° F. were used. In the first two cases the thermostat setting was lowered to 150° after 3 hours of dehydration; in the last two cases, the thermostat was set at 150° and 135°, respectively, throughout the experiment. In each case the drier was preheated to its maximum temperature, 190°, before it was loaded with food.

Time Required.—Approximately 30 minutes were required to preheat the drier to 190° (fig. 4). When the broccoli was put into the

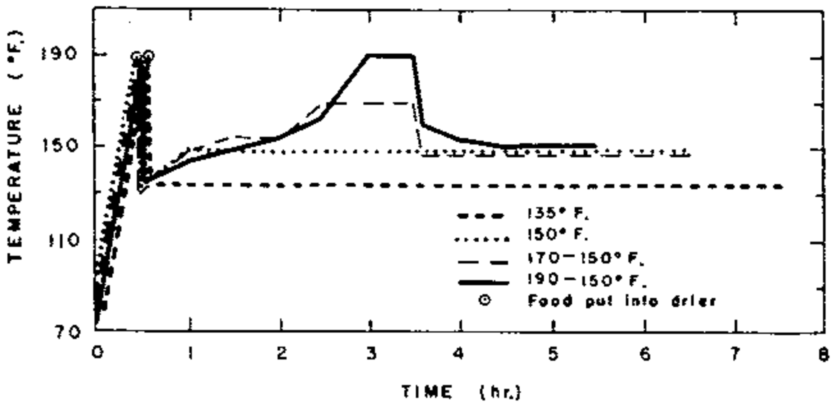

Figure 4.—Temperature in the dehydrator during dehydration of broccoli at different temperatures.

drier the temperature dropped to 130°; within 10 minutes the temperature reached 135°. At this temperature 7 hours were required for the broccoli to reach constant weight on successive weighings.

Thirty minutes were required for the temperature to reach 150° after the food was put into the preheated drier, and an additional $5\frac{1}{2}$ hours were needed to dehydrate the broccoli.

In attempting to dehydrate broccoli at a high initial temperature, it was found that the temperature within the drier did not reach 170° for 2 hours after the food was put into the preheated drier. Consequently, the temperature was 170° during only the third hour of drying. Three more hours at 150° were needed to complete the dehydration.

With the thermostat set at 190°, 2½ hours were required to reach this temperature after the food was placed in the drier. Therefore, the temperature was held at 190° for only one-half hour before lowering to 150°. At the lower temperature only 2 additional hours of drying were necessary for the broccoli to reach a constant weight. Total drying time was decreased 1 hour compared with the time for drying at 170° or 150°, and 2 hours compared with drying time at 135°. One hour was saved by drying at 150° compared with 135°.

Energy Used.—The energy consumed in dehydrating broccoli was slightly less at a dehydration temperature of 135° F. than at the other three temperatures used, in spite of the fact that a longer time, 7 hours, was required (table 16). At 190° to 150°, with a total drying time of 5 hours, less energy was consumed than at 150° or at 170° to 150° for 6 hours.

Table 16.—*Effect of dehydration temperature on time and energy consumed, drying ratio, and moisture content of 3 vegetables*

Vegetable	Preheat temperature	Temperature in dehydrator	Drying time	Energy consumed	Drying ratio (wet load/dry load)	Moisture content of dry food
	° F.	*° F.*	*Hours*	*Kilowatt-hours*		*Percent*
Broccoli (Calabresse variety)	190	135	7.0	5.49	9.20	8.3
	190	150	6.0	5.96	9.67	4.1
	190	170–150	6.0	6.05	9.46	10.4
	190	190–150	5.0	5.60	8.68	10.3
Carrots (Imperator variety)	----	150	6.75	6.04	7.24	6.9
	170	170–150	5.5	6.36	8.41	4.0
	190	190–150	5.0	6.24	7.94	6.1
Spinach (Savoy variety)	150	150	7.5	6.70	12.87	1.4
	170	170–150	5.5	5.63	8.72	2.3
	190	190–150	5.0	5.63	13.52	2.0

Water Absorption.—The temperature of drying seemed to influence the rate of water absorption of dehydrated broccoli. Forty grams of broccoli that had been dehydrated at 190° to 150° F. gained only 115 gm. of weight when soaked for half an hour in 440 ml. cold water, whereas the gains were 122 gm. and 134 gm. for broccoli dried at 170° to 150° and 150°, respectively (fig. 5). When the broccoli was soaked for 1¾ hours, the gain was 156, 172, and 182 gm. for samples dried at 190° to 150°, 170° to 150°, and 150°, respectively.

When boiled 10 minutes the soaked samples made additional gains of 11, 14, and 17 gm. The resultant rehydration ratios were 5.18, 5.66 and 5.95.

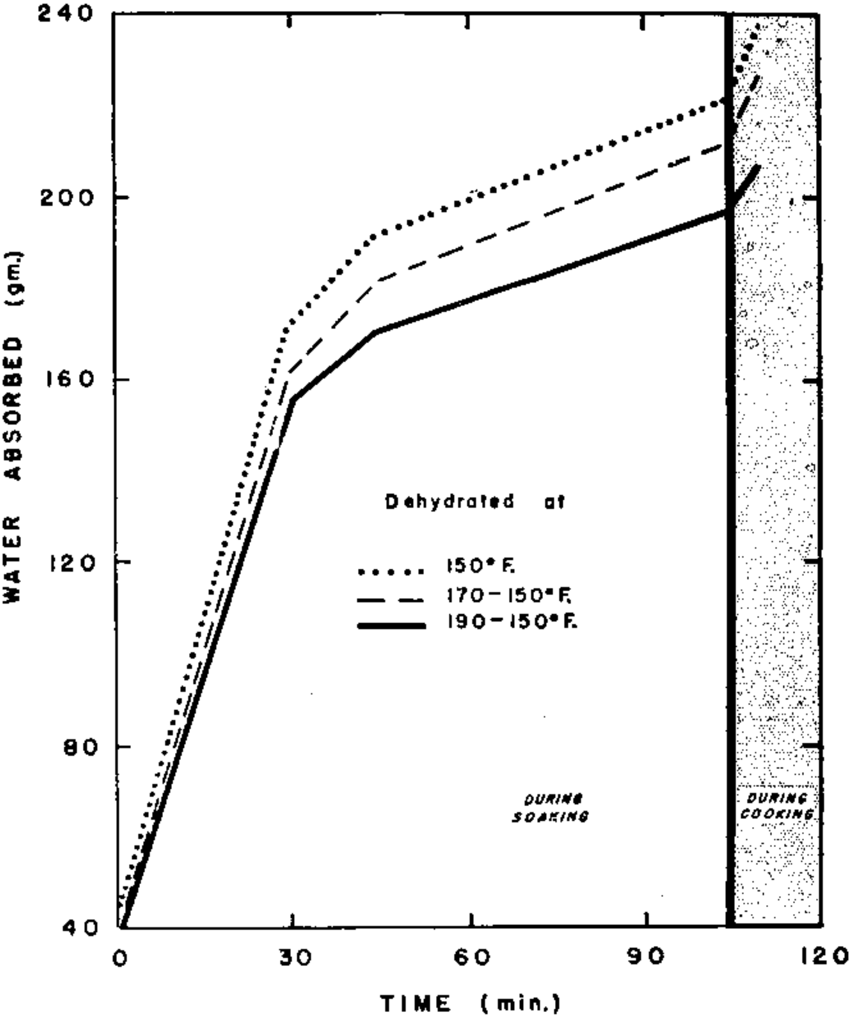

FIGURE 5.—Water absorption by 40 grams of broccoli dehydrated at different temperatures.

These differences were not so marked when the broccoli was reconstituted for palatability with a soaking time of one-half hour followed by cooking for 12 minutes (table 17). However, broccoli dried at 135° had the highest rehydration ratio and that dried at 190° to 150° had the lowest, indicating that dehydration at high temperatures retards water absorption during reconstitution.

TABLE 17.—*Effect of dehydration temperature on the quality of home-dehydrated vegetables*

Vegetable	Preheat temperature	Temperature in dehydrator	Rehydration ratio	Quality rating [1]					Acceptability rating [2]	Color by Munsell system		
				Plumpness	Color	Aroma	Texture	Flavor		Hue	Value	Chroma
	° F.	° F.										
Broccoli	190	135	5. 89	4. 3	4. 0	3. 8	4. 2	3. 8	81	26. 3	4. 7	6. 3
	190	150	5. 55	4. 3	3. 5	2. 8	3. 8	3. 3	72	24. 3	4. 7	6. 5
	190	170–150	5. 71	3. 8	3. 0	2. 5	3. 7	2. 8	64	19. 5	4. 8	6. 5
	190	190–150	5. 41	3. 5	2. 5	2. 0	3. 5	2. 7	59	20. 0	5. 0	5. 0
Carrots	---	150	4. 66	4. 3	4. 5	4. 2	4. 0	4. 0	83	12. 0	5. 0	10. 0
	170	170–150	6. 10	4. 7	4. 9	4. 2	4. 7	4. 3	91	12. 0	5. 3	8. 0
	190	190–150	6. 03	3. 8	4. 2	3. 4	3. 1	3. 5	70	12. 0	5. 5	9. 5
Spinach	150	150	7. 41	4. 2	3. 5	3. 7	4. 2	3. 3	74	37. 0	3. 0	2. 0
	170	170–150	5. 01	3. 8	3. 0	3. 3	3. 7	3. 5	70	35. 0	3. 5	3. 0
	150	190–150	7. 41	4. 2	3. 7	3. 0	4. 2	3. 3	75	35. 0	4. 0	3. 0

[1] Average of at least 3 ratings; 5 is maximum, 1 is minimum score.
[2] Rating scale: 90 to 100, very good; 70 to 89, good; 50 to 69, fair; 30 to 49, poor; 0 to 29, very poor.

QUALITY.—Palatability was lowered as the temperature of drying was increased. Aroma, flavor, and color were the quality characteristics most affected by dehydration at 190° and 170° F. Caramelization had taken place and a burnt flavor and aroma resulted. Some caramelization also occurred at 150°.

Dehydration at 135° did not injure the flavor quality of the vegetable with respect to caramelization. Loss of volatile flavoring constituents had occurred, however, since the broccoli had lost some of its characteristic flavor. No objectionable flavor had developed during dehydration at 135° such as were present in broccoli dehydrated at the higher temperatures. The original texture as well as flavor was better preserved by dehydration at 135°.

Color of the broccoli stalks was more sensitive to the temperature of dehydration than that of the buds, probably owing to the higher sugar content of the stalk. The stalks of broccoli dried at 190° to 150° had a red hue, whereas broccoli dried at 135° retained the natural green hue (fig. 6). In broccoli dried at 150° and 170° to 150° increasing amounts of red were present. Value darkened at the higher temperatures, while chroma showed no relationship to the temperature of drying (table 17).

CARROTS

In dehydrating carrots (Imperator variety) three temperature studies were made: (1) The drier was preheated to 190° F. and the thermostat left at 190° setting until the carrots had been in the drier 4 hours; then it was reset to maintain 150° for the latter part of

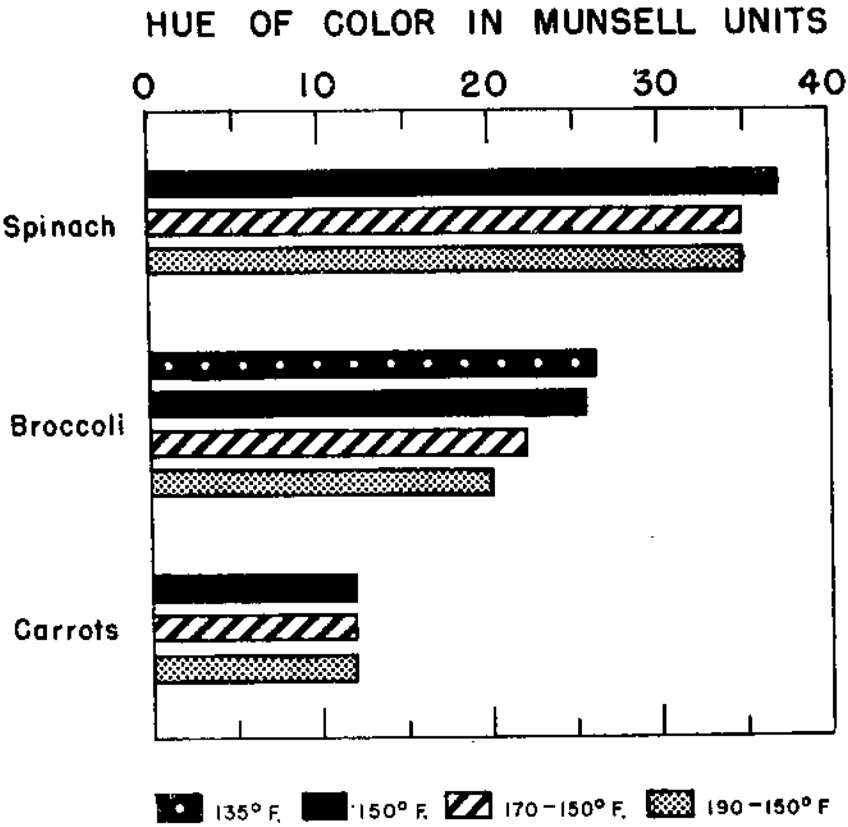

FIGURE 6.—Effect of various temperatures within the dehydrator on hue of dehydrated spinach, broccoli, and carrots.

the drying time when the vegetable was more sensitive to heat destruction because of its lowered moisture content. (2) The dehydrator was preheated to 170°; the thermostat was set at 170° for the first 4 hours of drying and reset to maintain 150° for the remainder of the drying time. (3) The thermostat was set to maintain 150° throughout the drying period; the drier was not preheated.

TIME REQUIRED.—The cooling effect of the introduction of cold food and the rapid evaporation of water prevented the attainment of high initial temperatures in the type of home dehydrator used. When the precooked shredded carrots were placed in the preheated drier, the temperature dropped to 135° and then increased slowly (fig. 7). Three hours were required to reach 190° (a few minutes later the temperature went up to 195° because of poor thermostatic control at this temperature) so that actually the temperature of the dehydrator was at the maximum for only 1 hour during the first 4 hours of drying.

In the second study, the drier required 2½ hours to return to a temperature of 170° after the cold food was introduced; therefore the temperature corresponded with the thermostat setting for only 1½ hours of the 4-hour period.

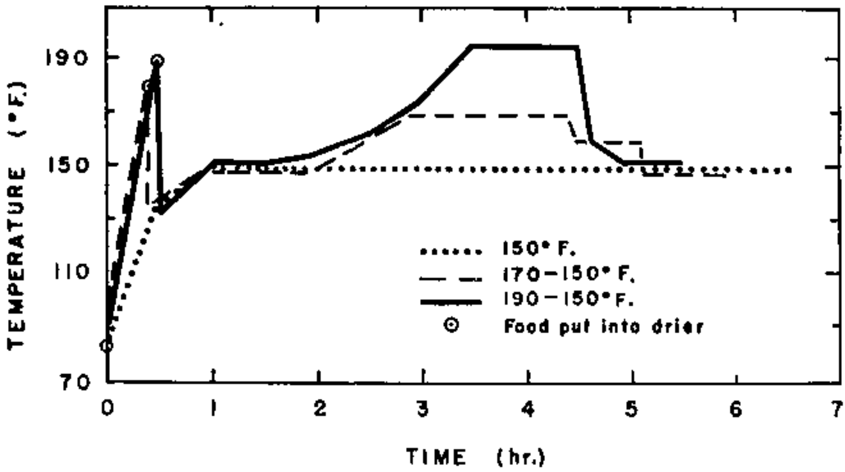

FIGURE 7.—Temperature in the dehydrator during dehydration of shredded carrots at different temperatures.

Preheating the drier helped to hasten the dehydration process, since the temperature never fell below 135° when the food was introduced. When food was put into the unheated drier with thermostat set at 150°, 1 hour was required to reach 150°, whereas in a preheated drier the temperaturo came back to 150° in one-half hour after introduction of the food. Total heating time was the same, however, since one-half hour was required to preheat the drier.

When dehydration was started in an unheated drier, a total of 6¾ hours at 150° was required to dehydrate the carrots to a moisture content of 6.9 percent. The time was shortened 1¾ hours by raising the temperature to 190°, and approximately 1¼ hours when the temperature was raised to 170° within the first 4 hours of dehydration (table 16, p. 34).

ENERGY USED.—When the drier, without preheating, was operated at 150° F. for the total time, electrical energy consumption was slightly less than when the temperature of the dehydrator was raised to 170° or 190° before and after the introduction of the food, even though a longer time was required for dehydration at the lower temperature.

QUALITY.—Dehydration temperatures up to 170° did not injure the quality of the dehydrated carrots (table 17, p. 36). When dehydrated at 190°, however, the carrots reconstituted unsatisfactorily by the standard method.

In order to determine whether this was a permanent effect of high-temperature dehydration, the reconstitution method was modified by increasing the cooking time from 15 minutes to 20, 30, and 40 minutes. In each case the product was hard and tough; aroma and flavor were stale and strong. When dehydrated, the carrots were soaked 15 minutes and cooked 25 minutes and they were still too firm. After soaking 17 minutes and cooking 30 minutes, the product was rated good in flavor and texture.

Although the high dehydration temperature did not permanently injure the quality of the product, the longer reconstitution time may be considered undesirable, regardless of the time saved during dehydration.

The color of the carrots was not affected by the temperature of dehydration. Hue of the dehydrated carrots was the same in all cases (fig. 6, p. 37). Value darkened very slightly as the temperature was increased. Chroma showed no relationship to the temperature of drying.

SPINACH

Spinach (Savoy variety) was dehydrated at 190°, 170°, and 150° F. for the first 3 hours and at 150° throughout the remainder of the drying time. The drier was preheated to 190° in all cases.

Time Required.—With spinach as with broccoli, the temperature of the preheated drier dropped drastically when the food was introduced into the drier (fig. 8). Thereafter it required 2½ hours to

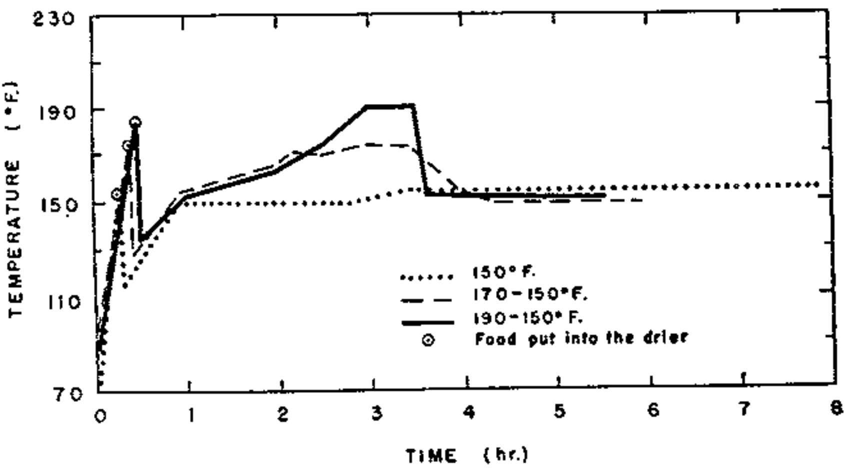

Figure 8.—Temperature in the dehydrator during dehydration of spinach at different temperatures.

reach 190° again, 2 hours to reach 170°, and 40 minutes to reach 150°. At drying temperatures of 170° and 150° there was a 5-degree departure from the thermostat setting, to 175° and 155°, respectively.

The time required to dehydrate spinach to constant weight varied with the drying temperatures; 5, 5½, and 7½ hours were required at temperatures of 190°, 170°, and 150°, respectively. Actually the temperature was at 190° for one-half hour only before being lowered to 150°.

Energy Used.—The electrical energy consumed during the longer time necessary for dehydration at 150° throughout the drying period was greater than that consumed during the shorter times at higher temperatures (table 16, p. 34).

Moisture Content.—It was possible to dehydrate spinach to a low moisture content (1 to 2 percent) in a home-type dehydrator at all dehydration temperatures from 150° to 190°.

Quality.—All samples reconstituted well, rating good in palatability (table 17, p. 36). Texture approached that of fresh spinach; the leaves retained their natural shape and appearance. The flavor lacked freshness but was not burnt or scorched even by the higher dehydration temperatures. In hue, the spinach dried at 150° was slightly more green than that dried at 170° to 150° or 190° to 150° (fig. 6, p. 37). Value was slightly darker as temperature of drying increased, and chroma somewhat brighter.

For home dehydration of spinach, an initial temperature as high as 190° can be recommended, since the quality of the dehydrated product was not impaired by this temperature and the cost of drying and the time required were reduced.

SUMMARY OF DEHYDRATION TEMPERATURE STUDY

The highest temperature attained in the drier for the first 2 or 3 hours of drying was low because of the cooling effect of evaporation of water from the food. During this period the maximum amount of heat was supplied by setting the thermostat as high as possible. Care was taken to lower the thermostat setting before the food became too hot.

The foods tested differed in the degree of heat they could withstand without losing quality. For broccoli, dehydration in a preheated drier set at 135° F. gave the best results under the conditions of this experiment. The color and palatability of the broccoli became less desirable as the temperature was increased from 135° to 190°. For carrots, a preheated drier set first at 170° and lowered after 4 hours to 150° proved best. Carrots dehydrated at 190° reconstituted with difficulty, and dehydration at 150° was not economical of time. Spinach did not seem to be injured by the higher temperatures; it was dried satisfactorily at 190° for the first 3 hours and 150° thereafter.

STORAGE

Since dehydration is one of the methods of preserving food for future use, it is important to determine conditions that will minimize changes in quality during storage after the food has been successfully dehydrated. Numerous research workers have reported that the moisture content of the dried product, the inactivation of enzymes, and the temperature of storage are factors determining the keeping quality of dehydrated vegetables.

High moisture content and high storage temperatures have been found to be especially detrimental to quality. In home dehydration the low moisture content of commercially dehydrated products is not always attainable. Although it is possible to dehydrate some vegetables such as spinach to a very low moisture content under home conditions, such vegetables as broccoli may not reach so low a moisture content under the same conditions.

This storage study was undertaken to find out how long the homemaker can expect dehydrated vegetables to keep high quality and ascorbic acid when the moisture content may range from 3 to 12 percent and cool storage facilities are unavailable.

BROCCOLI

Dehydrated broccoli of the Calabresse variety was chosen for this study because it is a vegetable that can be dehydrated successfully, and because it has high vitamin C potency, making changes due to dehydration and storage readily measurable. The broccoli was prepared by standard procedures (table 1, p. 5) and precooked three-fourths of the time required to cook tender. Catalase and peroxidase were inactivated effectively by this precooking period.

The entire storage study was performed with four replications. Samples were stored at 0°, 75°, and 110° F. for 3, 6, and 9 months in glass jars sealed with rubber rings and paraffin.

For the evaluation of quality characteristics, the broccoli was reconstituted by the standard method (table 2, p. 8). Ascorbic acid was determined on the dry samples only.

QUALITY.—The change in quality due to dehydration was greater than that due to storage. The palatability was rated fairly good immediately after dehydration and remained approximately the same throughout storage at 75° (table 18).

After 9 months the texture was a little less tender and the dehydrated broccoli became less able to absorb water as evidenced by the gradual lowering of the rehydration ratios.

The aroma was beginning to acquire a strong and scorched characteristic after 9 months in storage.

The color, including hue, chroma, and value, as measured by the Munsell color system, was affected by storage. The hue became progressively lower, containing more red as storage progressed. Value became darker, and chroma duller. This change in color was reflected in ratings for color by the tasting panel.

The average moisture content of these samples was around 8 percent. In a previous study on precooking time the moisture content attained in dehydration was 11 percent. In that case the higher moisture content caused some deterioration after 6 months at 75°.

Stored at 110°, dehydrated broccoli deteriorated very rapidly in quality. When examined at the end of 3 months the product had a burnt flavor and odor, a dark brown color, and a very powdery texture, which made it inedible.

Samples stored at 0° for 3, 6, and 9 months received essentially the same scores as the broccoli examined immediately after dehydration. These samples were introduced to obtain a measure of the variation to be expected in the judges' scores. In the rating of the individual quality characteristics, the average of the panel varied no more than 0.3 of a point on plumpness, 0.4 on color, 0.2 on aroma, 0.8 on texture, and 0.4 on flavor. Part of this variability can be attributed to inherent differences in the samples and in the rate of water uptake after storage.

TABLE 18.—*Effect of dehydration and storage on the quality of broccoli*

Stage of processing	Storage: Temperature	Storage: Time	Moisture	Rehydration ratio	Quality rating [1]: Plumpness	Quality rating [1]: Color	Quality rating [1]: Aroma	Quality rating [1]: Texture	Quality rating [1]: Flavor	Acceptability rating [2]	Color by Munsell system: Hue	Color by Munsell system: Value	Color by Munsell system: Chroma
	° F.	*Months*	*Percent*										
Before dehydration	------	------	90. 6	------	5. 0	4. 9	4. 7	4. 8	4. 6	97	32. 5	6. 3	4. 8
Immediately after dehydration	------	------	8. 1	5. 67	4. 0	3. 8	3. 3	4. 0	3. 6	76	27. 5	5. 9	4. 2
Dehydrated, stored	0	3	------	5. 56	3. 9	3. 8	3. 5	3. 6	3. 5	73	27. 2	5. 8	4. 2
Dehydrated, stored	0	6	------	5. 88	3. 9	4. 0	3. 3	4. 3	3. 6	78	27. 5	6. 8	4. 0
Dehydrated, stored	0	9	------	5. 61	4. 2	4. 2	3. 4	4. 4	3. 9	82	26. 5	5. 8	4. 2
Dehydrated, stored	75	3	------	5. 62	3. 9	3. 6	3. 5	3. 8	3. 4	72	27. 0	6. 0	4. 2
Dehydrated, stored	75	6	------	5. 54	3. 7	3. 4	3. 2	4. 1	3. 2	71	27. 0	5. 6	4. 0
Dehydrated, stored	75	9	------	5. 30	3. 8	3. 4	2. 6	3. 4	3. 1	68	22. 0	5. 7	4. 0
Dehydrated, stored	110	3	------	3. 29	1. 2	1. 0	1. 0	1. 0	1. 0	20	20. 0	2. 0	2. 0

[1] Average of 3 ratings on 4 replicates; 5 is maximum, 1 is minimum score.
[2] Rating scale: 90 to 100, very good; 70 to 89, good; 50 to 69, fair; 30 to 49, poor; 0 to 29, very poor.

The range in texture scores can be partially explained by the rehydration ratios which decreased and increased slightly.

Ascorbic Acid Content.—Ascorbic acid was retained fairly well in dehydrated broccoli through 9 months of storage at 75° F. (table 19). The dehydrated vegetable retained less than half of this nutrient present in the raw vegetable. The ascorbic acid content decreased gradually during storage and after 9 months the dehydrated broccoli retained a little more than one-quarter of its raw content.

Table 19.—*Effect of dehydration and storage on the ascorbic acid content of broccoli*

Stage of processing	Storage		Uncorrected reduced ascorbic acid			True vitamin C	
	Temperature	Time	Content per 100 gm. dry weight	Retention		Content per 100 gm. dry weight	Retention—raw to dehydrated
				Raw to dehydrated	Dehydrated to stored		
	° *F.*	*Months*	*Milligrams*	*Percent*	*Percent*	*Milligrams*	*Percent*
Before dehydration			1, 153				
Immediately after dehydration			550	48			
Dehydrated, stored	75	3	445	39	81		
	75	6	362	31	65	258	22
	75	9	311	27	56	199	17
	110	3	147	13	27		

Up to the time for testing the 6 months' storage samples, the measure of vitamin C value was the reduced ascorbic acid determined by dichlorophenolindophenol titration. The amounts of antiscorbutic material, including dehydroascorbic acid and excluding reductones, present at the end of 6 and 9 months were found to be 71 and 64 percent, respectively, of the uncorrected reduced ascorbic acid value.

Relationship Between Ascorbic Acid, Palatability, and Color.—Some studies were made of the relationships between palatability of dried broccoli as determined by a tasting panel, its vitamin C values, and its color. The hue and ascorbic acid content of broccoli were found to have the high correlation coefficient of 0.92; the greener the broccoli, the higher was the ascorbic acid content. Hue and palatability were found to have a correlation coefficient of 0.86; palatability and ascorbic acid, 0.79.

It would seem that hue, ascorbic acid content, and palatability of broccoli are similarly affected by dehydration and storage. Since under the conditions of this study color was highly correlated with nutritive value and palatability, it is possible that the quality of dehydrated broccoli can be estimated by the amount of green color present.

SUMMARY OF STORAGE STUDIES

Broccoli that had been precooked three-fourths of the time required to cook tender and stored after dehydration in sealed glass jars at 75° F. for 3, 6, and 9 months showed no appreciable loss in palatability. This broccoli had a moisture content of 8 percent.

The greatest loss in vitamin C occurred during dehydration and the first 3 months of storage; approximately a quarter of the raw content was retained after 9 months' storage. Since raw broccoli has a high ascorbic acid content, dehydrated broccoli is still a fairly good source of vitamin C.

COOKED DEHYDRATED VEGETABLES AS SOURCES OF VITAMIN C

Since dehydrated food must be reconstituted before it is eaten, it is important to know how much of the nutritive value is present in the form in which the food is consumed. Several studies made on the reconstitution of commercially dehydrated vegetables have emphasized the extremely large losses of ascorbic acid during dehydration and subsequent cooking (*23*, *25*, *31*).

Limited studies in which ascorbic acid content of the reconstituted home-dehydrated foods was measured were carried out with cauliflower and spinach, both good sources of vitamin C and representing bulky and leafy vegetables that would lend themselves to dehydration. All values were recorded as wet weights in order to evaluate the food as it is consumed, in terms of daily requirement.

Good quality cauliflower with ascorbic acid content of 54 mg. per 100 gm., which is fairly typical (*30*), was steamed 6¾ minutes (three-fourths total cooking time) and dipped for 15 seconds in a 0.5 percent solution of sodium bisulfite before dehydration.

Spinach used for the reconstitution study was steamed for 5 minutes before dehydration. This lot of spinach was fully cooked in this time.

Samples of both dehydrated products were stored for 6 months at 75° F.

The procedure for reconstitution and cooking consisted of taking enough dried sample and copper-free distilled water to provide four servings. A 2-quart uncovered enameled pan was used.

In reconstituting and cooking the dehydrated cauliflower, 560 ml. of water were brought to boil and 40 gm. of the dehydrated product added. The heat was then turned out and a 30-minute interval allowed for rehydration. At the end of this period the heat was again turned on and the cauliflower cooked for 8 minutes.

In the case of spinach, 675 ml. of water were brought to boil and 45 gm. of the dried vegetable were added. The spinach was allowed to boil for 6 minutes, during which time it was stirred at 2-minute intervals. The vegetables were then drained. For ascorbic acid analyses the vegetables and cooking liquids were cooled before they were weighed and measured.

CAULIFLOWER

The cooked freshly dehydrated cauliflower retained 69 percent of its original 54 mg. ascorbic acid per 100 gm. raw vegetable. The ascorbic acid content of the cauliflower was approximately 20 mg. per 100 gm. wet weight; the cooking liquid remaining with each 100 gm. of sample contained 17 mg. ascorbic acid. Although the vegetable contained 2,170 p.p.m. sulfur dioxide when freshly dehydrated, only 60 p.p.m. remained after cooking. The cooked dehydrated product rated fairly good in palatability; only a slight sulfur flavor and aroma were detected by the judging panel.

Cooked after 6 months' storage at 75° F., the dehydrated cauliflower retained 32 percent of its original raw ascorbic acid value. The value of the drained vegetable was approximately 8 mg. per 100 gm. and the cooking liquid contained another 9 mg. per 100 gm. of sample. Thus if the cooking liquid were consumed in the form of a gravy or soup, the product would provide 17 mg. of ascorbic acid per 100 gm. sample.

Dehydroascorbic acid and reductones were not determined on the freshly dehydrated samples. For this reason the above figures for stored samples, which represent reduced ascorbic acid only, were used in order to make a fair basis of comparison throughout the study. When dehydroascorbic acid and reductones are taken into account in computing the storage sample values, the actual antiscorbutic material is 82 percent of the recorded value, that is, 14 mg. per 100 gm. in the vegetable plus the cooking liquid, indicating it to be still a fair source of vitamin C.

The stored dehydrated sample contained 1,287 p. p. m. sulfur dioxide, representing a loss of 883 p. p. m. during 6 months of storage at 75°. The cooked sample contained only 50 p. p. m. This amount of sulfur dioxide was not detected by the judging panel.

SPINACH

The raw spinach had a low original ascorbic acid content, 16.5 mg. per 100 gm., about one-third of the amount present in a good grade of spinach (*5*). For this reason the percentage of the nutrient retained may not be typical. The freshly dehydrated cooked spinach retained only 4 mg. ascorbic acid per 100 gm. Of this, 3 mg. were contained in the cooked vegetable and 1 mg. in the cooking liquid.

Cooked after a 6-months' storage period at 75° F. the dehydrated spinach appeared to have retained 3.6 mg. of ascorbic acid per 100 gm. Reductone determinations, however, showed that none of the indophenol reducing material was ascorbic acid and the dehydroascorbic acid present was less than 1 mg. per 100 gm. Six months' storage, therefore, left the spinach depleted of its antiscorbutic matter.

SUMMARY OF VITAMIN C STUDIES ON COOKED DEHYDRATED VEGETABLES

When dehydrated cauliflower that had been stored 6 months at 75° F. was cooked, it was a fair source of ascorbic acid and had good palatability. The ascorbic acid content of spinach cooked immediately after dehydration was very low, and after storage and cooking no ascorbic acid was left.

UTILIZATION OF DEHYDRATED VEGETABLES IN RECIPES

The real measure of success of a dehydration process is a palatable, attractive product that can be served in the same way fresh food is served. Dehydration may cause slight changes in flavor, color, or texture of vegetables. In the Army objections to dehydrated foods were traced in almost all cases to poor preparation. It is therefore important to know the best method of preparing these foods for table use.

This experimental work and the Bureau's related publication, Cooking Dehydrated Vegetables (*41*), which contains the recipes tested here, along with Fenton's instructions for cooking dehydrated vegetables (*13*) should be valuable aids in increasing the acceptability of these foods, which are new to a great many people.

FOODS AND PROCEDURES

The dehydrated snap beans, beets, broccoli, carrots, corn, mushrooms, peas, spinach, and sweetpotatoes used in this study were dehydrated in the Bureau's laboratories. The kinds of utensils, quantities of food, methods of precooking, and types of dehydrators used were those available in, or suitable for, the family kitchen.

Beets were shredded; snap beans were cut in 1-inch pieces; broccoli was sliced about 1/16 inch thick, stalks and buds included; carrots were both shredded and cut in crosswise slices 1/8 inch thick; corn was stripped from the cob as whole kernels; mushrooms were cut in 1/8 inch slices; peas were shelled; spinach leaves were left whole with stems removed; and sweetpotatoes were sliced lengthwise about 1/4 inch thick. Before dehydration all the vegetables except mushrooms were cooked until almost done according to standards of this laboratory.

The dehydrated snap beans, broccoli, carrots, corn, and spinach used in recipe development had been stored for 3 months at room temperature. The mushrooms and sweetpotatoes had been at 32° F. for 1 year and at room temperature for 3 months. Beets and peas were used immediately after dehydration. All the foods except corn and sweetpotatoes were stored at 0° for comparison with those stored at room temperature.

Each food was reconstituted by the addition of the required amount of water. Whether or not the food was soaked prior to cooking depended upon the kind of food. The proportions of water to dry vegetable to produce approximately 3 cups of cooked food, and soaking and cooking times are given in table 20.

TABLE 20.—*Proportions and directions for cooking dehydrated vegetables* [1]

Vegetable	Form	Quantity of dry vegetable	Volume of water	Soaking time	Cooking time
		Cups	*Cups*	*Minutes*	*Minutes*
Beans, snap	1-inch pieces	1½ to 1¾	3	0	30
Beets	Shredded	1½	2½	0	30
Broccoli	Sliced	2½ to 3	2¾	30	6 to 15
Carrots	Shredded	1¼ to 1½	2½	0	15 to 20
	Sliced crosswise	1¼ to 1½	3	30	10 to 12
Corn	Whole kernel	1½	3	120	25
Mushrooms	Sliced	4	3	30	25
Peas	Whole	1½	2½	30	20
Spinach	Leaves	7 to 8	3	0	5 to 8
Sweetpotatoes	Sliced lengthwise	3	2½	60	15

[1] Yield: Approximately 3 cups of cooked food.

Reconstituted vegetables were made into soups, stews, timbales, and souffles. They were also creamed, scalloped, combined with other vegetables, and used in sauces. The recipes and methods of preparation have already been published by the Bureau of Human Nutrition and Home Economics (*41*).

The products were rated by a panel of six persons, three of whom were trained in judging dehydrated food and three of whom were untrained. The latter group represented consumer preference for food to a greater extent than the more critical trained group. The products were scored on the various quality characteristics—plumpness, color, aroma, texture, flavor, and general acceptability by a 5-point scale ranging from 5 for very good to 1 for very poor.

PALATABILITY OF PREPARED DEHYDRATED VEGETABLES

The results of this study illustrate that dehydrated vegetables can be used successfully in much the same way as fresh. In most cases, simply the addition of butter and salt greatly improved the palatability of the plain-cooked dehydrated vegetable (table 21). The scores in all cases increased when the dehydrated food was used in combination with other ingredients. All of the quality characteristics including plumpness, color, aroma, texture, and flavor were favorably affected.

TABLE 21.—*Palatability ratings of prepared dehydrated vegetables.*[1]

Dehydrated vegetable	Recipe	Quality rating: Plumpness	Quality rating: Color	Quality rating: Aroma	Quality rating: Texture	Quality rating: Flavor	Acceptability rating	Percent gain in acceptability score from plain cooked
Beans, snap	Plain cooked	3.6	4.0	4.1	4.2	3.8	3.7	-----
	Buttered and seasoned	3.9	4.3	4.1	4.4	3.8	4.3	16
	Succotash	4.2	4.5	4.5	4.6	4.4	4.4	19
	Sauteed with mushrooms.	4.1	4.3	4.4	4.5	4.6	4.5	22
	Chowder	4.1	4.5	4.7	4.7	4.9	4.8	30
	Boiled dinner	4.2	4.6	4.8	4.7	4.8	4.8	30
Beets	Plain cooked	3.8	4.8	4.2	4.0	3.8	3.8	-----
	Buttered and seasoned	4.0	4.6	4.4	4.3	4.4	4.3	13
	Borsch	4.2	4.2	4.4	4.3	3.8	4.0	5
	In orange sauce	4.4	4.9	4.3	4.4	4.3	4.2	11
	Spiced beet relish	4.8	4.3	5.0	4.7	4.5	4.5	18
	Harvard beets	4.6	4.9	4.9	4.7	4.8	4.8	26
Broccoli	Plain cooked	3.9	3.9	3.8	4.2	3.5	3.3	-----
	Buttered and seasoned	4.2	3.9	4.3	4.2	4.2	4.1	24
	With Hollandaise sauce.	3.9	3.6	4.2	3.8	4.1	4.1	24
	And chicken casserole	4.2	4.2	4.8	4.2	4.5	4.4	33
	Souffle	4.6	4.6	4.9	4.7	4.2	4.4	33
Carrots, shredded	Plain cooked	4.3	4.7	3.8	3.8	3.0	3.0	-----
	Buttered and seasoned	4.3	4.7	4.2	4.2	4.2	4.2	40
	In meat broth	4.4	4.3	4.2	4.2	3.8	3.8	27
	Pan-browned	4.5	4.7	4.5	4.4	4.2	4.2	40
	Creamed with hard-cooked egg.	4.8	5.0	4.4	4.5	4.7	4.4	47
	Carrots and potato patty.	5.0	4.8	5.0	4.9	4.4	4.6	53
	Mashed and seasoned	4.7	4.9	4.8	4.8	4.7	4.7	57
	Creamed	4.8	5.0	4.8	4.6	4.6	4.7	57
	Scalloped with cheese	4.8	5.0	4.8	4.3	4.7	4.7	57
	Cream of carrot soup	4.6	4.8	4.4	4.8	4.6	4.8	60
	Scalloped	4.8	5.0	4.8	4.8	4.8	4.8	60
	Vegetable soup	4.9	4.9	5.0	4.9	4.9	4.9	63
Carrots, sliced	Plain cooked	3.8	4.4	3.7	3.8	3.4	3.5	-----
	Glazed with cinnamon	4.0	3.7	3.8	3.7	3.5	3.5	0
	With celery	3.9	4.5	4.2	3.7	4.3	3.9	11
	Glazed	4.0	4.3	4.0	4.0	4.0	4.0	14
	With peas	3.8	4.4	4.2	4.2	4.4	4.2	20
	Scalloped with mushrooms.	4.2	4.4	4.4	4.4	4.2	4.3	23
	Vegetable soup	4.8	4.4	4.8	4.8	4.7	4.6	31
	In veal stew	4.4	4.7	5.0	4.5	4.5	4.8	37

[1] Average of 6 ratings; 5 is maximum, 1 is minimum score.

TABLE 21.—*Palatability ratings of prepared dehydrated vegetables*—Continued

Dehydrated vegetable	Recipe	Quality rating: Plumpness	Quality rating: Color	Quality rating: Aroma	Quality rating: Texture	Quality rating: Flavor	Acceptability rating	Percent gain in acceptability score from plain cooked
Corn	Plain cooked	3.1	3.6	2.8	3.1	2.5	2.7	------
	Buttered and seasoned	3.5	3.8	3.6	3.2	3.6	3.6	33
	Mexican-style	3.9	4.0	4.2	3.8	4.2	4.0	48
	Pudding	4.3	4.3	4.5	4.1	4.1	4.0	48
	Corn chowder	4.4	4.2	4.4	3.9	4.0	4.2	56
	Creamed with salmon	4.7	4.8	4.9	4.5	4.8	4.8	78
Mushrooms	Plain cooked	2.9	2.8	3.2	2.7	2.8	2.7	------
	Souffle	3.9	4.1	4.6	3.6	4.4	4.2	56
	Scalloped with salmon	3.2	3.8	4.6	3.7	4.2	4.2	56
	Cream of mushroom soup.	4.6	4.8	5.0	4.7	4.9	4.8	78
Peas	Plain cooked	4.7	4.4	4.2	4.3	4.2	4.2	------
	Buttered and seasoned	4.5	4.3	4.4	4.4	4.2	4.2	0
	Timbales	5.0	4.9	4.6	5.0	4.5	4.4	5
	Cream of pea soup	4.8	4.6	4.8	4.2	4.8	4.7	12
	Creamed with cauliflower.	4.8	4.8	4.9	4.3	4.7	4.8	14
	Scalloped with tomatoes and rice.	4.9	4.6	5.0	4.8	4.9	4.9	17
Spinach	Plain cooked	4.2	4.4	4.2	4.2	3.7	3.7	------
	Buttered and seasoned	4.3	4.5	4.5	4.4	4.2	4.2	14
	With piquant sauce	4.0	4.3	4.3	4.1	3.9	3.9	5
	Timbale	4.6	4.6	4.8	4.3	4.6	4.3	16
	Au gratin	4.7	4.6	4.8	4.6	4.8	4.8	30
Sweetpotatoes	Plain cooked	4.5	3.9	3.6	4.0	3.6	3.5	------
	Scalloped with apples	4.8	4.1	4.6	4.6	4.4	4.5	29
	Potato puff	5.0	4.5	4.6	4.9	4.7	4.6	31
	Glazed	4.9	4.7	5.0	4.7	4.6	4.6	31
Vegetable juice (mixture of all cooking liquids).		----	4.9	4.8	5.0	4.7	4.7	------

Dehydrated food used in recipes generally had a higher score on plumpness than the plain reconstituted product. Evidently the foods continued to take up moisture after reconstitution when in combination with other moist ingredients. Texture was improved along with plumpness.

Dehydrated snap beans were rated good in all quality characteristics when used in combination with other vegetables, as in succotash, with mushrooms, and in chowder or boiled dinner.

Dehydrated beets with only butter and salt added were considered quite acceptable by the palatability panel. When prepared as Harvard beets they were rated very good in acceptability. Served in an orange sauce or as a spiced beet relish, they were also a very acceptable product. In borsch the beets had a weak, flat flavor and the scores were somewhat lower.

The scores for broccoli increased 24 percent when butter and salt were added. They increased 33 percent when the broccoli was prepared as a souffle and as a broccoli and chicken casserole. The seasoned products were all rated in the good class. The plain rated fair.

The dehydrated shredded carrots available for this study rated low in flavor when served unseasoned. However, the scores increased 50 to 60 percent and the products rated very good when the carrot shreds were used in soup, scalloped with or without cheese, creamed, mashed and seasoned, or used in a carrot and potato patty. They were also rated good when pan-browned or simply served with butter and salt.

Dehydrated sliced carrots received their highest palatability score when served with veal in stew. When glazed with cinnamon they received their lowest score, owing to the darkened color of the carrots and foreign flavor of the cinnamon. When carrot slices were glazed with brown sugar the edges curled and an undesirable chewiness resulted. Dehydrated carrot slices rated very good in vegetable soup. The carrots in this case were added to the soup without preliminary soaking or cooking.

Dehydrated corn which rated fairly poor when served unseasoned rated good to very good when prepared as Mexican-style corn, corn pudding, corn chowder, or creamed with salmon.

Dehydrated mushrooms of rather poor quality were very satisfactory in mushroom souffle, scalloped with salmon, or made into cream of mushroom soup.

The freshly dehydrated peas used in this study were rated good when served plain without the addition of seasonings. When heated in butter they were scored slightly lower in color and plumpness. The peas probably lost moisture on additional heating and partial caramelization of the sugars may have occurred. In cream of pea soup and creamed with cauliflower, the peas became slightly hard. The dehydrated peas were rated very good scalloped with tomatoes and rice.

Dehydrated spinach rated fairly good without added seasonings. Buttered and seasoned, the spinach rated good in all quality characteristics. It rated highest, however, when served au gratin.

Dehydrated sliced sweetpotatoes were very satisfactory when served as potato puff, glazed, or scalloped with apples.

Vegetable juice cocktail prepared by mixing the cooking liquids from all the reconstituted vegetables and adding tomato juice and seasonings, was very well liked by the judges. This is an excellent way to conserve nutrients which often are discarded.

SUMMARY OF UTILIZATION STUDIES

Dehydrated snap beans, shredded beets, broccoli, shredded and sliced carrots, corn, sliced mushrooms, peas, spinach, and sliced sweetpotatoes were used in developing some or all of the following types of recipes: Soups, stews, creamed and scalloped dishes, timbales, souffles, combinations with other vegetables, and in sauces.

The eating quality of all the vegetables was greatly improved by the addition of butter and salt. Recipes using a variety of ingredients and seasonings received even better scores. Though the experimental work has been limited the following observations were made.

In general, good quality dehydrated vegetables can be used in any recipe that calls for cooked fresh vegetables.

A little more liquid is needed when using dehydrated vegetables in souffles, scalloped dishes, and stews than when using cooked fresh vegetables. Apparently reconstitution continues at the expense of the surrounding liquid.

On the other hand, without surrounding liquid, as in reheating or pan-browning, reconstituted snap beans, sliced carrots, mushrooms, and peas apparently lose liquid and become toughened.

In soups and stews, satisfactory products can be produced by adding dehydrated vegetables without preliminary soaking or cooking.

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APPENDIX

PRELIMINARY STUDIES OF HOME DEHYDRATION PROCEDURES FOR 20 VEGETABLES AND FRUITS

In 1941–43, the Bureau of Human Nutrition and Home Economics undertook studies to improve existing home dehydration methods. The factors investigated included pretreatments, types of home driers, temperature and time of dehydration, energy consumed in the drying process, yield of dried product, storage time, temperature, and container, and method of reconstitution.

Vegetables included in the investigations were snap beans, beets, beet greens, carrots, Swiss chard, corn, kale, mushrooms, mustard greens, green peppers, pumpkin, squash, sweetpotatoes, tomatoes, turnip greens. Fruits studied were blackberries, cherries, peaches, pears, prune plums. Not all factors were studied on all foods. In many cases only small quantities were prepared and few tests made.

General Procedures

Source of Foods.—Foods for drying were most often procured from local markets. Whenever possible, vegetables and fruits with known history were obtained from the Bureau of Plant Industry, Soils, and Agricultural Engineering or other cooperating stations.

Preparation of Raw Food.—In general the food was divided into small pieces for quick penetration of heat in pretreatment and quick evaporation of water during drying. Pretreatment usually consisted of steaming in equipment of the type available in most rural homes, or sulfuring in a simple box arrangement. Special dips such as lye and citric acid were used only when necessary to maintain quality. The time required for preparation was taken into consideration in selecting methods to be recommended.

Driers and Dehydration Methods.—Several kinds of driers were used, including forced-draft as in the electric dehydrators (*40*), natural-draft as in kerosene flue driers (*36*), and top-of-stove types (*37*). The drier trays were lined with cheesecloth in most instances.

Automatic recordings were made of temperatures measured by thermocouples placed at various points in the loaded driers and also temperature readings were taken by means of household thermometers. In nearly every case the driers were preheated. When more than one thermostat setting was used, the temperature at which the food was dried for the longest time is the one given. Approximate drying time and fuel consumption were also recorded. Practical tests, as described in each case, were used to determine when foods were dried sufficiently. As a check, laboratory determinations for moisture were made on a number of samples at the end of the drying process.

STORAGE.—Dried samples were stored in a variety of containers available to homemakers, including glass jars, tin cans, waxed and plain paper cartons, paper bags, and bags made of cellophane, paraffined cloth, and laminated paper.

Storage periods varied from 3 months to 1 year. Storage temperatures ranged from 0° to 100° F. Humidity was not controlled. Relative humidity was high a large part of the time in the laboratory used for room temperature storage.

The number of storage studies made depended on the quantity of sample available.

RECONSTITUTION.—Procedures for cooking dried vegetables and fruits were as nearly as possible like the methods for the fresh foods. The most satisfactory amount of water for reconstituting each kind of dried food was determined in preliminary experiments. Distilled water was used.

Before cooking, most dried vegetables and fruits were soaked in cold water for 1 to 2 hours or until plumped. They were considered sufficiently soaked when they resembled the fresh prepared product in color and size. The length of time required depended on the kind of food, size of pieces, and thoroughness of blanching prior to dehydration. Some dehydrated foods such as leafy greens, shredded or finely cut vegetables, and thinly sliced fruits did not require soaking.

In most cases the food was brought slowly to the boiling point in the soaking water and cooked gently until tender. Cooking time was counted from the minute boiling started until the food was removed from the heat. The length of time needed varied with each vegetable and fruit. Except for some of the sweetpotatoes and snap beans, the cooking time of the freshly dehydrated product was used as the standard for cooking the stored samples. In a few instances, other methods of cooking were tried after storage to see if any improvement in the standard method could be made.

The cooked food was drained, the liquid measured in a graduate cylinder, and the solid food weighed in the pan in which it was cooked.

PALATABILITY STUDIES.—Palatability studies were used to evaluate various methods of dehydration and also to determine the effect of storage time, temperature, and container on the quality of the dried foods. Samples of the fresh food cooked by standard methods were used as controls. All vegetables tested were served hot. Some were seasoned with salt and butter, others were served plain. Fruits were chilled after cooking.

Three to five food judges rated the products for appearance, odor, flavor, and consistency or texture. Over-all palatability was rated in terms of the descriptive ratings: Very good, good, fair, poor, very poor.

VEGETABLES

SNAP BEANS

VARIETIES.—Kentucky Wonder, Ideal Market, Blue Lake, Burger, Brown Kentucky Wonder, Refugee, Asgrow New Stringless, Bountiful, White Kentucky (R. R. Series).

PREPARATION.—Beans were cut in 1-inch pieces, shredded, or left whole. They were precooked in steam until tender.

DEHYDRATION.—In a kerosene flue drier, at an average temperature of 150° to 160° F., the time required for drying varied from 6½ hours for a 9-pound load of shredded beans to 18 hours for a similar load of whole beans. One-inch pieces took as long to dry to the brittle stage as whole beans, probably because the rate of heat penetration and evaporation depended on the diameter of the pieces, which was the same in both cases.

Dried on a string in the laboratory at room temperature, whole beans precooked by steaming required 6 days to attain a moisture content of 6 percent. Whole beans not precooked required 14 days to dry to a moisture content of 5 percent.

RECONSTITUTION.—Fifty grams of dry beans were soaked for 2 hours in 1,000 ml. water at room temperature and cooked 10 to 25 minutes or until tender in the soaking water to which 10 gm. salt had been added. The cooked beans were drained, and seasoned with 10 gm. melted butter before serving.

QUALITY.—Quality was only fair, whether beans were dried whole, in inch pieces, or shredded. Color of the cooked product was brownish green or olive green, due to effects of heat on chlorophyll pigment. Odor and flavor were haylike and texture was fibrous.

Precooking improved the quality of beans dried on a string at room temperature. Precooked samples rated "fair;" those dried without precooking, "poor."

The original quality of dehydrated snap beans was maintained quite well during 6 months' storage at room temperature. In general, glass jars sealed with rubber rings, heavily waxed cartons such as those used in storing frozen foods, and friction-top tin cans proved suitable for storage containers. Paper bags and unwaxed cartons were less efficient in maintaining quality. High storage temperatures and presence of daylight did not seem to have as adverse an effect on the quality of dehydrated snap beans as on the quality of some of the other dehydrated vegetables that were higher in sugar or starches.

No appreciable difference was noted among the varieties of snap beans studied. All were fair in palatability and yellowish green in color. With improvement in dehydration process, differences due to variety might be more noticeable.

BEETS

VARIETY.—Detroit Dark Red.

PREPARATION.—Beets were steamed whole 30 to 65 minutes or until tender. Some were sliced, others diced.

Dehydration.—In a kerosene flue drier at 162° F., a 12.1-pound load of sliced beets required 10 to 12½ hours to dry until brittle. At 148° a 14.5-pound load of diced beets dried in 8 to 10 hours. Moisture content of the dried product was approximately 6.5 percent in both cases.

Reconstitution.—Fifty grams of dehydrated beets were soaked 1 hour in 300 ml. water and cooked until tender, 6 to 12 minutes. Two gm. salt and 10 gm. butter were added before serving.

Quality.—Freshly dried diced beets rated good, sliced beets fair. After 3 months' storage in friction-top tin cans at room temperature, both samples rated fair.

When spiced or prepared as Harvard beets, dehydrated beets closely resembled the fresh product in color, flavor, and texture.

BEET GREENS

Preparation.—The greens were steamed for 10 minutes.

Dehydration.—In a kerosene flue drier at 163° F., an 8-pound load required 5 to 6 hours to dry until crisp. The moisture content was 4 to 6 percent.

Reconstitution.—Eighty grams of dehydrated beet greens were soaked 5 minutes in 800 ml. water, 6 gm. salt were added, and the greens were cooked covered for 7 minutes.

Quality.—When freshly dehydrated, beet greens were rated fairly good in palatability and showed only slight deterioration when stored in a waxed carton for 6 months at room temperature.

CARROTS

Varieties.—Nantes, Oxheart, Imperator.

Preparation.—The carrots were cut into various forms—crosswise slices, diagonal slices, lengthwise slices, shreds, chips, dice—and steamed 10 to 13 minutes.

Dehydration.—All forms of carrots were dried in a kerosene flue drier at 148° to 152° F. and crosswise slices in a small electric cabinet drier at 145°. About 17 hours were required to dry the samples to the brittle stage. Crosswise slices dried in the kerosene drier had a moisture content of 10 percent or higher as contrasted with 6.7 percent for the samples dehydrated in the electric drier.

Reconstitution.—In preparation for palatability tests, 30 gm. dehydrated carrots were soaked until plump (1 to 6 hours) in 300 to 450 ml. water. The carrots were cooked covered in the soaking water until tender, 4 to 16 minutes, and seasoned with 2 gm. salt and 10 gm. butter.

Quality.—Freshly dehydrated carrots varied considerably in quality, depending on the variety and the manner in which they were cut. Diagonal and crosswise slices, chips, and shreds were generally rated higher (fair to good) than the lengthwise strips or dice (poor), because they reconstituted more completely and had a better appearance.

Color varied from light yellow orange in Oxheart variety to a deeper orange in Nantes and Imperator varieties.

Stored for 6 months in glass jars at room temperature, the carrots with a moisture content of about 10 percent deteriorated rapidly in palatability. Those with the lower moisture content of 6.7 percent deteriorated very little.

SWISS CHARD

VARIETIES.—Common chard, Large Ribbed Dark Green, Lucullus, Fordhook Giant.

PREPARATION.—Stems and leaves were separated. Stems were cut into pieces 1 inch long and ½ inch wide; leaves were cut with scissors into 2- to 3-inch pieces. Leaves were steamed 5 to 6 minutes and stems 15 to 25 minutes or until tender.

DEHYDRATION.—Common chard and Large Ribbed Dark Green were dried at the same time in a kerosene flue drier at 163° F., with a total load of 15.7 pounds. The time required was 6 to 7½ hours for the leaves and 9 to 10 hours for stems.

Lucullus variety was dehydrated at 157° in a kerosene flue drier. For a 5.2-pound load, 5 to 8 hours were required to dry leaves, 7 hours to dry stems.

For a 7.2-pound load of Fordhook Giant, a small cabinet-type electric tunnel drier at 158° was used. Both leaves and stems required 5½ hours.

All four varieties of chard dehydrated satisfactorily. The end point of drying was a crisp texture and a very dark green color. Moisture content of the dried chard varied from 4.8 to 12.6 percent.

RECONSTITUTION.—Forty grams of dehydrated Swiss chard stems were soaked 30 minutes in 500 ml. water and cooked covered 10 minutes; then 15 gm. leaves were added and cooking continued until leaves were tender, 3 to 5 minutes. Ten grams melted butter and 3 gm. salt were added.

QUALITY.—Initial quality of dried Swiss chard was fairly good. After 6-months' storage in waxed cartons at room temperature the chard rated fair to poor. The varieties differed little except in color of the reconstituted product. Lucullus was olive yellow with straw-colored stalks; Fordhook Giant was very dark green with tannish stalks; Common chard had green leaves and stalks; Large Ribbed was greenish black with tan-colored stalks.

CORN

VARIETY.—Yellow Bantam.

PREPARATION.—Whole kernels of corn were cut from cob and steam-blanched until milk was set (about 15 minutes).

DEHYDRATION.—Precooked corn was spread ½ to ¾ inch deep on drier trays. Some was dehydrated in a kerosene flue drier (natural draft) and the rest in an electric drier (forced draft), with the temperature in each case around 160° F. Corn was considered dry when it could be shattered by a blow of a hammer.

With a 28-pound load, the kerosene flue drier took 13 to 15 hours to dehydrate corn. With half as large a load (14 pounds) only 5½ to 7 hours were required. In the electric tunnel drier, 20 pounds of corn required 20 hours to dry.

The yield ranged from 25 percent of the prepared blanched weight when corn was dehydrated in the kerosene flue drier to 32 percent in the electric tunnel drier.

RECONSTITUTION.—(1) Sixty-eight grams of corn dehydrated in the kerosene flue drier were soaked 2 hours in 300 ml. water, and cooked covered 15 minutes. Melted butter and salt were added before serving. (2) Twenty-eight grams corn dehydrated in the electric drier were soaked 18½ hours in 240 ml. water and cooked covered 11 minutes. Butter and salt were omitted.

QUALITY.—Before storage, corn dried in the kerosene drier had a sweet flavor and was tender in texture, but rated only fair in over-all quality because of its appearance. After 6 months' storage at room temperature in waxed cardboard cartons, it had a somewhat lower rating due to deterioration in color.

Corn dehydrated in the electric drier rated good when freshly dried and fair at the end of 6 months' storage at room temperature. It was bright yellow in color before and after storage, but flavor had changed from sweet and natural to stale and starchy.

KALE

PREPARATION.—The kale was trimmed severely; heavy outer leaves, underdeveloped or crushed leaves, and heavy stems and midribs were discarded. It was then steamed 20 to 30 minutes.

DEHYDRATION.—Drying was done in a large electric drier with forced draft at three different temperatures. At 150° F. a 25.1-pound load took 9 to 11½ hours to dry; at 155° to 160° an 11.6-pound load took 3 to 3½ hours; at 180° an 11.8-pound load took 2 to 2½ hours. Moisture content of the kale after drying until crisp in texture ranged from 3.5 to 5.2 percent.

RECONSTITUTION.—Fifty grams of kale were cooked in 1,000 to 1,350 ml. water 11 to 15 minutes.

QUALITY.—Increasing the temperature of dehydration over 150° seemed to be detrimental to the quality of dried kale. Dehydrated at 150°, kale rated good when freshly dried; at 160° it rated fairly good, and at 180°, fair to poor. Kale that was good in palatability before storage was still fairly good after 3 months' storage in glass jars at 45° to 75°. Quality was fair after 1 to 3 months at 86° and after 6 months at 75°.

Study of various containers indicated that for storage of kale at moderate humidities only partially moisture-proof containers were necessary for retention of quality. Under conditions of high humidity, paper packages were unable to keep moisture content of the product low enough to prevent deterioration.

MUSHROOMS

PREPARATION.—Mushrooms were prepared for dehydration in the following ways: Whole mushrooms were sliced, separated caps and stems were sliced in some cases and left unsliced in others. Some of the mushrooms were dried without pretreatment; some raw-sulfured; some raw-brined; and some precooked by steaming 5 to 20 minutes.

DEHYDRATION.—Mushrooms were spread ½ to ¾ inch deep on drier trays. In a kerosene flue drier at 150° F. loads varying from 1.6 to 3.3 pounds were dehydrated in 6 to 7 hours. In a large electric tunnel drier at 150°, 11- to 19-pound loads were dried in 3½ to 5 hours for the smaller loads and 7 to 8 hours for the larger. Mushrooms hung on a string took 2 days to dry in the laboratory at room temperature in July. The test for dryness was a leathery to brittle texture.

Dried mushrooms that had been separated into caps and stems were carefully sampled. Caps and stems from each tray were weighed separately and the ratio for each tray load calculated. Dried mushrooms used for immediate testing and for storage purposes were weighed according to the cap: stem ratio which varied from 1.9:1 to 2.5:1.

RECONSTITUTION.—Several methods of reconstitution were tried. The general method was to soak 50 gm. mushrooms in 600 ml. water for ½ hour. Some of the mushrooms were simmered until tender and served plain or in cream sauce, some were browned in butter, some made into cream soup.

QUALITY.—Whether mushrooms were sliced or not had little effect on quality of the dried product. Raw untreated mushrooms were just as palatable as those brined or sulfured and definitely superior to steamed ones. Mushrooms dehydrated raw scored good to fair whereas those precooked scored fair to poor. As precooking time increased, the mushrooms became more tough and rubbery. Precooking also caused loss of flavor. Since mushrooms are generally used for flavoring purposes, this was considered a serious shortcoming.

In the precooked dehydrated mushrooms a light color was maintained; those not precooked became very dark. It is possible that a steaming time just long enough to inactivate the enzymes without toughening the texture might be used to prevent darkening, but this was not determined in this study.

No change in quality occurred in mushrooms stored 1 month at 45° or 80°. As storage progressed to 3 months, deterioration occurred in most samples regardless of pretreatment or storage temperature.

Reconstituted mushrooms were more palatable when used in cream soup or cream sauce than when simmered and served plain or when browned in butter.

MUSTARD GREENS

PREPARATION.—The greens were steamed 7 minutes.

DEHYDRATION.—A small cabinet-type electric drier at 138° F. was used. To dry a 20-pound load of greens until crisp required 6½ hours. The moisture content was 9 percent.

RECONSTITUTION.—Thirty grams of dehydrated mustard greens were cooked, without previous soaking, in 900 ml. water until tender (10 to 30 minutes); 10 gm. melted butter and 6 gm. salt were added.

QUALITY.—Freshly dehydrated mustard greens were fair in quality. Flavor was good but texture was slightly tough. After 12 months' storage in a 3-gallon slip-top tin can, opened at monthly intervals for removal of samples, texture was very woody, making the vegetables almost inedible. Flavor, however, was about the same as before storage.

GREEN PEPPERS

PREPARATION.—Green peppers were cut in halves, and seeds, cores, and white membrane removed. Some were steamed 10 to 15 minutes; some were not pretreated.

DEHYDRATION.—The peppers were dehydrated in a large electric tunnel drier at 150° F. until crisp. A 27-pound load required 20 to 22½ hours. The dried peppers had a moisture content of approximately 8 percent in spite of the long drying period.

RECONSTITUTION.—Dried peppers were soaked and cooked covered in various amounts of water. Peppers that had been blanched rehydrated more completely than the unblanched during both the soaking and the cooking periods. After soaking 2 hours the unblanched peppers had absorbed 2.7 ml. water per gm., whereas water uptake of the blanched was 4 ml. per gm.

QUALITY.—Blanched peppers rated fair to poor in quality; unblanched, poor. Length of soaking and cooking time apparently had no effect on palatability scores; samples rated the same whether they were unsoaked or soaked 2 hours, or cooked 10, 20, or 60 minutes. They also rated the same whether cooked in 30 or 45 times their weight of water. Reconstituted peppers had a strong, bitter flavor, and were characterized by tough outer skin and pulp of soft consistency. Under conditions used in this experiment no satisfactory results were obtained.

PUMPKIN

PREPARATION.—Pumpkin was pared. One lot was cut into 1½-inch strips about ¼ to ½ inch thick and steamed 8 minutes, until partially translucent. Another lot was cut into ¼-inch slices and steamed 13 minutes, until translucent throughout.

DEHYDRATION.—Less thoroughly steamed pieces of pumpkin were placed on edge in single layers on drier trays; those precooked 13 minutes were laid lengthwise in a single layer. A 32-pound load required 15 to 16½ hours to dry in a large electric tunnel drier at 160° F.

When dry, the pumpkin was leathery in texture. Pieces underdone in blanching were opaque and woody; those precooked until done remained translucent.

Reconstitution.—Ninety grams of dried pumpkin were soaked 2½ hours in 710 ml. water, then cooked 20 minutes, strained, and prepared as filling in a pie.

Quality.—Pumpkin prepared by either method rated good in palatability when prepared as filling in a pie.

SQUASH

Variety.—Hubbard.

Preparation.—Squash was sawed in halves, pared, and cut into strips or wedges 1½ inches long and ¼ to ½ inch thick. Some was steamed 8 to 10 minutes, some 15 minutes or until translucent.

Dehydration.—A 16-pound load of prepared squash was dehydrated at 160° F. in a large electric tunnel drier until leathery. Time required was 16 hours. The squash precooked by steaming 8 to 10 minutes was opaque and woody when dried. However, that steamed until translucent and tender was too soft to handle easily in transferring from steamer to drier tray.

Reconstitution.—Forty-five grams of dried squash were soaked 3 hours in 300 ml. water and boiled 30, 45, or 60 minutes. One sample was prepared as filling in a pie.

Quality.—Boiled dehydrated squash rated good to fair in palatability; as pie filling it rated good. Cooking time made little difference in the score.

SWEETPOTATOES

Varieties.—Orange Little Stem, Triumph, Nancy Hall, N. C. No. 1, B–204, B–219.

Preparation.—The sweetpotatoes were steamed until tender, then peeled. This proved to be a satisfactory method, far superior to lye peeling for home procedure. Lye peeling is inconvenient and even dangerous under conditions and with equipment found in most home kitchens. Peeling the cooked potato resulted in very low figures for waste in preparation. Losses due to peeling ranged from 12 to 18 percent for the different varieties. Orange Little Stem had the lowest percentage waste and Triumph the highest.

Peeled potatoes were sliced lengthwise about ¼ inch in thickness, dipped in 2-percent citric acid solution to prevent darkening, and drained.

Dehydration.—Sweetpotato slices were placed one layer deep on cheesecloth-covered drier trays. With drying loads varying from 14 to 27 pounds, the time required to dehydrate the sweetpotatoes to the brittle stage in a forced-draft electric drier ranged from 12 to 24 hours. Moisture content was approximately 5 percent. The dehydration temperature ranged from 120° to 195° F., with a finishing temperature around 150° in all cases.

Yield of dry product, calculated on the basis of the precooked product as it was ready to go into drier, was around 33 percent for all varieties except Orange Little Stem, which had a yield of only 23 percent. Apparently the total solid content of this variety was lower than that of the others.

RECONSTITUTION.—Dehydrated sweetpotatoes were soaked in four times their weight of water (just enough to cover) for 1 to 2 hours or until plumped, then cooked in soaking water until tender (10 to 30 minutes).

QUALITY.—Nancy Hall and N. C. No. 1 were varieties most suitable to the dehydration methods used in this study. Orange Little Stem, Triumph, B–204, and B–219 gave products fair in quality. Some of these rated only fair before dehydration. B–204 had an unattractive, grayish-cream color; Triumph and B–219 were yellow; Nancy Hall, Orange Little Stem, and N. C. No. 1 had an attractive orange color.

Stored at 32°, 45°, or 75° for 6 to 9 months, dehydrated sweetpotatoes changed very little in table quality, whether packed in air, carbon dioxide, or nitrogen. Color became duller in some samples and faded slightly in others, but color change did not affect palatability appreciably.

At a storage temperature of 100°, deterioration of quality was more rapid than at 75° or below, resulting in a poor product within 6 months. Only air packs were stored at 100°. The presence of an inert atmosphere might have improved the keeping quality at high temperatures, although heat alone may have caused the caramel odor and flavor, and brown color. The palatability scores showed better keeping quality for the citric acid treated sweetpotato than for untreated samples.

Glass jars, friction-top tin cans, and used coffee cans proved to be equally satisfactory containers for storing dehydrated sweetpotatoes. Cardboard boxes, on the other hand, were not satisfactory, since the percent relative humidity of the atmosphere at the time of this study was moderately high.

TOMATOES

VARIETIES.—Marglobe, Earliana New Smooth, Chalk's Early Jewel, Matchless, Bonny Best.

PREPARATION.—Unpeeled tomatoes were cut in ½-inch slices. Some of each variety were left untreated; some were treated as follows: Dipped in cold 0.5 percent calcium chloride solution 15 minutes; dipped in boiling water 4 to 5 minutes; dipped in boiling calcium chloride solution 4 to 5 minutes. Soft tomatoes were heated, sieved, and cooked until very thick to make tomato paste.

DEHYDRATION.—Loads of 9 to 20 pounds of tomatoes were dehydrated in approximately 12 hours in a kerosene flue drier at temperatures from 145° to 160° F. The tomatoes were leathery and a dull red when taken out of the drier. One experiment with solid trays and screen trays indicated that screen trays permitted somewhat faster drying than did solid ones and for that reason were preferable for use in a natural-draft drier such as the kerosene flue.

Tomato paste, after drying, was shaped into a roll and stored in glass jars.

Reconstitution.—Forty grams of dehydrated sliced tomatoes were soaked ½-hour in 400 ml. of boiling water, then cooked until tender (8 to 13 minutes) in a covered aluminum pan. In two cases half of the cooked sample was put through a strainer to remove seeds and skins.

Nine grams dehydrated tomato paste were soaked in 30 ml. boiling water until well dispersed (35 to 53 minutes).

All samples were judged while hot.

Quality.—Comparison of pretreated tomatoes with those having no pretreatment showed that, in general, pretreatment did not improve the product. Marglobe variety without pretreatment and pretreated by dipping in cold calcium chloride solution, and puree made from Chalk's Early Jewel without pretreatment were the only ones that rated fairly good in palatability. Others scored fair to poor.

Reconstituted tomato paste was of the consistency of tomato sauce. The product was fair in quality before storage. After 6 months at room temperature it had lost its characteristic tomato flavor and had become brown in color.

Since tomatoes can be canned successfully without the use of a pressure cooker, it seems that they should be preserved by that method rather than by drying.

TURNIP GREENS

Preparation.—Two lots of greens were steamed until just wilted; another lot was steamed until tender.

Dehydration.—In a kerosene flue drier at 140° F. an 8-pound load took 5 to 7½ hours to dehydrate; at 145° an 11-pound load took 7 to 8 hours. In a large electric tunnel drier at 170°, it took 6½ to 7 hours for a 10-pound load to dry. Moisture content of the greens, dried until crisp, was 3 to 8.2 percent.

Reconstitution.—Thirty grams of dehydrated turnip greens, unsoaked, were cooked uncovered until tender (12 to 15 minutes) in 900 ml. water to which 5 gm. salt had been added.

Quality.—Greens steamed until just wilted rated good in quality, whether dehydrated in the kerosene flue drier at 140° or in the electric tunnel drier at 170°. Greens steamed until tender were fair.

After 6 months' storage at 74° in paper bags, the dehydrated greens maintained their original quality fairly well; those steamed until just wilted before dehydration rated fairly good after 6 months.

Fruits

BLACKBERRIES

Preparation.—The berries were washed and drained.

Dehydration.—A small electric tunnel cabinet drier at 153° F. was used. Eleven pounds of blackberries, part of the total drier load, required 14 hours to dry until no moisture was visible when the berries were crushed.

Reconstitution.—Fifty grams of berries were soaked in 800 ml. water 16 hours and heated in a sweet thickened sauce made from the juice.

Quality.—Tested as a tart filling, dehydrated blackberries rated fairly good before storage and fair after 6 months at room temperature. Berries were chewy and seedy and lacking in natural fresh flavor.

CHERRIES

Variety.—Montmorency.

Preparation.—Some of the cherries were untreated; some were dipped in a lye bath. All but one lot of lye-dipped cherries were pitted.

Dehydration.—The cherries were dried at 125° to 145° F. over boiling water, in a tin-bottom improvised drier on a wash boiler, or on the lid of a ham boiler. One lot was spread one layer thick on trays and dried, together with several other foods, in a small electric tunnel drier. The cherries were considered sufficiently dry when they were only slightly sticky and had glossy skins. The wash-boiler drier, which required approximately 25 hours to dry a 3- to 4-pound load, was wasteful of time and fuel. The small electric tunnel drier took 14½ hours to dry a 14-pound load. This time might have been shortened had the cherries been the only food in the drier.

Reconstitution.—Fifty grams of dried cherries were soaked in 150 ml. water for 16 hours in a refrigerator, then cooked covered for 6 minutes. To make a tart filling 150 gm. dried cherries were soaked 14 hours in 600 ml. water and heated in a sweet thickened sauce made from the juice.

Quality.—All samples dehydrated in the wash boiler were faded and shriveled when reconstituted. Lye dipping proved harmful to appearance and flavor of cherries. When tested as stewed cherries after 10 months' storage, the undipped sample was fair in quality, the two lye-dipped samples were poor.

Drying on the lid of a ham boiler over boiling water was unsuccessful, resulting in very poor dehydrated products.

Untreated cherries dehydrated in the electric drier were attractive in color, tender, and natural in flavor when tested in a tart filling. They rated good both when freshly dried and after 6 months' storage at 75°.

PEACHES

Varieties.—Golden Jubilee, Fireglow, July Elberta, Goldeneast, Dewson.

Preparation.—Peeled and unpeeled peaches were cut in halves and pits removed. Some were sulfured 2 hours in sulfur fumes; some were steamed 3 to 5 minutes.

Dehydration.—Loads of 16 to 33 pounds were dehydrated in a kerosene flue drier at 154° F. in 13 to 18 hours. In a large electric drier at 150° to 152°, loads of 29 to 49 pounds dried in 18 to 48 hours. The peaches were considered dry when they were pliable and leathery.

Intermittent drying of peaches on 3 days in a kerosene flue drier was successful, whereas most other foods spoiled when left without application of heat for any length of time.

RECONSTITUTION.—One hundred grams of dried peaches were placed in from 300 to 370 ml. boiling water and soaked 1 hour. The fruit was cooked 4 to 16 minutes or until tender, then chilled.

QUALITY.—When peaches were sulfured and dried, Golden Jubilee, Fireglow, and July Elberta varieties rated good; Goldeneast and Dewson rated fair. Removal of the skin improved the appearance of peaches, the difference being more noticeable in unsulfured peaches. Steaming before dehydration did not give as good results as sulfuring.

After 6 months' storage at room temperature in waxed cartons, dehydrated peaches showed little change in quality with the exception of two samples that spoiled, owing probably to too high moisture content.

PEARS

PREPARATION.—Pears were peeled, cored, and cut in quarters or eighths, then sulfured 3 hours in sulfur fumes.

DEHYDRATION.—In a top-of-stove cabinet drier at 142° F., pears, dehydrated together with some prune plums, dried in approximately 20 hours. They were leathery with a springy feel when dry.

RECONSTITUTION.—Fifty grams of dehydrated pears were covered with 240 ml. boiling water, soaked 1 hour, then simmered 5 minutes.

QUALITY.—Color of reconstituted dried pears was almost the same as that of fresh pears. Samples stored in waxed paper cartons for 6 months at room temperature were fairly good, almost the same as immediately after dehydration; texture was slightly more firm and chewy.

A cooking time longer than 5 minutes might have improved the texture of pears cut in quarters, since those cut in smaller pieces and therefore requiring less time were rated more tender.

PRUNE PLUMS

PREPARATION.—Plums were cut in halves and the pits removed.

DEHYDRATION.—Plums were dehydrated together with pears in a top-of-stove cabinet drier at 145° F. Approximately 5 pounds plums out of a total drier load of 10 pounds took 24½ to 26 hours to dry until pliable and leathery.

RECONSTITUTION.—Fifty-five grams of dehydrated plums were placed in 180 ml. boiling water, soaked 1 hour, and simmered 8 minutes with 10 gm. sugar added.

QUALITY.—Dehydrated plums rated fair and retained initial quality after 6 months' storage in a glass jar at room temperature.

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