THE EFFECT OF SCALDING AND STORAGE ON ENZYME ACTIVITY AND FLAVOR RETENTION IN FROZEN ASPARAGUS

By

Agneta A. Rappe

AN ABSTRACT

Submitted to the School of Graduate Studies of Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Department of Food Technology

Year 1952

Approved C L Bedford

AGNETA A. RAPPE

ABSTRACT

A study was carried during the 1951 season on the effect of various scalding treatments and storage time on enzyme activity and flavor retention in frozen asparagus.

The asparagus was harvested at five different times under a period of three weeks, and every time processed within three hours after harvest. Three different scalding media were tried, boiling water, steam and infrared light, for various lengths of time. After scalding the asparagus stalks were cooled, dry-packed, frozen and stored for seven months.

Before and after scalding and at the end of the storage period the stalks were tested for peroxidase and catalase activity. The results from the enzyme tests indicated that 2-minute scalding, either in steam or boiling water is necessary to completely inactivate the enzymes. Shorter scalding time could bring about temporary inactivation, but regeneration was apt to occur during the storage period. The exposure of the asparagus to infrared light for 5 to 15 minutes did bring about a temporary inactivation, but after the storage period high activity of both catalase and peroxidase was noticed.

AGNETA A. RAPPE

ABSTRACT

On subjective evaluation of the asparagus for flavor, color and texture, it was found that the quality coincided fairly closely with the enzymatic activities. The under-scalded material, in which enzyme activity was detected, had an hay-like off-flavor and poor color and texture. Over-scalding also seemed to have a detrimental effect, with loss of flavor and softening of the texture.

The best quality of the frozen, thawed asparagus was obtained after 2-minute water- or 2- to 3-minute steam-scalding. There did not appear to be any appreciable difference in the effect of water and steam as scalding media.

The samples scalded under infrared light all had a very definite off-flavor, and increasing scalding time did not seem to improve the quality. From this experiment it thus can be concluded that infrared light is not a satisfactory scalding medium for asparagus to be frozen.

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ACKNOWLEDGMENTS

It is a pleasure to express my appreciation to Dr. C. L. Bedford for his continuous help and valuable advice throughout the course of this investigation and in the preparation of the manuscript.

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INTRODUCTION

Asparagus is one of the more important vegetable crops grown in the United States. At present the public demand for asparagus is high both during the growing and out of season months. Its popularity among the consumers is primarily attributed to its fine structure and taste. In addition to its palatable advantages, asparagus stands rather high among the vegetables for its nutritive value. An indication of the increasing popularity of asparagus among American families can be gained from the fact that the United States' acreage of asparagus increased from 30,600 acres in 1925 to 132,910 acres in 1950. Michigan is fifth in total acreage in the United States, having 5,700 acres. Asparagus is grown over the whole country, with California as the main producer.

The harvesting season for the asparagus plants is relatively short, lasting about one month. Due to this fact and because of the high popularity of asparagus, there has been great interest in preservation methods that will retain good quality. Up to 1930 most asparagus was preserved by canning. However, with the basic principles of freezing established by

Kohman (24), Cruess and Joslyn (19), more interest has been shown in freezing preservation. Since 1942 the amount of frozen asparagus has increased from about 2,000 tons to 9,000 tons in 1950.

One of the decisive advantages of the frozen products over the canned ones is their closer similarity to the fresh material. The degree of this similarity, however, depends on the quality of the raw material and the manner of handling it from the time of harvest till it is consumed. Immediately after harvest the asparagus shoots start to change in composition and structure, with consequent impairment in flavor, appearance and nutritive value (17). At present the knowledge of the factors involved in this rapid deterioration is relatively meager, but there are reasons to believe that the nature and the activity of the enzymes present in the tissue are of specially great importance. Therefore, most of the research work in freezing of asparagus, as well as most other vegetables, has centered around this factor.

Recently, Michigan processors have reported the development of off-flavor during frozen storage of asparagus, even when considered adequately scalded. In order to obtain further

information on the types of enzymes involved and the extent of scalding necessary for flavor retention, the present study was made to determine the effect of scalding and storage on enzyme activity and flavor retention in frozen asparagus.

REVIEW OF LITERATURE

Raw Material

The interest developed in the study of the factors affecting the quality of frozen vegetables has originated primarily from the difficulties encountered in producing a high quality end product. Kohman (24), Joslyn and Cruess (19), who were the first to experiment with vegetable freezing, did not pay much attention to the difference in quality obtained with different varieties. But later several investigators showed that the quality of the frozen product depends not only on the processing methods, but also on growing conditions, variety, maturity and freshness of the vegetable used. As a result of detailed studies on several vegetables, varietal recommendations have been given (11), (23), (40).

The physical and chemical factors affecting the growth of asparagus were summarized by Working (45) as early as 1924. Several investigators (1), (36), have given recommendations on the cultivation of asparagus. Peaty loam or light, sandy soils, high in organic matter, are considered the best

growing media. These soils are very rich and usually need no fertilization. They are found in delta lands, where also the possibilities for efficient watering systems are present. Asparagus grown in the Sacramento and San Joaquin valleys of California, where the growing conditions are excellent, are considered superior to asparagus grown in other sections of the country.

The two varieties of asparagus used in the freezing industry are the Mary and Martha Washington (41). Their green color and the characteristic of not shriveling on freezing and thawing give them the desired properties for freezing. An additional advantageous property is that the stalks are succulent and comparatively free from woodiness.

When the asparagus stalks have reached the approximate height of 12 to 14 inches over the surface of the ground, they should be harvested before the buds open up to a great extent. The harvesting of asparagus is completely hand operated, and is done either by cutting or "snapping." The latter method is most commonly used, because it gives a more uniform product, and at the same time saves about 50 percent of the labor, compared to the other method (6).

Asparagus should be harvested with reasonable care, because bruising or damaging the tender epidermis results in focal points for growth of microorganisms and increased action of enzymes. Joslyn and Bedford (17) have summarized physical and chemical characteristics of developing asparagus shoots. Joslyn (14) explains that mechanical injury as well as freezing disorganizes the tissues, renders them permeable and liberates the enzymes. Thus the chain of reactions in the cell is disturbed and intermediate products might accumulate and cause off-flavor and odor. Enzyme activity and thus also respiration are definitely affected by temperature. Penzer (31) has reported that with a rise in temperature of about 20° F., within the range of 32° to 80° F., a three-fold increase in the respiration rate of the vegetable tissue is not uncommon.

Fast growing vegetables, especially the growing tips, show high degree of metabolic activity. Asparagus is probably the most "live" material that is dealt with in commercial horticulture. Its respiration rate is about twice as great as that of most other vegetables (31). For this reason it is of considerable importance that the asparagus stalks be processed as quickly as possible after harvest. More than a few hours'

holding period in ordinary temperature is very detrimental. If immediate processing is not possible, the asparagus should be chilled in ice-cold water or stored in a temperature just above the freezing point (41). This precooling, besides checking the rate of respiration, controls other reactions, such as conversion of sugar to starch and oxidation of ascorbic acid to dehydro-ascorbic acid. The activities of microorganisms, which attack the asparagus tissue, are also checked by temperatures of 40° F. or lower (37).

Scalding

The necessity of scalding vegetables for freezing, in order to inactivate the enzymes and preserve quality, has been shown by several investigators (12), (19), (24), (29). Joslyn (16) pointed out that the destruction of the enzymes by heat should be carried out under conditions which would result in the minimum injury to flavor and texture. Joslyn and Marsh (22) indicated after a freezing study on peas, string beans and spinach that there is a critical temperature range, somewhat different for each vegetable, at which flavor and texture are best. The problems involved in the destruction of enzymes by heat, and their

possible regeneration have been summarized by Ball (4). During the years from 1935 and up till the present time several studies have been reported, dealing with vegetable freezing, and much information concerning the scalding time for different vegetables has become available (21), (41). Joslyn and Bedford in 1940 (17) studied the freezing of asparagus. They reported that scalding time for over two and less than five minutes, in either steam or boiling water, is required for proper retention of flavor and color in asparagus.

It was found of great importance to have tests which will give indication of adequate scalding of vegetables. The methods used for this purpose almost all center around measuring different enzymatic activities. Though not one particular enzyme can be ascribed as responsible for the deterioration of the frozen material, it is now commonly accepted that one or more of the respiratory enzymes are involved (14). Tests for peroxidase and catalase have been extensively used and have continued to provide adequate information concerning scalding time.

Joslyn and Marsh (22) observed that peroxidase was present in tissues of vegetables which retained their flavor during freezing storage. This led them to believe that peroxidase

may not be the causative agent involved in the deterioration. Even so, peroxidase test has been found to serve as a satisfactory index for adequate scalding (4). Tressler (39) implies that the deterioration reactions are both oxidative and hydrolytic in nature, and suggests that enzymes like catalase and tyrosinase are involved. Diehl, Dingle, and Berry (12) found that the catalase activity in peas served as a good index for adequate scalding. However, at the present time the peroxidase test is considered of higher validity than the catalase test, because peroxidase was found to more closely parallel the enzymes involved in the off-flavor formation than catalase (15). Further, this enzyme seems to offer the best possibilities for adaptation to a simple and rapid quantitative determination (26).

Boiling water and steam are the two commonly used media in scalding of vegetables. The boiling water method, though more rapid than steam, has the disadvantage of dissolving and leaching away parts of the soluble constituents, typified by ascorbic acid. In steam scalding only a minimum of leaching of dissolved nutrients is possible (28). Batchelder, Kirkpatrick, Stein and Marron (7) however, were not able to detect any appreciable difference in the palatability and ascorbic acid content

of asparagus scalded in steam for 3 to 6-1/2 minutes and in water for 3 minutes. Bedford and Joslyn (17) indicated that steam scalded asparagus was somewhat superior to water scalded.

Freezing

When a food product is frozen the low temperature retards the rate of deterioration and thus provides a means of preservation. However, during freezing and thawing certain irreversible changes occur, that render the frozen and thawed product quite different from the fresh in texture and general appearance. Woodroof (43) has given a good summary of the changes that occur and the various theories offered in explanation thereof. He and several others (9), (20) seem to favor the theory that the collapse of the tissue after thawing is caused by puncturing of the cell walls during the formation of ice crystals. The effect of freezing rate on the formation of ice crystals is evident. The generally accepted rule is that the slower the freezing rate, the larger the ice crystals and the more rupture of the tissue (25), (32), (33). Joslyn and Marsh (20) however, studied the effect of freezing rate and came to the conclusion

that, with the possible exception of asparagus, rapid freezing rate did not improve the texture of the vegetables.

McArthur (27) studied the effect of five different freezing methods on asparagus. She found that freezing of the unpacked product by immersion in freezing liquid caused the least rupture of the tissue. Airblast on the packed product at both -20° F. and at 0° F. caused very little tissue rupture, but less in the dry packed than in the wet packed product. Contact freezing at as low a temperature as -50° F. caused very little tissue rupture, but at higher temperatures quite extensive rupture was noticed. Plagge (34) reported that a temperature of approximately 0° F. is satisfactory for freezing of most vegetables. Objections have been raised against this statement and later reports advise a freezing temperature of -5° to -10° F. as preferable for several vegetables (27). Bedford and Joslyn (17) concluded from their study on asparagus that any freezing method at a temperature of -10° F. or lower will give a satisfactory product with this particular vegetable.

Frozen Storage

Proper pretreatment and freezing alone will not insure a first class frozen product on the market. Successful storage is as important as freezing itself. A frozen food product should be able to keep its quality during at least a year. The quality of frozen vegetables is directly related to storage temperature, so that the lower the storage temperature the more satisfactory the preservation (44). However, reasons of economy dictate that frozen food storage must be kept at the highest temperature at which a satisfactory storage life can be assured. The suggested storage temperatures vary for different vegetables and even for different varieties. Tressler (41) sets the rule that no frozen food product should be stored at a temperature higher than 5^{o} F.

Woodroof and Shelor (44) compared the quality of different lots of asparagus stored at -15^{o}, 0^{o} and 15^{o} F. They found that -15^{o} F. was the best storage temperature. Samples from the two other storage conditions had lost in flavor, color and texture. The quality of samples from all three storage conditions dropped gradually as the storage period continued.

A general suggestion for storage of frozen asparagus today is that this vegetable should be stored at -5° F. or lower (41).

Fluctuation of the storage temperature has been believed to cause desiccation of the frozen food (15). Storage temperatures which fluctuate above zero and range upward to 10° F. greatly speed up vitamin losses of both fruits and vegetables and cause rapid deterioration in quality.

Oxidation of frozen products occurs mostly on the surface exposed to the air. Proper packaging will lessen the oxidation during frozen storage. Bedford and Joslyn (17) found that the type of package used in freezing of asparagus affected the flavor retention. The best flavor was found in the samples packed dry in hermetically sealed containers.

EXPERIMENTAL PROCEDURE

Asparagus of the variety Martha Washington was used in the present study. The plants were grown on the Horticulture Experimental Farm at Michigan State College, East Lansing, Michigan, and were four years old at the 1951 harvest.

The first harvest was made on the eighth day of May, and successive harvests were made on the tenth, fifteenth, seventeenth, twenty-ninth, and thirty-first. The frequency of harvests depended on the weather conditions, which determined the rate of asparagus growth. The asparagus was harvested by the field snapping method early in the morning and processed within three hours after harvesting. The average yield per harvest was between 25 to 40 pounds.

The asparagus shoots were washed free from soil particles in running cold water and cut into 6-inch spears. The cut asparagus was sorted into three sizes, small, medium and large. The small and the large-sized stalks were not included in the study due to lack of sufficient material. The diameter of the cut ends of thirty stalks from each harvest was measured. The average diameter of the medium-sized stalks was 1.33 cm.

Three different scalding treatments were used, water at 100° C., steam at atmospheric pressure and infrared light. The boiling water scalding time ranged from 1/2 to 3 minutes, and the steam scalding ranged from 1/2 to 5 minutes. The scalding under infrared light was for 5, 10 and 15 minutes respectively, followed by 15 seconds of steam scalding.

For the water scalding the spears were placed in a wire mesh basket and immersed in boiling water, heated by live steam, for the desired length of time. Each successive lot was scalded in the same water, but not more than four lots in this water. After scalding the spears were cooled in a cold water tank for about 2 minutes and allowed to drain before packing. The asparagus spears to be steam scalded were placed in a single layer on perforated metal trays. The samples were exposed to flowing steam for the prescribed length of time and cooled under cold water spray for 2 minutes. The samples treated by the infrared light were arranged in the same manner as the samples prepared for steam scalding. They were exposed to the light for the prescribed length of time, then steamed for 15 seconds and cooled.

The scalded asparagus spears were packed in quart Marapak bags, heat-sealed and closed in Freeztex cartons. Fourteen ounces of asparagus were packed in each bag. The packages were placed on refrigerated shelves in a "walk-in" freezer, frozen at -10° F. in an airblast and then stored at 0° F.

The asparagus stalks were tested for peroxidase and catalase activity before and after scalding and after seven months of frozen storage. Six stalks from each lot were cut into small pieces and alternate cuts were collected. From these pieces a representative 30 grams sample was weighed out, and blended for 3 minutes with 100 ml. ice-cold distilled water in a Waring blendor. The mixture was filtered through a cotton milk filter and the first 10 ml. of the filtrate discarded.

A qualitative test for the catalase activity was made on the extract. Five drops of 0.3 percent hydrogen peroxide were added to a test tube containing approximately 5 ml. of the filtrate. The development of air bubbles in the sample was taken as an indication of presence of catalase.

Peroxidase was determined both qualitatively and quantitatively. The method used for the qualitative test was taken from the U. S. D. A. information sheet on "Test for Adequacy of Blanching in Frozen Vegetables" (42). One ml. of 0.5 percent guaiacol solution and 1 ml. of 0.08 percent hydrogen peroxide were added to a test tube containing 2 ml. of the filtrate and 20 ml. distilled water. The test tube was inverted and color development within 3-1/2 minutes was considered as a positive test.

The quantitative peroxidase test was carried according to the procedure described by Ponting and Joslyn (35). The rate of the color development was determined in an Evelyn colorimeter, using a 420 mμ filter. To a colorimeter tube containing 1 ml. of 0.5 percent guaiacol, 1 ml. 0.1 N hydrogen peroxide and 20 ml. acetate buffer at a pH of 5, 1/2 or 1 ml. of the enzyme extract was added. The contents were well mixed by inversion, the tube placed in the colorimeter, immediately adjusted to 100 percent transmission, and readings taken every ten seconds or at longer time intervals, depending on the rate of color development.

At the end of the storage period a consumer preference test was made on thirteen of the asparagus samples. The scoring was based on color, flavor and texture. All the samples were cooked under identical conditions. The unthawed samples were placed in a pan with 130 ml. boiling water and were cooked for 12 minutes under cover, then the stalks were transferred to a white enamel dish for scoring.

DATA AND DISCUSSION

The results obtained from the enzyme determinations are summarized in Table I. In general, there seemed to be a good agreement between the qualitative tests for catalase and peroxidase. According to the qualitative tests carried on before freezing, 1-minute scalding treatment in either steam or boiling water was sufficient to inactivate both catalase and peroxidase. The apparent absence of peroxidase activity, however, was not always substantiated by the quantitative measurements. The disagreement noticed between the qualitative and quantitative peroxidase tests may rise from the fact that the qualitative test is not sensitive for low concentrations of peroxidase.

It is interesting to note that in several samples, where enzymatic activity was absent before freezing, definitely positive results were obtained for both catalase and peroxidase after frozen storage. The reappearance of enzyme activity took place when the scalding time was under 1 minute, in both steam and water. Longer scalding time seemed to completely

Table I. Catalase and Peroxidase Activity of Scalded and Frozen Asparagus.

Treatment	Scalding Time min.	Avg. Diameter of Stalks cm.	Catalase		Peroxidase			
			Qualitative		Qualitative		Quantitative	
			Scalded	Frozen 7 mos.	Scalded	Frozen 7 mos.	Scalded Δlog T/sec.	Frozen 7 mos. Δlog T/sec.
Raw	0	-	+++	+++	+++	+++	0.00412	0.00340
Water	1/2	1.36	+	++	++	+	0.00097	0.00008
Water	1	1.36	-	+	-	-	-	-
Water	2	1.36	-	-	-	-	-	-
Water	3	1.36	-	-	-	-	-	-
Steam	1/2	1.31	++	++	+++	++	0.00291	0.00155
Steam	1	1.31	-	+	-	+	0.00007	0.000065
Steam	2	1.31	-	-	-	-	-	-
Steam	3	1.31	-	-	-	-	-	-
Steam	4	1.31	-	-	-	-	-	-
Steam	5	1.31	-	-	-	-	-	-
Infrared Light	5	1.30	-	+++	-	++	-	0.00079
Infrared Light	10	1.30	-	++	-	+	-	0.00002
Infrared Light	15	1.30	-	+	-	-	-	-

inactivate both peroxidase and catalase. The apparent increase of enzyme activity during frozen storage is considered by Ball and Hale (5) and Ball (4) to be an actual regeneration of the enzymes. It has also been suggested by several investigators (2), (19) that the positive results on catalase test, after what is considered adequate scalding to inactivate this enzyme, might be due to constituents other than catalase in the tissue, which decompose hydrogen peroxide. Joslyn and Bedford in their study of 1940 (17) observed that the evolution of oxygen gas continued even in over-scalded asparagus.

In the raw asparagus, when 1 ml. aliquot of the enzyme extract was used for the quantitative peroxidase test, the Δlog T/sec. values were not constant, but decreased with time, as is indicated in Table II. However, when 0.5 ml. aliquots were used the Δlog T/sec. values were constant for 4 minutes.

The lack of constant rate has been reported by others (18), (35), particularly when concentrated enzyme solutions are used. Cruess and Sugihara (10) have shown that the hydrogen peroxide concentration affects the activity of the peroxidase and that there is an optimum concentration for the enzyme. The constant rate obtained when 0.5 ml. of the enzyme solution was

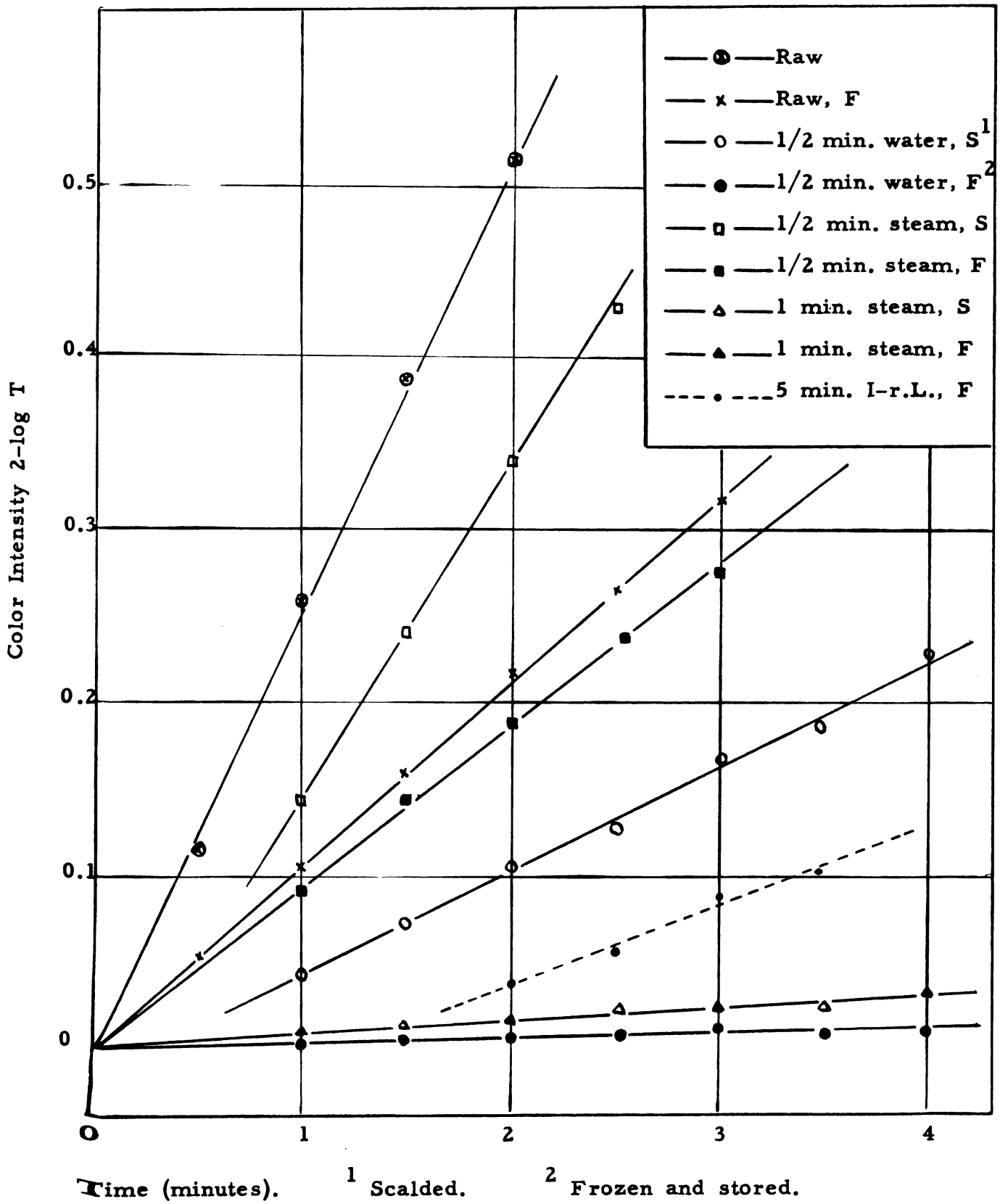
Table II. Measurement of Frozen Raw Asparagus Peroxidase Activity.

Time Sec.	Δ Log T Units Per Second		
	1 ml. aliquot	1/2 ml. aliquot	2 x value for 1/2 ml. aliquot
30	0.0045	0.0018	0.0036
60	0.0038	0.0019	0.0038
90	0.0033	0.0018	0.0036
120	0.0031	0.0018	0.0036
150	0.0027	0.0017	0.0034

used indicates that the hydrogen peroxide concentration was too low for the enzyme concentration present in the 1 ml. aliquot, but was within the optimum range for the enzyme concentration in the 0.5 ml. sample.

Figure 1 shows that the enzyme activity is a straight line function with time. The slope of the straight line is found to be proportional to the enzyme concentration. In all cases, with the exception of the infrared light treatment, the enzyme activity decreased upon frozen storage. The decrease in rate varied from 7 percent up to 92 percent. The highest decrease was observed in the water-scalded material. This reason plus the fact that the water-scalded asparagus exhibited the lowest

Figure 1. Measurement of asparagus peroxidase activity.



enzymatic activity before freezing, point out that water as a scalding medium is more efficient than steam for the inactivation of the enzymes. In the 1-minute steam-scalded sample, the decrease in activity during frozen storage was within experimental error and no differentiation between the two curves is possible.

The infrared treatment presents an interesting set of data. In all three time treatments catalase and peroxidase activities were absent before freezing, but reappeared after frozen storage. There is no additional information available to substantiate this phenomenon. Evidently infrared light, under the conditions used, brings about a temporary inactivation of the enzyme with no actual destruction.

The subjective evaluation of the frozen thawed asparagus for flavor, color and texture was based on numerical scoring. Flavor was determined on a five-point scale, with 5 as the highest score, while color and texture were determined on a three-point scale, with 3 as the highest score.

The taste panel, representing a "consumers group," was chosen among faculty and graduate students in the horticulture department at the college. Such a panel can not be considered

as truly representative of the ultimate consumers. The number of judges is too small and the distribution of age, sex, income and intelligence does not represent the average consumer (38). The average values of the numerical scores of sixteen judges are presented in Table III.

The results obtained from the subjective scoring agreed fairly close with the results of the enzyme tests. The samples showing enzyme activity after storage, all scored low in flavor, with the most objectionable sample being the 1/2-minute steam-scalded one, which also showed the highest enzymatic activity. It was somewhat surprising that the 1/2-minute water-scalded sample scored as high as 3, with 69 percent of the judges considering it acceptable. This material upon cooking developed a strong off-odor. The fairly high score might be explained by the fact that a slight hay-like flavor is fairly common in commercially preserved asparagus, so the consumers have accepted this particular flavor and are used to it. Another possible explanation might be the tendency among mass taste panels to prefer the food sample first offered, as was the case with the 1/2-minute water-scalded one (30).

Table III. Average Numerical Values of the Subjective Scoring of Frozen Asparagus by Sixteen Judges.

Treatment		Water				Steam						Infrared Light		
Time (minutes)		1/2	1	2	3	1/2	1	2	3	4	5	5	10	15
Flavor[1]		3.0	3.8	3.6	3.0	1.2	2.8	3.4	3.3	3.3	3.0	2.3	2.5	2.1
Color[2]		2.6	2.4	2.8	2.7	1.5	2.1	2.6	2.5	2.4	2.4	2.5	2.4	1.8
Texture[3]		2.4	2.6	2.7	2.5	1.7	2.3	2.4	2.4	2.3	2.4	2.4	2.2	1.9
	%													
General]	Yes	69.0	81.0	88.0	63.0	0.0	56.0	81.0	88.0	56.0	63.0	50.0	44.0	19.0
Acceptance]	No	31.0	19.0	12.0	37.0	100.0	44.0	19.0	12.0	44.0	37.0	50.0	56.0	81

[1] 5 very good, 4 good, 3 fair, 2 poor, 1 very poor.

[2] 3 good, 2 fair, 1 poor.

[3] 3 good, 2 fair, 1 poor.

Positive enzyme activity appears to influence color and texture. The under-scalded material exhibited a more yellowish color and its texture was somewhat tough and stringy. On the other hand, the over-scalded material, as was the case with the 5-minute steam-scalded asparagus, had lost in flavor and color and the stalks had a soft texture with some noticeable scaling.

The scoring values for flavor, color and texture in several cases did not agree with the percental values of general acceptance. This disagreement made it rather difficult to conclude which was the best scalding treatment. It was apparent that some of the judges did not have the ability to differentiate between the samples and carry a consistent scoring. In order to eliminate their inconsistencies and get a more representative table, Table IV was prepared.

This table presents the average numerical scores of six of the judges, who were picked out because they had more experience than the other ten. This selected group represents more a "trained panel" than a "consumers group." The advantage of this selection is that usually more consistent results are obtained, on a complicated scoring like this one, when only the best judges are used (41). Those six judges considered the

Table IV. Average Numerical Values of the Subjective Scoring of Frozen Asparagus by Six Selected Judges.

Treatment		Water				Steam						Infrared Light		
Time (minutes)		1/2	1	2	3	1/2	1	2	3	4	5	5	10	15
Flavor[1]		2.2	3.3	4.3	3.7	1.0	2.7	4.0	3.8	4.0	3.3	2.5	2.3	1.7
Color[2]		2.0	2.2	2.8	3.0	1.3	2.0	2.8	2.8	3.0	2.2	2.5	2.3	1.8
Texture[3]		1.8	2.5	2.8	2.7	1.5	2.2	2.5	2.7	2.7	2.3	2.3	2.2	2.3
	%													
General]	Yes	17.0	66.0	100.0	83.0	0.0	50.0	100.0	83.0	83.0	50.0	17.0	17.0	0.0
Acceptance]	No	83.0	34.0	0.0	17.0	100.0	50.0	0.0	17.0	17.0	50.0	83.0	83.0	100.0

[1] 5 very good, 4 good, 3 fair, 2 poor, 1 very poor.

[2] 3 good, 2 fair, 1 poor.

[3] 3 good, 2 fair, 1 poor.

flavor of the 1/2-minute water-scalded asparagus poor, and only one out of the six marked the product as acceptable. They were also able to detect some off-flavor in the 1-minute water-scalded sample, which is substantiated considering the positive result of the catalase test after storage. The 2-minute water- or steam-scalding were unanimously chosen as the best scalding treatments, while the larger panel considered 1- and 2-minute water and 2- and 3-minute steam-scalding all equally good.

From the results of both tables it can be concluded that 2-minute water-scalding or 2- to 3-minute steam-scalding are in all respects the best scalding treatments before freezing. Three-minute water-scald and 4-minute steam scald were questionable. Some judges considered them as good as the previous treatments, while others indicated that some flavor was lost. Therefore, these samples can also be judged as slightly over-scalded.

The three samples treated with infrared light were scored low in all respects. A definite off-flavor, similar to that in the raw and 1/2-minute scalded samples, was noticed. They all had a brownish color and the texture seemed rather soft but stringy, especially in the last two samples. Increasing

scalding time under infrared light did not improve the quality. The longer exposure to the light had an unfavorable drying effect on the stalks. Thus can be concluded from the subjective scoring, as well as from the enzyme tests, that infrared light is not a satisfactory scalding treatment for preservation by freezing.

SUMMARY AND CONCLUSIONS

The effect of various scalding treatments and storage time on enzyme activity and flavor retention in frozen asparagus was studied.

On the basis of the data obtained on evaluation of the material after seven months of frozen storage, the following conclusions were made:

1. The best quality of the frozen, thawed asparagus was obtained after a pretreatment of 2-minute water-scalding or 2- to 3-minute steam-scalding.

2. Water-scalding was more effective in inactivating the enzymes, but in the quality of the final product no significant difference between water and steam-scalded material could be detected.

3. Scalding by infrared light did not give a satisfactory product of frozen asparagus as was indicated by the enzymatic and subjective tests.

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