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FOOD STORAGE EFFECTS

Changes in Light Reflectance and Ascorbic Acid Content of Foods During Frozen Storage

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Reflection measurements made by a General Electric recording spectrophotometer and reduced ascorbic acid values determined by a conventional method of assay on samples prepared in a uniform manner from frozen fruits and vegetables stored at +10°, 0°, and −20° F. for 12 months reveal that the storage temperature had a very definite effect on the capacity of the foods to reflect visible light and on the reduced ascorbic acid content of the foods. The greatest change in reflectance and in vitamin content occurred in foods that had been stored at the higher temperatures. Changes in the reflectance of the foods during frozen storage seem to parallel changes in ascorbic acid content.

Color is recognized as one of the important factors in determining the acceptability of foods to the consumer. Proper color is usually regarded as an indication of the quality of a natural food. While a degree of correlation exists between color and quality in some foods, it appears less definite in other foods. Color is a readily evident characteristic that is widely considered in the quality grading of food. Food control officials, in general, have included color as a quality characteristic in setting up standards for marketable foods. On the other hand, nutritional investigators have associated changes in ascorbic acid content with changes in food quality.

Visual differentiation in food colors is subject to inherent errors which are dependent upon a number of factors, including the grader's ability to detect small color differences and to correlate these differences with the different grades of food. This ability is frequently affected by optical fatigue, lighting conditions, and other factors.

In recent years attempts have been made to eliminate the personal element in the measurement of color changes or color differences in foods. Some devices, as well as their application, have been described (*1–5, 8*). One device which has performed satisfactorily in measuring reflectance directly and color indirectly and has yielded reproducible data under properly controlled operating conditions is the General Electric (Hardy) recording spectrophotometer, used for the reflectance measurements reported here. While the reflectance data recorded by this instrument constitute informative and useful information, this information is not identical with that obtained through visual inspection. The instrument measures physical properties directly, which may be translated indirectly into color components through mathematical manipulation.

Evaluation of the changes in the ascorbic acid content of most foods presents a less complicated problem, as relatively simple and effective methods are available for measuring both the reduced form and total ascorbic acid content of many foods, particularly the ascorbic acid content of foods that have not been heated extensively.

For several years the Pennsylvania Agricultural Experiment Station has studied the influence of certain technological factors on the quality of frozen foods, with particular reference to methods of preparation and handling previous to freezing, methods and rate of freezing, and temperature and duration of storage. These studies have involved the cooperative efforts and facilities of several subdivisions of the institution, particularly Agricultural Engineering, Animal Husbandry, Bacteriology, Biochemistry, Foods and Nutrition, and Horticulture. The Department of Biochemistry has assayed for vitamins, measured reflectance and "drip," determined moisture, free fatty acids, and ether extractable materials, and tested for enzyme activity. Some of the data obtained in these cooperative studies have appeared in print (*6*, *7*). At this time the changes in reflection and in the ascorbic acid content of typical fruits and vegetables are reported.

Experimental

The data reported are concerned with changes which took place in fruits and vegetables primarily during frozen storage. While measurements were made in both transmitted and reflected light, only the results of reflection measurements are reported, inasmuch as the physical condition of the foods, the extractability of pigments, etc., made it difficult to prepare fruit and vegetable extracts that yielded reproducible transmittance values under all conditions of the investigation. Reflected lights are the principal ones involved in the selection of foods.

The foods used in this study, as well as the steps taken in preparing these foods for freezing, are described in Table I. Each food was of known origin and was selected for the particular study just previous to freezing. The vetables were carefully sorted, blanched, packaged in the specified containers, and frozen. The fruits were hand-picked, stemmed, pitted, or peeled, sugared, and frozen in plastic containers. Samples of each food were stored at +10°, 0°, and −20° F. for 1 year.

Preliminary reflectance measurements made on duplicate samples of foods that provided a nonuniform reflectance surface revealed that reproducible recordings could seldom be attained, as had

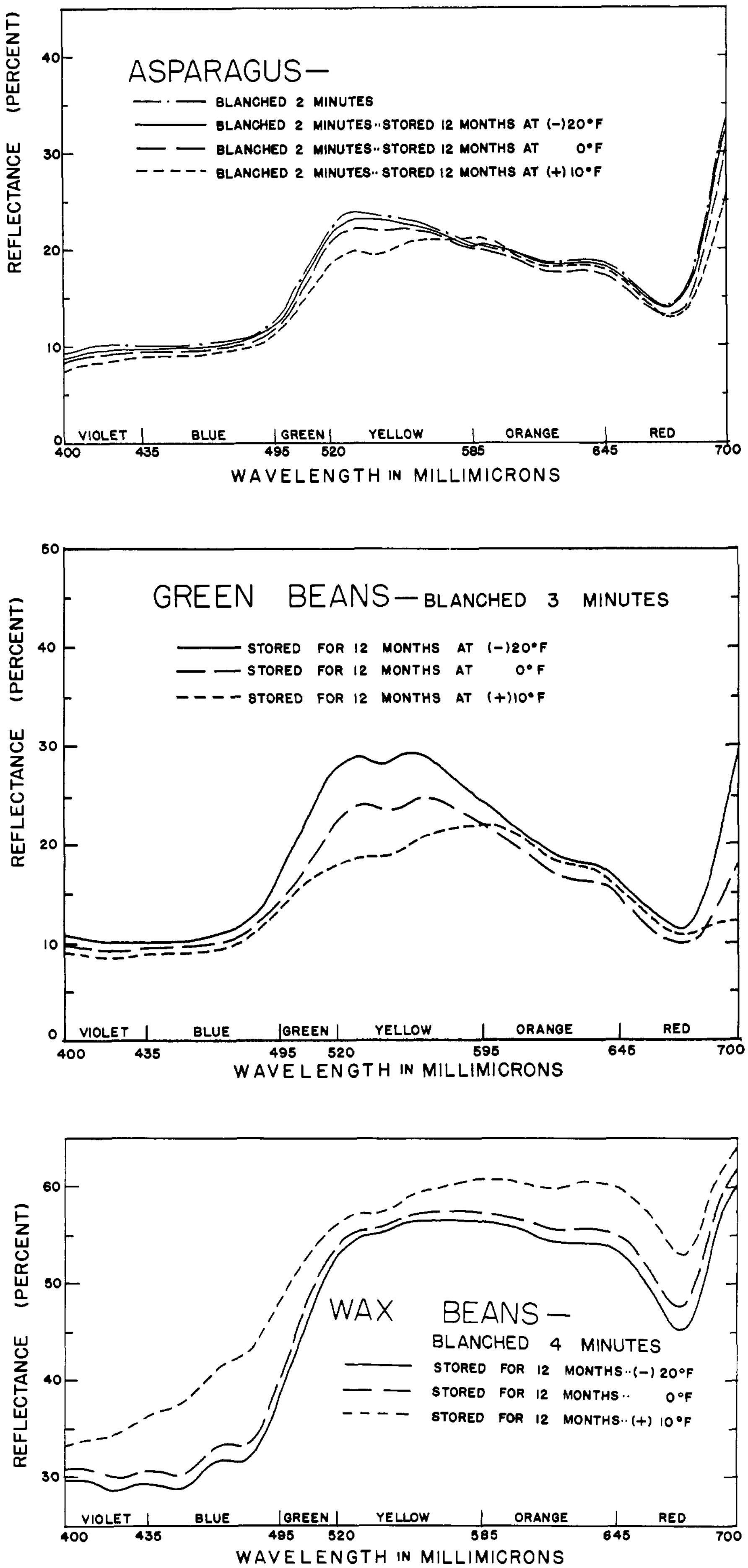

Figure 1. Light reflectance of frozen vegetables

Table I. Foods Reported on and Essential Steps Taken in Preparing Them for Freezing

Food	Variety	Preparation for Freezing
Asparagus	Martha Washington	Washed in cold water, tender parts of stalk cut into 1-inch pieces, blanched for 2 minutes in 200° F. water, cooled in iced water, drained, packed in pint-size plastic containers, frozen to −8° F.
Beans	Burpee Green Pod	Washed in cold water, ends removed, beans cut into 1-inch lengths, blanched for 3 minutes in 200° F. water, cooled in iced water, drained, packed in pint-size plastic containers, frozen to −7° F.
Beans	Wax, Cherokee	Washed in cold water, ends removed, beans cut into 1-inch lengths, blanched for 4 minutes in 200° F. water, cooled in iced water, drained, packed in pint-size plastic containers, frozen to −19° F.
Broccoli	Green Sprouting	Washed in cold water containing 0.5 lb. of salt per 50 gallons, cut into 4.5 × 0.5 inch pieces, blanched for 2 minutes in 200° F. water, cooled in iced water, packed in pint-size plastic containers, frozen to −16° F.
Cauliflower	Holland Effurt	Heads soaked in salted water for 15 minutes, separated into flowerets about 1 inch in diameter, blanched for 2 minutes in 200° F. water, cooled in iced water, drained, packed in 1$^1/_2$ pint-size plastic containers, frozen to −25° F.
Corn	Golden Cross Bantam	Shucked, silks brushed off, blanched on cob for 4 minutes in 200° F. water, cooled in iced water, cut from cob (cob scraped), packed in pint-size plastic containers, frozen to −36° F.
Spinach	Savoy	Washed twice in cold water, drained, stems removed by hand, blanched for 1.5 minutes in 200° F. water, cooled in iced water, again drained, packed in pint-size plastic containers, frozen to −50° F.
Peaches	Elberta	Held at room temperature until completely ripe, washed in cold water, dipped in boiling water for 10 seconds, skins removed by hand, cut into 12 slices each, slices from 6–8 peaches placed in plastic containers, covered with 60% sirup, frozen to −10° F.
Strawberries	Premier	Washed in cold water, drained, stemmed, large berries cut in half, 1 part of sugar added to 4 parts of berries, mixed, packed in pint-size plastic containers, frozen to −22° F.

been indicated by the studies of Eastmond, Peterson, and Stumpf (*3*) with shelled peas. In order to increase the uniformity of the reflecting surface, all foods were blended before being subjected to reflectance measurement.

Representative samples of fruits (100 grams), taken at certain stages during the preparation for freezing and at intervals during frozen storage, were blended in a Waring Blendor until the product had a uniform consistency. This usually required 2 or 3 minutes of continuous blending, depending on the nature of the food. As reflectance measurements made on successive aliquots of the foods immediately after blending frequently led to inconsistent recordings, the blended foods were allowed to stand at room temperature for 10 minutes to allow the greater portion of the incorporated air to escape before proceeding with the measurement. The blended foods were then stirred gently to ensure uniformity of composition and a portion was transferred to one of a pair of matched optical cells of such dimensions as would completely cover the reflectance window of the recording spectrograph. If the blended food was carefully transferred to the optical cell while the cell was held in an inclined position, the lower face of the cell was free of air bubbles. This face was always placed before the reflectance window of the instrument. Reflectance was measured in the usual manner, by using a magnesium oxide reference standard which was prepared at frequent intervals by packing finely dispersed magnesium oxide (Baker's an-

Table II. Steps Taken in Preparing Samples for Reflectance Measurement

			Steps Taken in Preparing Samples[a]	
Food	Variety	Grams	Water added, g.	Time of blending, min.
Asparagus	Martha Washington	100	+100	3
Beans	Burpee Green Pod	100	+100	3
Beans, wax	Cherokee	100	+100	3
Broccoli	Green Sprouting	100	+100	3
Cauliflower	Holland Effurt	100	+100	2
Corn	Golden Cross Bantam	100	+ 50	2
Spinach	Savoy	100	+100	2
Peaches	Elberta	200 (including sirup)		3
Strawberries	Premier	200 (including sugar)		2

[a] The author acknowledges the technical assistance of R. T. Pierce.

Table III. Reduced Ascorbic Acid Content of Foods

Food	Ascorbic Acid Content after Freezing, Mg./100 G.	Ascorbic Acid Retained[a] after 12 Months of Storage, % +10° F.	0° F.	−20° F.
Asparagus	40	10	100	100
Beans, green	14	5	70	100
Beans, wax	22	15	75	100
Broccoli	78	15	75	90
Cauliflower	78	5	35	80
Corn	9	5	35	80
Spinach	31	10	45	90
Peaches	6	25	75	75
Strawberries	38	25	85	100

[a] To nearest 5%.

alyzed, C.P., MgO) into the other optical glass cell and then checking its performance against a didymium glass filter before and after each series of reflectance measurements.

Weighed portions of the vegetables were blended with an equal weight of distilled water in order to obtain a product having suitable consistency for reflectance measurement. The reflectance was measured in the same manner as with the fruits.

Ascorbic acid determinations were made on extracts of the fruits and vegetables prepared by blending 40-gram portions with 200 ml. of a solution of 0.5% oxalic acid in a Waring Blendor for 3 minutes and filtering the extract through coarse filter paper. Reduced ascorbic acid was measured by direct titration of the extract with a standardized solution of 2,6-dichlorobenzenone-indophenol.

In Table II are listed the essential steps in preparing samples for reflectance measurements. Reflection measurements were made in some instances during the preparation of the food for freezing, always after the food had been frozen, and again after 4, 8, and 12 months of frozen storage.

Results

Ascorbic acid values of the foods after being frozen and after 12 months of frozen storage at the three temperatures stipulated are presented in Table III.

Typical results of the reflectance measurements are presented in Figures 1 to 3, in the recorded form, rather than after being integrated into their tristimulus values. To facilitate interpretation, the wave length ranges frequently assigned to the color components of the visible spectrum (400 to 700 mμ) have been inscribed on the abscissas of the graphs. On each graph is presented also a brief explanation of the reflectance curves.

Discussion

The reflectance graphs reported are for foods frequently preserved in the frozen state. Changes in food reflectance during frozen storage varied with the food, with the storage temperature, and with different portions of the visible spectrum. As these changes tended to increase with storage time, the reflectance data reported are for foods that had been maintained in frozen storage for 12 months.

Blending of foods to produce uniformity of composition previous to measuring light reflectance may result in less contrast in reflectance than would have

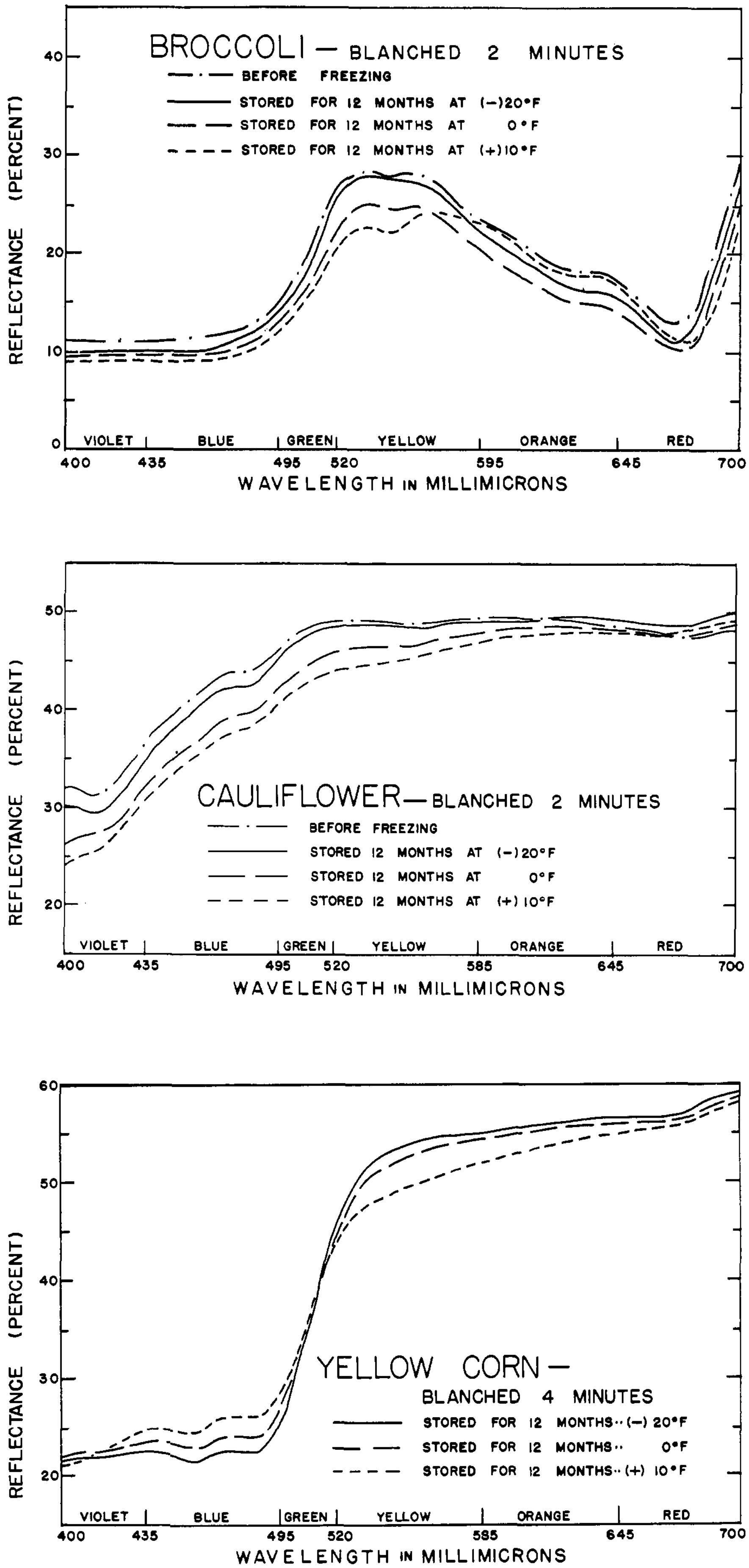

Figure 2. Light reflectance of frozen vegetables

been recorded had it been feasible to effect reproducible recordings on comparable samplings of the unblended foods. Foods while in frozen storage generally undergo a more marked change in pigmentation on the surface of the package than in the interior. Many foods naturally are more highly pigmented on the surface than internally; hence, blending of such foods tends to dilute pigmentation. Furthermore, the addition of water to food before blending to promote the formation of a homogeneous blend further dilutes pigmentation, and undoubtedly affects the reflectance recorded. Changes in pigmentation frequently take place more rapidly in blended than in unblended foods, but such changes are usually more marked in unblanched than in blanched foods. Hence, it would appear advantageous to carry out light reflectance measurements on the unaltered foods in frozen condition. However, reflectance measurements attempted on foods in this state have invariably yielded erratic and irreproducible data. The dilution and blending of the foods and the permitting of the blended food to stand until the contained air has escaped, undesirable as these treatments may be, lead to reproducible data. Data obtained under the stipulated conditions admittedly are not absolute values, but are relative values that permit a comparison of the effect of the one variable under study —namely, the effect of the storage temperature on the capacity of similarly treated frozen foods to reflect wave lengths of light comprising the visible spectrum.

In the studies reported, the blended foods reflected less light after standing for 10 minutes at room temperature than immediately after blending. This was believed to be due primarily to differences in the amounts of dispersed air contained by the samples. Furthermore, repeated reflectance measurements on a series of aliquots of a blended food after it had stood for the specified period yielded essentially the same recordings. This was interpreted as indicating essentially no change in the reflective capacity of the blended food during this interval which could not be attributed to the escape of incorporated air.

Asparagus, being relatively deficient in plant pigments, underwent no great change in reflectance as the result of either blanching or temperature of frozen storage. The greatest change

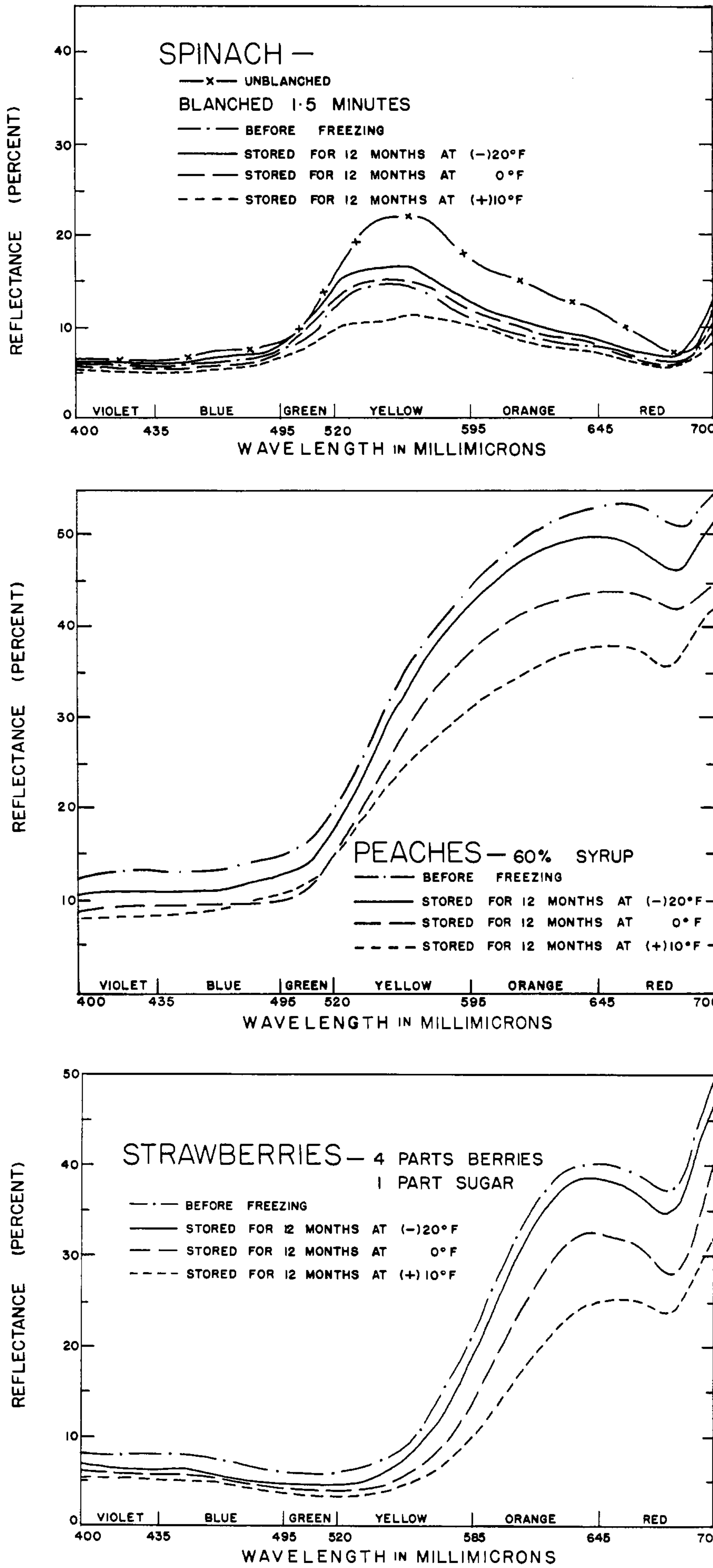

Figure 3. Light reflectance of frozen vegetables and fruit

was in the green-yellow region of the visible spectrum (520 to 550 mμ) and the extent of the change increased with an increase in the temperature of storage. These changes in reflectance indicate a darkening of the asparagus, most evident in samples stored at +10° F. Table III shows that ascorbic acid retention was favorable in all samples of asparagus except those stored at +10° F.

Green beans, on the other hand, underwent marked changes in reflectance as the result of storage for 12 months. The change was greatest in the green-yellow region and in the longer wave lengths of the red region. The beans stored at +10° F. were definitely darker than those stored at 0° or at −20° F., as was indicated by the lower reflectance recorded, particularly in the green-yellow range. Here again, ascorbic acid retention was lowest in the beans undergoing the greatest change in reflectance.

Wax beans, unlike green beans, produced a higher reflectance after being stored at +10° F. than at −20° or 0° F. for 12 months. The reflectance measurements indicated that the beans became definitely lighter in color during storage at the higher temperatures. Furthermore, the maximum change in reflectance occurred at 420 to 500 mμ, which suggests that at least part of the change in reflectance was due to a greater loss of carotenoid pigments at the higher storage temperatures. Ascorbic acid retention was less favorable in the beans undergoing the greatest change in reflectance.

Broccoli, like green beans, sustained its greatest change in light reflectance in the green-yellow region of the spectrum and the change was most evident in samples that had been stored at the highest temperature. Reflectance data indicated that the broccoli stored at +10° and 0° F. darkened more than that stored at −20° F., and the ascorbic acid data showed the lowest vitamin content in the samples having the lowest reflectance.

Cauliflower, being relatively low in chlorophyll, did not show a markedly depressed reflectance in the red region of the spectrum. However, there was evidence that the vegetable became darker, as was indicated by a decrease in reflectance, particularly in the blue-green-yellow region; the effect was most evident in cauliflower that had been stored at the higher temperatures. All samples of cauliflower decreased in vitamin content during frozen storage, but the decrease was greatest in samples showing the greatest decrease in reflectance.

Samples of yellow corn, after being stored at the three temperatures for 12 months, yielded a rather interesting pattern of light reflectance. Recordings in the blue region of the spectrum indicated that the corn became lighter in color when stored at +10° F. than at 0° F., whereas similar recordings in the longer wave lengths (yellow-orange-red region) indicated that this food actually became darker when stored at the higher temperature. The higher reflectance recorded in the blue region of the spectrum may have been related to a decrease in the carotenoid content of the corn, owing to the effect of the storage temperature on the stability of carotenoid pigments, and the darkening effect noted in the longer wave lengths may be an indication that the corn has become more grayish in color. Here again ascorbic acid data indicate the lowest retention of the vitamin in samples of corn that underwent the greatest change in reflectance.

Spinach yielded reflectance recordings similar to those of asparagus, green beans, and broccoli. The effect of storage temperature on the reflectance of this vegetable was evident throughout the range but was most marked in the green-yellow-orange region, with the spinach that had been stored at the higher temperatures becoming measurably darker as indicated by a lower reflectance. Spinach stored at +10° F. retained only 10% of its prestorage ascorbic acid content, while that stored at 0° and at −20° F. retained 45 and 90%, respectively.

Peaches stored for 12 months at the three temperatures underwent considerable change in reflectance throughout the visible range, the most significant change being in the orange-red region. Here again, the higher the temperature of storage the darker the fruit became during frozen storage. Peaches stored at +10° F. for 12 months lost 75% of their ascorbic acid, whereas those stored at 0° or −20° F. lost only 25% of the vitamin. Although the data are not included, peaches frozen in 30% sirup yielded a lower reflectance (darker) at the end of the storage period than peaches frozen in 60% sirup. The addition of 0.1% ascorbic acid to the sirups resulted in the fruit's having higher reflectance (lighter) at the end of the storage period; the effect of the ascorbic acid on reflectance was most marked when the vitamin was added to the 30% sirup and storage was at +10° F.

The temperature of storage for 12 months had a definite effect on the reflectance of strawberries, which was most noticeable in the orange-red region. Berries stored at +10° F. yielded a measurably lower reflectance (darker) than those stored at 0° F. and a much lower reflectance than those stored at −20° F. In fact, strawberries stored at −20° F., while yielding a slightly lower reflectance throughout the visible range, showed good retention of the orange-red pigments and excellent retention of ascorbic acid. On the other hand, strawberries stored at +10° F. showed a reduced reflectance in the orange-red region and retained only 25% of their prestorage ascorbic acid content.

With the exception of wax beans and yellow corn, the foods whose reflectance values are reported showed not only evidence of reflecting a lower intensity of light after storage at the higher temperatures for 12 months, but also evidence of reflecting light of a longer wave length, as was indicated by the shift in reflectance maxima. This would seem to merit the interpretation that the foods became darker in general (lowered reflectance), the green foods became more yellowish, the orange-tinted foods took on a more reddish color, and the light red pigments assumed a darker red coloration during storage.

Both peaches and strawberries, under the condition of measurement, yielded reflectance curves which indicated the presence of chorophyll. This was a rather general observation and it seems to be equally true of the commercially frozen fruits.

Reference to the graphs and to the data presented in Table III indicates a degree of correlation between the changes in reflectance, as measured at the end of 12 months of storage and as influenced by differences in storage temperature, and the change in the reduced ascorbic acid content of the respective fruits and vegetables. Those samples of fruits and vegetables which changed most in reflectance during frozen storage also decreased most in ascorbic acid content.

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