Effect of Blanching and Subsequent Holding on Some Chemical Constituents and Enzyme Activities in Peas, Snap Beans, and Lima Beans

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Effect of Blanching and Subsequent Holding on Some Chemical Constituents and Enzyme Activities in Peas, Snap Beans, and Lima Beans[1]

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Abstract

THE immediate purpose of the tests reported here was to study the effect of blanching and subsequent holding on the chemical composition of green peas, snap beans, and lima beans, and to search for a possible correlation between losses in ascorbic acid and the residual activity of the three enzymes catalase, ascorbic acid oxidase, and peroxidase.

The major conclusion which may be drawn from the present experiments is that while there are substantial losses of ascorbic acid during the blanching of these vegetables, there are no further losses during subsequent 4-hour periods of holding, providing the vegetables were properly blanched. If the blanching was insufficient, severe losses may occur during the holding or even during the brief periods required for preparing samples for analyses.

It is as yet not possible to define "proper" blanching in terms of the activities of the three enzymes studied.

Under the conditions of these tests, there was usually less loss of ascorbic acid and of other water-soluble chemical constituents when the blanching was performed for brief periods at high temperatures rather than for longer periods of time at a lower temperature.

Introduction

THE desirability of blanching (scalding) peas, snap beans, and lima beans before they are placed in the can or are frozen is now generally accepted. In the case of canned vegetables, the blanch-

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ing process has commanded the attention of several investigators (5,6,8,9,10,14,15,27,28,29)[4], yet the changes caused by blanching in the tissues and in their behavior during subsequent operations is far from clear.

Blanching is an effective cleansing operation which removes adhering pieces of foreign plant materials and also reduces the bacterial flora of the vegetables (20). In several cases blanching also removes certain constituents which are undesirable from the flavor standpoint or prevents the occurrence of detrimental changes in color, odor, and flavor associated with the unblanched material (2,11). Finally, the use of blanching has been advocated because the resulting wilting of tissues permits better filling of the cans and also removes most of the intercellular gases.

The extent of blanching which will give the best overall results is at present debatable. The general tendency is towards shorter periods of blanching at higher temperatures as contrasted with longer blanching at comparatively low temperatures. Several studies indicate that in such preliminary thermal treatment of plant material it is important to pass with maximum rapidity through the temperature region where tissue structures are destroyed without a simultaneously complete inactivation of the enzymes present (7,21).

The investigations reported in this bulletin had as their first objective establishing the progress of the inactivation during blanching of some enzymes in peas, snap beans, and lima beans. Second, they were designed to show some of the chemical changes which occur in these vegetables during blanching at different temperatures for various lengths of time, and, if possible, to correlate the behavior of enzymes with these chemical changes.

The holding of vegetables in the canning factory after blanching but before processing is often necessary because of uneven deliveries of the raw material, breakdown of machinery, and other unavoidable delays. Therefore, a third objective of this study was to determine the extent of losses and changes in various chemical constituents, especially in ascorbic acid (vitamin C), during such holding and to note the influence of the degree of blanching on these changes.

Although the present study yielded some new and interesting results, it will be seen that most observations support the conclusions

[4]Reference is to Literature Cited, page 32.

drawn from previous investigations. We have felt that it is desirable to record at least some of our experiments in considerable detail because both the number of time-temperature variants and the types of observations made in any given test run are much more extensive than those found in the literature. It was hoped that in addition to supporting the conclusions drawn from the present study, such detailed data will aid future investigators of this topic in the selection of experimental conditions and methods.

The experimental methods and the results obtained are presented below separately for the three vegetables studied, but the results are compared and evaluated together in the summary discussion.

Peas

Experimental Methods

Raw materials and blanching operations

The present investigations were conducted during 1946 and 1947 at Geneva. In 1946, Surprise peas of two widely different stages of maturities were used. Each sample was obtained from a single truckload of peas shipped immediately after vining at a nearby canning plant. The less mature ungraded peas (Table 1) gave a tenderometer reading of 118 (ungraded) and yielded a "fancy" canned pack. Peas of the more mature lot gave a tenderometer reading of 192 (ungraded) and the finished canned pack was of "standard" quality grade (Table 2). The fresh peas were separated according to size and only those of sieve size 4 were used. Several other less extensive runs were made in 1946, but the results are not reported here.

In 1947, Thomas Laxton, Surprise, and Canner King were used. Ungraded samples of these peas gave tenderometer readings of 100, 124, and 96, respectively. Only sieve size 5 peas were used and the finished packs were all of "fancy" grade. Because of similarities of results obtained on the three varieties, only the data for Canner King is reported here (Table 3), but any dissimilarities observed in the behavior of the peas of different varieties will be noted.

Raw samples were taken from the washed peas. The blanching was accomplished in a miniature rotary water blancher (18) at the times and temperatures listed in the tables. From the blancher the peas passed under sprays of cold water and were cooled to a temperature of 70° to 80° F. For the holding tests, the blanched and cooled vegetables were held in perforated buckets of the type used in commercial canneries. These buckets were filled to at least two-thirds of their capacity and held at room temperature for the periods indicated in the tables.

Methods of analysis

All determinations were either completed within a few minutes after the sample was prepared or carried to a point in the analyses where the occurrence of chemical changes was prevented.

The homogenates used in the enzyme tests were prepared by mixing one (weighed) part of peas or other vegetables with two parts of distilled water in a Waring blendor followed by several minutes of further comminution in a Potter-Elvehjem grinder (19). All enzyme tests were made at 86° F (30° C). The catalase activity was determined according to the method of Thompson (26) with a 5-minute reaction period. Peroxidase was determined by several methods. The procedure of Balls and Hale (BH) (3) was followed using one tenth of all recommended quantities.

In addition to the regular titration procedure, the reaction mixtures covered with mineral oil were allowed to stand at room temperature for 24 hours. It has been the authors' experience that on the day following the quantitative (titrimetric) analyses, the color of these mixtures is a dependable indication of low peroxidase activities. These additional colorimetric observations are recorded in the tables under the heading "Peroxidase, BH, Color." The signs +, ++, and +++ indicate increasingly dark coloration observed after 24 hours, the sign "O" indicates negative reading, and "—" that no determination was made.

Another method of measuring peroxidase activity used in some parts of this study was that of Smith, Robinson, and Stotz (SRS) (24) which is based on the oxidation of an indophenol dye in the presence of hydrogen peroxide. When the concentration of the dye and the peroxide are carefully controlled, the rate of development of the blue color resulting from the oxidation of the dye is directly proportional to the concentration of the enzyme. The rate of color development was followed photometrically.

The ascorbic acid oxidase activity was measured in the following manner: Two ml of 0.1M phosphate-citrate buffer of pH 6.0, 0.5 mg of ascorbic acid, and 4.0 ml of the tissue homogenate were placed in an acid-washed Pyrex tube. In the case of the unblanched samples, 1 ml was diluted with water and the contents were incubated until no more than half of the ascorbic acid was oxidized in a period not exceeding 2 hours. At the end of the incubation period an equal volume of 5 per cent metaphosphoric acid was added to stop further oxidation and the amount of ascorbic acid oxidized was determined by comparison with a control established by adding acid to a duplicate tube at the start of the incubation. The activities were calculated on the basis of the mg of ascorbic acid oxidized per hour per gram of (wet) tissue.

The dry matter determinations were made by drying duplicate 25-gram samples at 203° F (96° C) for 2 days. In all cases the number of peas in the samples was recorded to permit calculation of the "per

unit" (single pea basis) changes (13). Unfortunately, similar treatment of the data was not possible with the results obtained with snap beans and lima beans.

The alcohol-insoluble solids (AIS) determinations were made by the method of Kertesz (12).

The ascorbic acid determinations were performed according to the method of Robinson and Stotz (22).

For the estimation of the total sugar content, a modernized version of Bertrand's method (4) was used after extraction with hot 80 per cent ethanol, followed by evaporation and clarification of the extract, and hydrolysis with dilute hydrochloric acid. The nitrogenous fractions were determined in the hot 80 per cent ethanol extract and in the residue (23) by the micromethod of Ma and Zuazaga (16).

Crude fiber, ash, and calcium were determined by the official methods (1).

Experimental Results

Effect of blanching on enzyme activities

In Tables 1 to 3 are shown the residual enzyme activities after various degrees of blanching, expressed as the percentages of the original activity in the raw material. No attempt was made to express enzyme activities in absolute units since the purpose of this study was to investigate the changes caused by blanching and subsequent holding. However, it was clear from the tests made that catalase and ascorbic acid oxidase activities were higher in the younger peas (Tables 1 and 3) than in older peas (Table 2). The same trend existed in the three 1947 samples. The reverse was true in the case of peroxidase activity.

Catalase was completely and permanently inactivated in all blanched samples, including that exposed to the mildest heat treatment at 160° F for 1 minute. In harmony with previous observations, no re-occurrence (regeneration) of catalase activity was found in any of these samples.

In the evaluation of the peroxidase activities, consideration must be given to the method of estimation applied. According to the method of Balls and Hale (BH) (3), and with increasing temperatures and duration of blanching, there was progressive inactivation of peroxidase until the residual activities reached the order of a few per cent. At this low level, the BH results became irregular because of the variations in the blank values used to compensate for the effects of the vegetable tissues aside from the peroxidase activity. For reasons which are not clear at the present time, the extent of

TABLE 1.—*Inactivation of enzymes and various chemical changes in blanched and subsequently held peas, Early Sweet variety, fancy grade, 1946.**

Blanch		Holding time, hours	Residual enzyme activity†					Dry matter, per cent	Single unit weight, grams		Alcohol-insoluble solids, per cent	Crude fibre, per cent	Ascorbic acid, mg per 100 grams	Total sugars, per cent	Soluble nitrogen, per cent	Total nitrogen, per cent	Ash, per cent
°F	Minutes		Catalase, per cent	Peroxidase BH, per cent	Peroxidase BH, color	Peroxidase SRS, per cent	Ascorbic acid oxidase, per cent		Fresh	Dry							
—	—	0	(100)	(100)	+++	(100)	(100)	21.53	0.392	0.0887	15.1	2.01	22.7	3.82	0.126	0.538	0.741
—	—	0.5	–	—	—	102	—	21.29	0.394	0.0844	15.0	—	22.8	3.68	0.134	0.567	0.716
—	—	1.0	–	90	+++	—	—	21.70	0.392	0.0848	15.4	—	23.1	3.67	0.122	0.535	—
—	—	2.0	81	96	+++	—	104	21.17	0.394	0.0840	15.8	1.98	23.6	3.18	0.130	0.549	0.706
190	1	0	0	3.8	+	3.9	0.4	21.82	0.384	0.0832	16.0	2.16	20.9	3.20	0.103	0.511	0.702
190	1	0.5	–	5.4	++	3.6	—	—	—	—	—	—	—	—	—	—	—
190	1	1.0	0	5.9	++	4.2	0.5	20.64	0.373	0.0770	15.7	—	17.3	3.26	0.112	0.513	0.608
190	1	2.0	0	5.4	++	—	0.0	21.18	0.373	0.0789	15.8	2.15	21.3	3.49	0.128	0.535	0.677
190	3	0	0	1.0	0	0.0	0.0	20.32	0.379	0.0770	15.3	2.15	17.8	3.07	0.113	0.532	0.573
190	3	1.0	–	1.2	0	0.0	—	20.83	0.379	0.0785	15.4	—	18.6	3.05	0.111	0.512	0.574
190	3	2.0	0	1.3	0	0.0	—	20.70	0.368	0.0760	14.8	2.08	19.0	3.14	0.109	0.517	0.626
190	5	0	–	1.2	0	0.0	0.5	19.19	0.379	0.0726	14.7	2.04	16.6	3.13	0.094	0.493	0.578
190	5	1.0	–	—	–	0.0	—	19.55	0.379	0.0740	15.3	—	18.9	2.47	0.103	0.513	0.596
190	5	2.0	–	1.0	0	0.0	—	20.42	0.379	0.0773	15.2	—	17.9	2.73	0.105	0.496	0.592
200	1	0	0	0.8	0	0.0	0.0	20.58	0.392	0.0803	14.9	2.05	19.6	2.85	0.107	0.388	0.600
200	1	1.0	–	1.0	0	0.1	—	20.69	0.385	0.0794	14.9	—	21.0	2.76	0.121	0.508	0.634
200	1	2.0	0	0.9	0	—	—	20.65	0.392	0.0807	14.9	2.06	20.6	2.86	0.124	0.515	0.636
200	3	0	0	0.0	0	0.0	0.0	20.03	0.385	0.0780	15.7	2.06	19.8	2.48	0.098	0.482	0.615
200	3	1.0	–	1.5	0	—	—	—	—	—	—	—	—	—	—	—	—
200	3	2.0	–	1.4	0	0.0	—	20.36	0.392	0.0794	15.6	—	18.5	2.81	0.097	0.492	0.612
200	5	0	0	0.6	0	0.0	0.0	19.16	0.376	0.0720	14.5	2.15	17.3	2.77	0.091	0.480	0.576
200	5	2.0	–	1.0	0	0.0	—	20.49	0.385	0.0788	15.8	—	18.8	2.92	0.093	0.465	0.594
210	1	0	0	2.1	0	0.1	0.0	21.06	0.385	0.0810	15.5	2.02	19.0	3.27	0.121	0.527	0.678
210	1	1.0	–	1.6	0	0.2	—	21.65	0.394	0.0859	15.0	—	18.3	3.09	0.118	0.528	0.613
210	1	2.0	–	1.3	0	0.2	—	21.32	0.394	0.0846	15.3	2.11	19.3	—	—	—	0.707
210	3	0	0	0.0	0	0.0	0.0	21.68	0.384	0.0829	15.6	2.17	18.8	3.08	0.114	0.508	0.578
210	3	2.0	–	0.8	0	0.1	—	21.79	0.379	0.0825	15.5	—	16.7	2.72	0.104	0.495	0.574
210	5	0	0	0.6	0	0.0	0.7	20.56	0.379	0.0780	15.7	2.14	15.9	2.30	0.093	0.496	0.600
210	5	2.0	–	—	—	—	—	20.80	0.379	0.0788	15.7	—	14.9	2.59	0.111	0.511	0.584

*On fresh weight basis. Harvested July 2, 1946. Sieve size No. 4. Tenderometer reading (ungraded) 118.
†See page 6 for meaning of abbreviations.

TABLE 2.—*Inactivation of enzymes and various chemical changes in blanched and subsequently held peas, Early Sweet variety, standard grade, 1946.**

BLANCH		HOLDING TIME, HOURS	RESIDUAL ENZYME ACTIVITY†					DRY MATTER, PER CENT	SINGLE UNIT WEIGHT, GRAMS		ALCOHOL-INSOLUBLE SOLIDS, PER CENT	CRUDE FIBRE, PER CENT	ASCORBIC ACID, MG PER 100 GRAMS	TOTAL SUGARS, PER CENT	SOLUBLE NITROGEN, PER CENT	TOTAL NITROGEN, PER CENT	ASH, PER CENT
°F	Minutes		Catalase, per cent	Peroxidase			Ascorbic acid oxidase, per cent		Fresh	Dry							
				BH, per cent	BH, color	SRS, per cent											
—	—	—	(100)	(100)	+++	(100)	(100)	27.31	0.443	0.122	23.1	2.29	21.3	2.19	0.088	0.441	1.062
190	1	0	0	7.0	++	0.6	2.8	29.65	0.413	0.123	23.8	2.33	20.2	2.11	0.079	0.434	1.040
190	1	2	0	7.6	+	0.8	—	—	—	—	—	—	20.6	—	—	—	—
190	3	0	0	0.0	0	0.0	1.6	28.48	0.417	0.119	23.5	2.35	18.8	1.75	0.067	0.426	0.971
190	5	0	0	0.0	0	0.0	0.8	28.85	0.439	0.127	23.8	2.26	17.7	1.61	0.060	0.410	0.945
200	1	0	0	0.7	0	0.0	0.0	28.56	0.424	0.122	23.9	2.37	19.6	1.68	0.065	0.427	1.042
200	1	2	0	0.0	0	0.0	—	—	—	—	—	—	18.0	—	—	—	—
200	3	0	0	1.1	0	0.0	1.2	28.03	0.424	0.119	23.9	2.03	17.9	1.69	0.059	0.413	0.995
200	5	0	0	0.0	0	0.0	0.4	28.60	0.431	0.123	23.4	2.32	17.7	1.55	0.058	0.400	0.931
210	1	0	0	0.0	0	0.0	0.0	27.60	0.431	0.119	23.4	2.36	19.6	1.76	0.065	0.414	1.024
210	1	2	0	0.0	0	—	—	—	—	—	—	—	19.0	—	—	—	—
210	3	0	0	0.3	0	0.0	0.0	27.91	0.431	0.121	23.8	1.75	17.7	1.72	0.052	0.404	0.986
210	5	0	0	0.0	0	0.0	0.0	27.49	0.423	0.117	24.7	1.67	16.6	1.86	0.053	0.408	0.951

**On fresh weight basis. Harvested July 9, 1946. Sieve size No. 4. Tenderometer reading (ungraded) 192.

†See page 6 for meaning of abbreviations.

TABLE 3.—*Inactivation of enzymes and various chemical changes in blanched and subsequently held peas, Canner King variety, 1947.**

BLANCH		HOLDING TIME, HOURS	RESIDUAL ENZYME ACTIVITY†				DRY MATTER, PER CENT	SINGLE UNIT WEIGHT, GRAMS		ASCORBIC ACID, MG PER 100 GRAMS	ASH, PER CENT	CALCIUM, PER CENT
°F	Minutes		Catalase, per cent	Peroxidase BH, per cent	Peroxidase BH, color	Ascorbic acid oxidase, per cent		Wet	Dry			
—	—	0	100	100	+++	100	19.56	0.581	0.114	21.85	0.644	0.018
—	—	1	83	100	+++	—	19.11	0.575	0.110	22.43	0.620	—
—	—	2	85	100	+++	—	20.06	0.588	0.118	20.52	0.659	—
160	1	0	0	39	+++	12	18.41	0.521	0.096	10.02	0.560	—
160	1	1	—	36	+++	—	18.54	0.516	0.096	8.86	0.565	—
160	1	2	—	40	+++	—	18.00	0.550	0.099	9.59	0.570	—
160	3	0	0	39	+++	2.6	19.09	0.568	0.108	14.74	0.532	—
160	3	1	—	38	+++	—	18.94	0.562	0.106	11.98	0.546	—
160	3	2	—	38	+++	—	18.67	0.544	0.101	6.51	0.570	—
160	5	0	—	32	++	3.0	16.60	—	—	16.40	0.530	—
160	5	1	—	38	+++	—	18.71	0.581	0.109	11.63	0.545	—
160	5	2	—	37	++	—	17.86	0.562	0.100	8.91	0.521	—
160	7	0	—	31	++	1.9	18.24	0.550	0.100	14.85	0.485	0.024
160	7	1	—	34	++	—	17.96	0.550	0.098	10.52	0.488	—
160	7	2	—	33	++	—	17.90	0.556	0.100	8.49	0.498	—
175	1	0	0	28	+++	1.1	17.31	0.556	0.096	20.35	0.571	—
175	1	1	—	30	++	—	18.42	0.556	0.102	12.26	0.553	—
175	1	2	—	20	++	—	18.60	0.568	0.106	9.91	0.568	—
175	3	0	0	13	+	1.5	17.93	0.532	0.096	21.76	0.518	—
175	3	1	0	19	+	—	17.98	0.544	0.098	15.95	0.550	—
175	3	2	—	16	+	—	18.46	0.510	0.094	17.22	0.534	—
175	5	0	—	7.0	+	2.9	18.50	0.544	0.100	17.46	0.494	—
175	5	1	—	7.6	+	—	17.89	0.562	0.100	15.49	0.511	—
175	5	2	—	7.4	+	—	18.63	0.556	0.104	17.21	0.521	—
175	7	0	—	6.9	+	2.9	18.10	0.556	0.100	16.84	0.487	—
175	7	1	—	6.7	+	—	18.04	0.581	0.105	17.20	0.508	—
175	7	2	—	7.8	++	—	18.24	0.562	0.102	14.90	0.489	—

190	1	0	0	15	+	2.1	17.80	0.562	0.100	20.69	0.534	—
190	1	1	—	15	+	—	18.87	0.556	0.104	18.19	0.557	—
190	1	2	—	16	++	—	19.99	0.575	0.115	16.38	0.575	—
190	3	0	—	1.6	0	1.7	17.85	0.556	0.099	15.58	0.533	—
190	3	1	—	7.4	+	—	18.75	0.568	0.106	17.52	0.552	—
190	3	2	—	7.5	+	—	19.10	0.556	0.106	16.55	0.536	—
190	5	0	—	0	0	3.9	17.42	0.550	0.096	16.74	0.489	—
190	5	1	—	0	0	—	18.45	0.562	0.104	16.61	0.514	—
190	5	2	—	0	0	—	18.98	0.575	0.109	17.02	0.508	—
205	1	0	0	1.6	+	4.0	17.94	0.557	0.100	17.39	0.516	0.026
205	1	1	—	1.3	+	—	18.71	0.568	0.106	18.59	0.551	—
205	1	2	—	—	—	—	—	—	—	—	—	—
205	3	0	—	0	0	4.3	16.71	0.544	0.091	16.32	0.471	—
205	3	1	—	0	0	—	18.59	0.562	0.104	17.49	0.524	—
205	3	2	—	—	—	—	—	—	—	—	—	—
205	5	0	—	0	0	4.8	18.17	0.562	0.102	15.20	0.485	—
205	5	1	—	0	0	—	18.55	0.538	0.100	15.61	0.501	—
205	5	2	—	0	0	—	18.73	0.538	0.100	15.98	0.506	—

***On fresh weight basis. Sieve size No. 5. Tenderometer reading (graded) 96. Harvested July 15, 1947.**
†See page 6 for meaning of abbreviations.

residual or apparent peroxidase activity which can be observed in plant tissues heated to inactivate all peroxidase enzyme varied with different lots of peas.

Complete peroxidase inactivation depended on the temperature and duration of the blanch as well as the condition of the raw material. For example, as shown in Tables 1 and 2, in 1946 no peroxidase activity was found after 3 minutes of blanching at 190° F whereas increasing the temperature to 200° F reduced the time required for complete inactivation to 1 minute. In 1947, when sieve size 5 peas were used instead of size 4, the blanching required for inactivation was 5 minutes at 190° F or 3 minutes at 205° F (Table 3). Clearly, the larger size of peas used in the 1947 experiments offered more resistance to complete heat penetration.

Renewed peroxidase activity (regeneration) was observed in several samples during holding after blanching. For example, the sample blanched at 210° F for 3 minutes (Table 1) was negative when tested immediately after blanching but showed definite activity after holding for 2 hours. This re-occurrence of peroxidase activity in blanched vegetables has often been observed with the peroxidases of plant tissues.

The color observations on the reaction mixtures of the Balls-Hale (BH) method yielded good relationship between the amount of heating and color formation and aided in distinguishing low activities from complete inactivation. By and large, the extent of heating required for complete inactivation of the peroxidase was more exactly shown by the BH color tests than by the titration values obtained by the same method. The peroxidase method of Smith, Robinson, and Stotz (SRS) (24) was more sensitive than the BH method, and in a few cases indicated activity in samples that gave negative results when the latter method was used. However, in most instances the results obtained by the two methods (BH and SRS) were in agreement.

The ascorbic acid oxidase indicated an intermediate degree of heat lability between that of catalase and peroxidase. In the determination of this enzyme at very low levels of activity, it is again difficult to differentiate between enzymic and non-enzymic oxidation which in turn makes it impossible to specify with certainty the complete absence of enzyme activity. Increases in the blanching temperatures progressively reduced the times required for inactivation. In the experiments shown in Table 1, apparently all heated samples were

devoid of this enzyme. In the run shown in Table 2, the sample heated to 190° F for 1 minute contained traces of activity and this might have been the case in the sample heated to 200° F for 3 minutes. In the 1947 experiment on Canner King (Table 3) only the sample heated for 1 minute to 160° F showed a definite oxidase activity, while in two experiments on Surprise and Thomas Laxton peas, not shown here, there was some residual activity in the samples heated to 160° F for 3 minutes and to 175° F for 1 minute. We shall return later to the relationship of residual enzyme activity and ascorbic acid losses during holding subsequent to blanching.

Changes in water content and unit weight of peas during and after blanching

During the blanching of peas in hot water as well as during the cold water cooling which follows, water-soluble constituents of the peas are removed (leached). Meanwhile, due apparently to the heat treatment of the tissues, the latter will show an increased water-holding capacity. Thus, on one hand, solids will be lost from the peas, while on the other, their weight (per single pea) will increase due to the uptake of water resulting from the increased power of imbibition. These changes, proceeding in opposite directions, can confuse the conclusions which may be drawn from the results of chemical analyses since the weight of a given sample of peas will change during blanching and thus a 100-gram sample taken after the treatment might represent 105 or 95 grams of the original starting material. This led to use of calculations based on number of units in a sample and expressions of chemical analyses on a "single unit" or "single pea" basis (13).

To overcome this difficulty leading to distortion in the results of chemical analyses performed on the samples in the present study, the number of peas in all dry matter samples were counted and recorded. This allowed us to determine the extent of leaching as well as the extent of increase in the imbibition during the blanching and washing. All the results obtained on peas were calculated on the fresh (wet) basis, dry matter basis, and, in addition, on the basis of the weight of a single fresh (wet) or dried pea. For sake of economy, only the fresh weight basis calculations are given here, but sufficient information is included in the tables on the dry matter contents and on the weight of single peas to allow a recalculation of the analytical results in various ways.

Expressed on the fresh weight basis, blanching caused a slight increase in the solids content of mature peas and a slight (about 2 per cent) decrease in the solids content of young peas. When the results were calculated on the "single pea basis", there was about a 10 per cent loss of solids from the young peas but no comparable loss in the more mature peas. The extent of loss of solids from the younger peas varied with different blanching conditions, the duration of the blanching being more important than the temperature of the water used. However, the extent of leaching (loss of solids) increased somewhat as the blanching water temperature was raised to 190° F. Above this temperature the extent of leaching decreased.

No changes in dry matter content and single unit weight of peas could be observed during the 2-hour holding period after blanching. While there was some indication of loss of dry matter from peas held without blanching, the results were not consistent enough to warrant a detailed discussion here.

Changes in some chemical constituents

In the extensive 1946 study, chemical analyses were made of the peas after blanching and after holding for 1- and 2-hour intervals. These analyses included total solids, total sugars, alcohol-insoluble solids (AIS), crude fiber, ascorbic acid, total and 80 per cent alcohol-soluble and alcohol-insoluble nitrogen, and ash (Tables 1 and 2). In the 1947 tests the analyses were confined to total solids, ascorbic acid, ash, and calcium (Table 3).

Ascorbic acid.—The initial ascorbic acid content of the peas used in these experiments was well within the range reported in the literature. If any loss of ascorbic acid occurred during the few hours of holding the unblanched peas, such changes were within the experimental error.

The loss of ascorbic acid from vegetables during blanching may result either from oxidation by enzymes and other factors or by leaching. As shown in previous reports and in Tables 1 and 2, the extent of loss due to leaching is more extensive in the younger peas. The 1946 experiments also established the fact that prolonging the blanching time from 1 to 5 minutes increased the ascorbic acid losses more than the elevation of the blanching temperatures from 190° to 210° F. However, in this comparison, it must be assumed that all blanching treatments were sufficient to inactivate the oxidative systems which were naturally present.

The results of the 1947 studies on three different varieties are similar and only the data from the experiments with Canner King are presented here (Table 3). The 1947 tests covered a wide range of temperatures (160° to 205° F) and this has helped to demonstrate the factors affecting the destruction of ascorbic acid during blanching and subsequent holding. The holding experiments were found valuable, for without a consideration of the fate of ascorbic acid in these samples it would be difficult to explain the pronounced loss of ascorbic acid at some of the lower blanching temperatures as indicated by the analyses made immediately after blanching and cooling. Little or no loss of ascorbic acid was encountered on holding unblanched samples or those blanched at 190° F or higher. However, in peas which were blanched at 160° F for 1 minute, the ascorbic acid losses were considerable (60 per cent) and they continued during the subsequent holding period. Increasing the blanching time or raising the blanching temperature reduced these losses. Such excessive ascorbic acid losses during blanching and holding are believed to be due to heat disruption of the tissues with a resulting contact of enzyme (ascorbic acid oxidase) and substrate (ascorbic acid) at a temperature too low for enzyme inactivation (7,21).

It is important to note that the results of the ascorbic acid oxidase determinations bear no relationship to the occurrence of such ascorbic acid losses due to "thermal maceration." In peas, at least, an extent of heating required to inactivate the peroxidase completely was required to prevent this type of ascorbic acid loss.

Total sugars.—Blanching appreciably reduced the sugar content, especially of younger peas. In general, the loss of sugar was more accentuated by lengthening the blanching period from 1 to 5 minutes than by raising the blanching temperature from 190° to 210° F (Tables 1 and 2). In the 1946 blanching experiments where 190° F was the lowest blanching temperature used, no sugar losses occurred in any of the samples on subsequent holding except in the case of raw peas where a 17 per cent loss occurred in 2 hours. No sugar determinations were performed on the 1947 samples.

Alcohol-insoluble solids and crude fiber.—No consistent trends were noted in the alcohol-insoluble solids or crude fiber after blanching or holding within the time and temperature ranges employed in the 1946 experiments. No such determinations were made in 1947.

Total nitrogen and nitrogenous fractions.—These components

were determined only in the 1946 samples. The alcohol-insoluble fraction, which included the proteins and perhaps polypeptides, showed an insignificant loss during blanching of both "fancy" and "standard" peas. On the other hand, the alcohol-soluble nitrogenous compounds, probably consisting mostly of amino acids and other low molecular weight nitrogenous compounds, showed considerable losses from both "fancy" and "standard" peas. These losses were enhanced by increases in the blanching time or temperature, a notable exception being the highest temperature used (210° F) where the loss from the "fancy" peas has diminished. The more mature peas were found to lose in blanching a greater proportion of their nitrogen contents although they had less originally. There was no significant change in either of the two nitrogenous fractions during the holding of the raw or blanched pea samples. The changes in the total nitrogen content of peas were the direct result of losses from the 80 per cent alcohol-soluble fraction.

Ash and calcium.—The extent of leaching out of mineral constituents was ascertained by ash determinations. Such analyses were performed on both the 1946 and 1947 samples. The results obtained indicate that upon blanching the older peas retained a much higher proportion of their original mineral contents. The ash retention was also affected by the nature of the blanching, varying the blanching time having more influence on the amount of minerals removed than variations in the temperature. Of course, no changes were observed in the ash content during holding the peas either raw or after blanching.

In spite of general mineral losses during blanching, the calcium content of the blanched peas was found to be higher than that of the control. This effect is shown in Table 3 for the 1947 Canner King sample. Data obtained on the two other varieties studied in 1947 showed the same relationship. The calcium content of untreated Thomas Laxton was 0.018 per cent while the blanched peas, of which eight samples were analyzed, showed 0.021 to 0.041 per cent calcium with an average of 0.026 per cent. The increase was less pronounced in the three samples analyzed from the experiment with Surprise. Unfortunately there is an insufficient number of analyses available to allow drawing any conclusions concerning the effects of temperature and duration of blanching on calcium uptake.

This affinity of peas for calcium is fairly well established (23) and

apparently depends on the formation of insoluble pectic compounds and of phytates (17). It is doubted that such an increase would be of nutritional significance although it is more than likely that the increased calcium content would affect quality by increasing the firmness of the seed coat (23).

Snap Beans

Experimental Methods

The beans used were selected at a nearby canning plant from large lots delivered by a single grower in the vicinity. In 1946, whole (size 2) and cut (size 5) Refugee beans were used. Following snipping, the whole beans of size 2 were selected manually from the picking table with the aid of size gauges. The cut beans were mechanically graded. The beans were immediately transported to Geneva and held at 35° F until used as the different blanching treatments were made. All experiments were completed within one day. The experimental treatment consisted of washing the beans on a moving wire belt under jets of water followed by blanching in a small rotary-type water blancher (18) and cooling on a wire belt under water sprays. The cooled beans were held at room temperature (about 77° F). The temperature of the blanched, cooled beans in the buckets was within 4° of 77° F during the holding tests. The results for the whole beans are shown in Table 4, but for sake of economy the data obtained for the cut size 5 beans are not presented here.

In 1947 the same general plan was followed except that 1-inch cut green Tendergreen beans and cut Yellow Wax beans were used. The cut beans were mechanically graded to size 4 at the canning plant and then brought to Geneva and kept at 35° F until used in the tests. The results of these experiments are shown in Tables 5 and 6.

The methods used in sampling and analyses were identical with those described for peas.

Experimental Results

Effect of blanching on enzyme activities

It is clear from the experimental results presented in Tables 4 to 6 that the catalase in the bean samples blanched during this study required more severe heat treatment for complete inactivation than did that of the peas. Whereas the catalase in all pea samples was inactivated by the minimum extent of blanching used (1 minute at 160° F), catalase was active in some of the bean samples even after heating to 180° F for 5 minutes. However, a direct comparison of

the inactivation of the catalase in peas and beans is hardly warranted on account of the different size, shape, and morphological structure of the particles heated.

All whole Refugee bean samples heated to 180° F showed some catalase activity (Table 4), but none of those heated to 190° and above. The second set of results obtained in 1946 on cut Refugee beans, size 5, gave similar results. In the 1947 study the cut size 4 Tendergreen beans (Table 5) showed some catalase activity in the samples heated for 4 minutes to 165° and for 2 minutes to 180°, but in none of the samples which were heated longer or at higher temperatures. However, in the run with the cut Yellow Wax beans, all samples heated to 165° and those heated to 180° for 2 or 4 minutes showed some catalase activity. It is quite clear from these results that either the catalase in different lots of beans show different susceptibilities to heat, or that such differences occur between varieties. The present data are insufficient to answer this question.

Peroxidase was completely inactivated by a blanch of 4 to 5 minutes at 210° F in all except the largest beans. A small amount of activity was retained in the size 5 cut Refugee beans (1946) even after 5 minutes of blanching at 210° F.

The BH and the SRS methods for estimation of this enzyme agreed in showing a progressive decline in residual activity with increased blanching times at all temperatures used (Table 4). However, there was always a stubbornly resistant small residual activity that required a high temperature of 210° F for complete inactivation. Occasionally, indications of a slight regeneration of peroxidase activity during the storage following blanching were observed, as for instance in Table 4 with the sample heated for 1 minute at 200° F. Due to the fairly high blank values obtained with enzyme heated for 10 minutes to 212°, the BH color readings were found to be most helpful in these tests.

Ascorbic acid oxidase required a temperature of at least 180° F for complete inactivation. Above that temperature all blanches of more than 1 minute duration showed the absence of this enzyme while below 180° complete inactivation was never achieved. This behavior was consistent in all tests with different varieties and sizes of beans.

Effect of blanching on solids content

Unfortunately snap beans do not lend themselves to the calcu-

TABLE 4.—*Inactivation of enzymes and various chemical changes in blanched and subsequently held whole snap beans, Refugee variety, size 2, 1946.**

Blanch		Holding time, hours	Residual enzyme activity†					Dry matter, per cent	Alcohol-insoluble solids, per cent	Crude fibre, per cent	Ascorbic acid, mg per 100 grams	Total sugars, per cent	Soluble nitrogen, per cent	Total nitrogen, per cent	Ash, per cent
			Catalase, per cent	Peroxidase			Ascorbic acid oxidase, per cent								
°F	Minutes			BH, per cent	BH, color	SRS, per cent									
—	–	0	100	100	+++	100	100	8.74	5.2	0.96	10.6	2.89	0.091	0.340	0.479
—	–	4	—	99	+++	90	—	8.32	5.6	1.03	10.0	—	—	—	0.450
180	1	0	16	53	+++	42	8.6	7.74	4.2	0.87	8.1	2.55	0.079	0.346	0.508
180	3	0	11	35	+++	26	1.0	7.59	4.4	0.90	7.8	2.57	0.069	0.315	0.539
180	5	0	16	29	++	19	2.5	8.06	5.8	1.05	8.5	2.60	0.089	0.338	0.425
190	1	0	0	20	++	13	0.8	8.19	4.4	0.92	9.4	2.59	0.069	0.333	0.422
190	3	0	0	12	++	4.3	0.7	8.50	5.3	1.08	8.5	2.80	0.067	0.319	0.457
190	5	0	0	9.5	+	3.6	0.7	8.18	4.8	0.95	8.7	2.65	0.070	0.319	0.472
200	1	0	0	15	+	12	0.7	7.94	4.5	0.92	10.1	2.57	0.055	0.315	0.474
200	1	4	0	19	++	12	—	8.03	4.5	0.90	7.1	2.58	0.069	0.334	0.551
200	3	0	0	7.4	+	5.1	0.9	7.87	4.9	0.88	8.0	2.62	0.083	0.345	0.429
200	3	4	0	7.8	+	5.0	—	8.62	4.9	—	4.5	2.30	0.074	0.331	0.510
200	5	0	0	8.9	+	2.7	1.0	8.29	4.4	0.86	5.3	2.46	0.073	0.339	0.455
200	5	4	0	6.8	+	3.2	—	8.49	5.0	0.89	3.6	2.44	0.081	0.338	0.438
210	1	0	0	10.4	+	2.9	0.7	8.22	4.6	0.88	8.9	2.47	0.066	0.329	0.493
210	3	0	0	6.1	+	0.4	0.8	8.05	5.0	0.91	7.5	2.34	0.067	0.315	0.488
210	5	0	0	4.0	0	0.0	0.6	8.17	4.4	0.87	7.9	2.30	0.063	0.339	0.432

*On fresh weight basis. Harvested August 27, 1946.
†See page 6 for meaning of abbreviations.

TABLE 5.—*Inactivation of enzymes and various chemical changes in cut snap beans during blanching and subsequent holding, Tendergreen variety, fancy grade, size 4, 1947.**

Blanch		Holding time, hours	Residual enzyme activity†				Dry matter, per cent	Ascorbic acid, mg per 100 grams	Ash, per cent	Calcium, per cent
			Catalase, per cent	Peroxidase		Ascorbic acid oxidase, per cent				
°F	Minutes			BH, per cent	BH, color					
—	—	0	100	100	+++	100	8.16	9.8	0.516	0.0417
—	—	1	—	—	—	—	8.38	9.6	0.539	—
—	—	2	—	—	—	—	8.31	10.2	0.527	—
165	4	0	7	59	+++	3.2	7.24	7.7	0.422	0.0413
165	4	1	0	60	+++	—	8.12	6.2	—	—
165	4	2	—	35	+++	—	7.41	5.2	—	—
165	6	0	0	33	+++	1.7	7.04	5.7	0.415	—
165	6	1	—	36	+++	—	7.54	6.4	—	—
165	6	2	—	45	+++	—	7.15	5.4	—	—
165	8	0	0	32	+++	0.1	7.20	7.1	0.415	—
165	8	1	—	43	+++	—	7.99	5.8	—	—
165	8	2	—	45	+++	—	7.64	5.4	—	—
180	2	0	20	41	+++	0.9	7.51	9.6	0.448	—
180	2	1	—	53	+++	—	7.71	7.4	—	—
180	2	2	—	42	+++	—	7.64	6.4	—	—
180	4	0	0	30	+++	0	7.74	8.7	0.462	—
180	4	1	—	51	+++	—	—	7.2	—	—
180	4	2	—	34	++	—	7.02	8.0	—	—
180	6	0	—	26	++	0	7.56	6.0	0.421	—
180	6	1	—	39	++	—	—	6.4	—	—
180	6	2	—	19	++	—	7.19	6.4	—	—
180	8	0	—	22	++	0	6.96	6.5	0.393	—
180	8	1	—	23	++	—	—	5.5	—	—
180	8	2	—	29	+	—	7.42	6.4	—	—
195	2	0	0	23	++	—	7.55	7.3	0.425	—
195	2	1	—	15	++	—	7.76	7.6	—	—
195	2	2	—	2.3	+	—	7.85	7.0	—	—
195	4	0	0	22	+	—	7.99	6.7	0.407	—
195	4	1	—	4.6	+	—	—	6.6	—	—
195	4	2	—	16	+	—	7.29	5.6	—	—
195	6	0	0	20	+	—	7.39	6.8	0.420	—
195	6	1	—	25	+	—	—	6.4	—	—
195	6	2	—	23	++	—	7.49	7.1	—	—
195	8	0	—	17	+	—	7.36	5.2	0.430	—
195	8	1	—	3.8	+	—	—	5.5	—	—
195	8	2	—	25	+	—	—	4.7	—	—
210	2	0	0	19	+	—	7.64	7.7	0.439	0.0411
210	2	1	—	13	+	—	—	8.0	—	—
210	2	2	—	26	+	—	7.89	6.2	—	—
210	4	0	—	0	0	0	6.35	6.2	0.393	—
210	4	1	—	0	0	—	—	6.2	—	—
210	4	2	—	—	—	—	7.06	5.0	—	—
210	6	0	—	0	0	0	6.92	6.7	0.402	—
210	6	1	—	0	0	—	—	5.6	—	—
210	6	2	—	—	—	—	—	5.2	—	—

*On fresh weight basis. Harvested September 9, 1947.

†See page 6 for meaning of abbreviations.

lation of unit weight since the weight and shape variation between individual pieces of cut beans is so great that they overshadow the slight unit weight changes which one might expect during blanching. The dry matter determinations, however, show some interesting trends. Blanching appeared to reduce the dry matter content of beans in all of the experiments. This was the result, in part, of leaching as indicated by the consistent loss of 10 to 20 per cent of the sugar content (Table 4). At the same time, it is quite clear that the major effect causing the apparent decrease of solids content must have been the increased imbibition resulting from heating the bean tissues. This is indicated by the crude fiber content of the samples (Table 4). This constituent is by definition not subject to leaching action and still it showed a fairly consistent although slight drop. The alcohol-insoluble solids content, shown in the same table, also tends to support these conclusions. The extent of additional water uptake seemed particularly pronounced with blanching temperatures of 200° F and above.

Changes in some chemical constituents

Ascorbic acid.—Comparing the similar blanching treatments in the three experiments reported in Tables 4 to 6 and in the experiment with cut size 5 Refugee beans for which the data are not given here, the average losses of ascorbic acid due to the blanching treatment alone ranged from 69 to 80 per cent. As observed with peas, lengthening the blanching treatment had a more detrimental effect on the ascorbic acid content than did an elevation of the blanching temperature. However, the results are far from regular, perhaps due mainly to two factors. First, the extent of leaching possible in a cut tissue is likely to be more irregular than with whole units like peas, and, secondly, it is not quite clear at exactly what temperature and duration of blanching the "thermal maceration" became a factor.

The ascorbic acid in beans is susceptible to destruction during blanching and subsequent holding (Tables 4 to 6). Interestingly enough, a temperature zone where heating causes the type of ascorbic acid loss ascribable to "thermal maceration" occurs at a higher temperature than in the case of peas. With peas this phenomenon was not observed in samples heated to 190° F or above. Marked losses occurred, on the other hand, in some of the bean samples stored even after blanching for 6 minutes at 210°. This apparent resistance is explained, at least in part, by the larger tissue particles heated in

TABLE 6.—*Inactivation of enzymes and various chemical changes in cut snap beans during blanching and subsequent holding, Yellow Wax variety, fancy grade, size 4, 1947.**

Blanch		Holding time, hours	Residual enzyme activity†				Dry matter, per cent	Ascorbic acid, mg per 100 grams	Ash, per cent	Calcium, per cent
			Catalase, per cent	Peroxidase		Ascorbic acid oxidase, per cent				
°F	Minutes			BH, per cent	BH, color					
—	—	0	(100)	100	+++	100	7.85	9.0	0.443	0.0419
—	—	1	—	—	—	—	7.70	9.9	0.448	—
—	—	2	—	—	—	—	7.63	8.6	0.449	—
165	4	0	4	52	+++	0.7	7.52	7.1	0.399	0.0417
165	4	1	—	37	+++	—	7.27	5.9	—	—
165	4	2	—	45	+++	—	7.74	6.6	—	—
165	6	0	2	30	+++	0.7	6.99	6.5	0.389	—
165	6	1	—	30	+++	—	7.91	7.0	—	—
165	6	2	—	16	+++	—	7.37	5.9	—	—
165	8	0	3	20	+++	0.8	7.34	6.3	0.391	0.0427
165	8	1	—	30	+++	—	7.30	6.3	—	—
165	8	2	—	27	+++	—	7.04	5.9	—	—
180	2	0	3	23	+++	0	7.36	7.9	0.421	0.0407
180	2	1	—	23	+++	—	7.75	8.0	—	—
180	2	2	—	31	+++	—	7.07	7.8	—	—
180	4	0	4	20	+++	0.2	7.35	7.3	0.406	—
180	4	1	—	20	+++	—	7.41	7.7	—	—
180	4	2	—	2.4	++	—	7.10	7.9	—	—
180	6	0	0	11	++	0	7.28	6.7	0.363	—
180	6	1	—	11	++	—	7.46	6.5	—	—
180	6	2	—	9.0	++	—	6.90	7.4	—	—
180	8	0	0	10	++	0	7.89	6.4	0.404	0.0441
180	8	1	—	6.7	++	—	7.44	6.5	—	—
180	8	2	—	18	++	—	6.57	6.4	—	—
195	2	0	0	13	++	0.5	7.08	7.8	0.400	0.0419
195	2	1	—	14	++	—	7.02	8.3	—	—
195	2	2	—	13	++	—	7.23	8.6	—	—
195	4	0	—	3.5	+	0	7.85	7.8	0.388	—
195	4	1	0	0	+	—	7.11	7.8	—	—
195	4	2	—	0	+	—	7.40	6.4	—	—
195	6	0	0	11	++	0	6.92	6.8	0.387	—
195	6	1	—	5.3	+	—	6.96	7.1	—	—
195	6	2	—	5.1	+	—	7.08	5.6	—	—
195	8	0	0	24	++	0	6.99	6.9	0.385	0.0440
195	8	1	—	21	++	—	7.66	7.0	—	—
195	8	2	—	28	++	—	7.00	5.8	—	—
210	2	0	0	3.8	+	0	7.12	7.9	0.396	0.0431
210	2	1	—	4.2	+	—	7.44	7.1	—	—
210	2	2	—	7.6	+	—	7.44	5.5	—	—
210	4	0	0	0	0	0	6.83	6.6	0.394	—
210	4	1	—	0	0	0	7.20	—	—	—
210	4	2	—	—	—	—	7.30	5.8	—	—
210	6	0	0	0	0	0	6.93	6.4	0.381	0.0436
210	6	1	—	0	0	—	7.16	—	—	—
210	6	2	—	—	—	—	7.03	1.5	—	—

**On fresh weight basis. Harvested September 2, 1947.*
†See page 6 for meaning of abbreviations.

the case of the beans, but it would seem that this effect might be related to enzyme systems more resistant to heat or to conditions in the tissue providing some protective action. It is quite striking, again, that the results of the ascorbic acid oxidase determinations, as performed in this study, bear no relationship to the occurrence of "thermal maceration" and the resultant ascorbic acid losses.

These observations bring to mind the possible existence in beans of catalytic systems of non-enzymic nature (25) which may be responsible for some of the oxidation of ascorbic acid. While the present results suggest such a possibility, further work is required to ascertain the true causes of ascorbic acid losses during partial blanching.

Total sugars.—In the experiment shown in Table 4 where sugar determinations were made, there was an approximate average 20 per cent loss of sugars on the fresh weight basis and 10 per cent loss on the dry matter content basis. The comparatively few analyses available do not warrant the drawing of more precise conclusions.

Alcohol-insoluble solids and crude fiber.—We have already noted above that both of these constituents showed a slight but definite decrease due to blanching, indicating a change in the water-holding capacity of the tissue rather than any absolute losses (Table 4). This change was more definite with beans blanched at 200° F and above than with milder heat treatments.

Total nitrogen and nitrogenous fractions.—The total nitrogen content of the beans used in the experiment given in Table 4 did not change materially, the average of all blanching treatments being 0.33 per cent as compared with 0.34 per cent in the unblanched control. This is somewhat puzzling in view of the fairly well established increased water contents of the blanched samples. On the other hand, there seemed to have occurred a definite change of alcohol-soluble nitrogenous compounds to alcohol-insoluble ones, this change being discernible in every one of the 15 blanched samples. The meaning of these observations is obscure.

Ash and calcium.—The results of the ash determinations on the 1946 bean samples were somewhat inconsistent, although with long blanching times a definite increase in the loss of ash was quite clear. The 1947 results in Tables 5 and 6 show quite consistent ash losses in the range of 5 to 24 per cent in every one of the blanched samples. Generally speaking, both increased blanching tempera-

tures and longer blanching times tended to accentuate the loss of mineral constituents. The calcium contents of the bean samples analyzed indicated a slight increase in several of the blanched samples, particularly in beans which were blanched for longer periods. This again indicates the interplay of loss of mineral constituents, on one hand, and the picking up of additional calcium, on the other, in the pattern observed with the blanched peas.

Commercial-scale Bean Blanching Tests

In the course of these tests, we have made a comparison between two lots of blanched and canned cut Yellow Wax beans, one of which was blanched at 185° F for 4.5 minutes and the other at 212° F for 1.5 minutes. These tests were made under commercial conditions in a canning factory where the lower temperature blanch was used in the commercial packing of the beans.

The samples were obtained from one lot of well-mixed beans and were blanched by the full-scale rotary water blancher of the plant. Afterwards the beans were immediately canned and processed. Samples were taken immediately after blanching from the blanched beans, cooled, and part analyzed at once and part after 2 hours of holding at room temperature. The canned beans were analyzed for dry matter, ash, ascorbic acid, and thiamine. The results obtained are shown in Table 7.

Both the short, high-temperature blanch (SH) and the longer, lower-temperature blanch (LL) completely inactivated the catalase and ascorbic acid oxidase. Peroxidase activity was absent in the SH beans, but 59 per cent of the original activity remained in the LL lot. Dry matter and ash values were slightly higher in the SH sample, either because of less leaching or less imbibition of water. Of course, both factors may be involved, but previous pilot plant experiments would indicate that imbibition was the more important cause. A greater destruction of ascorbic acid occurred in the SH lot during the blanching operation. However, after canning, the situation was reversed so that the difference had no evident practical significance. The thiamine content of the LL beans was also higher, but after canning the difference was slight.

A comparison of the quality of the beans in the two lots indicated no discernible differences in color, flavor, or texture. Judging from the few chemical constituents determined in this test, there was little demonstrable difference between the two lots of beans. The ascorbic

TABLE 7.—*Comparison of the chemical composition of wax beans processed at 185° F for 4.5 minutes ("LL") and at 212° F for 1.5 minutes ("SH"), calculated on fresh weight basis.*

SAMPLE	RESIDUAL ENZYME ACTIVITY			DRY MATTER, PER CENT	ASH, PER CENT	ASCORBIC ACID, MG PER GRAMS	THIAMINE, MG PER 100 GRAMS
	Catalase, per cent	Peroxidase, per cent	Acsorbic acid oxidase, per cent				
Raw beans	(100)	(100)	(100)	9.38	0.595	15.8	0.093
Blanched "LL"	0	59	0	8.68	0.471	14.2	0.087
Same, held 2 hours	0	–	0	—	—	13.4	—
Blanched "SH"	0	0	0	8.88	0.501	11.5	0.061
Same, held 2 hours	0	0	0	—	—	10.1	—
Canned "LL"							
Beans only	0	0	0	7.72	0.958	3.5	0.035
Brine only	–	–	–	—	—	5.8	0.041
Total on bean basis	–	–	–	—	—	6.6	0.057
Canned "SH"							
Beans only	0	0	0	8.16	1.146	4.0	0.034
Brine only	–	–	–	—	—	6.7	0.030
Total on bean basis	–	–	–	—	—	7.6	0.050

acid apparently saved by the use of the lower temperature was eventually lost in the canning procedure. Blanching at the lower temperature left a considerable residual peroxidase activity, but there was no evidence of any related ill effect on the quality of the finished product.

Lima Beans

Experimental Methods

The only experiment with lima beans was conducted in 1946. The beans were shelled and washed at a nearby processing plant and, after covering with ice, were conveyed to the Station laboratory. Unfortunately, no mechanical size graders were available for this work. The lima beans were subjected to an approximate size grading by passing them over a sorting table and removing all very small and very large beans. The final samples represented an approximate average size 4 or "medium," with a considerable proportion of the immediately smaller and larger sizes also present. The size and weight distribution curves for the final samples showed considerable heterogeneity in these respects. However, usually about 50 individual lima beans were present in the duplicate 50-gram samples taken for analysis and therefore the sampling error was reduced even if not eliminated. Quadruplicate samples were taken of the fresh unblanched lima beans.

After sorting, the beans were thoroughly washed and blanched in the same miniature experimental blancher as used for the peas and beans. The times and temperatures of blanching used are listed in Table 8.

Experimental Results

Enzyme activities after blanching

The three enzymes investigated in this study showed the same order of resistance to heat as they did in peas and snap beans (Table 8). Catalase was the most heat labile, ascorbic acid oxidase was only slightly more resistant, and peroxidase showed a relatively high heat resistance. Except for a slight catalase activity in the sample blanched at 180° F for 2 minutes, all catalase tests were negative. Assuming a "base value" of 3 per cent, the only positive ascorbic acid oxidase tests were obtained in the samples blanched at 180° and 190° F. In a few instances definite regeneration of peroxidase activity could be noted after 4 hours of storage, but interestingly enough such regeneration was more noticeable with the titrimetric and colorimetric BH method than by the SR method. Just as with the snap beans, heating at 210° for longer than 2 minutes was required for the complete inactivation of the peroxidase.

Changes in water content

The dry matter content of the lima beans ranged from 29.5 to 32.9 per cent, an approximately 10 per cent variation. Although the weights of single lima bean, both fresh (wet) and dry were determined in all samples used for dry matter determination, the variations observed were too great to calculate the results on "single lima bean basis." The results shown in Table 8 indicate no definite trends in water contents. If such changes occurred, they were masked by the experimental variations in the raw lima beans used.

Changes in ascorbic acid content

With a few exceptions, the losses caused in the ascorbic acid content of the lima beans by blanching and holding were considerably less than the losses observed with peas and snap beans. The raw (unblanched) sample lost no ascorbic acid during the 4 hours of holding. A distinct increase in the ascorbic acid losses due to blanching occurred as the blanching temperatures and durations increased. Only in the sample blanched at 180° F for 2 minutes did ascorbic acid loss occur of the type due to "thermal maceration" and pre-

TABLE 8.—*Inactivation of enzymes and chemical changes in blanched and subsequently held lima beans, approximate average size 4.**

Blanch		Holding time, hours	Residual enzyme activity†				Dry matter, per cent	Single unit weight, grams		Alcohol-insoluble solids, per cent	Crude fibre, per cent	Ascorbic acid, mg per 100 grams	Total sugars, per cent	Soluble nitrogen, per cent	Insoluble nitrogen, per cent	Ash, per cent
			Catalase, per cent	Peroxidase												
°F	Minutes			BH, per cent	BH, color	SRS, per cent	Ascorbic acid oxidase, per cent		Fresh	Dry						
—	—	0	100	100	+++	100	100	32.7	2.27	0.742	29.0	1.86	27.4	1.40	0.072	0.262	1.173
—	—	2	–	—	—	—	—	31.5	2.00	0.631	29.0	—	26.1	1.35	0.075	0.286	1.119
—	—	4	–	—	—	—	—	31.8	2.00	0.636	30.3	1.80	27.8	1.40	0.081	0.257	1.086
180	2	0	2	29	+++	21.4	7.7	31.1	2.17	0.676	27.9	1.32	20.9	1.20	0.067	0.282	1.024
180	2	4	–	29	+++	22.1	—	32.5	2.08	0.678	28.7	—	17.3	1.38	0.068	0.266	1.028
180	4	0	0	28	+++	16.1	1.6	29.5	2.00	0.591	28.5	1.41	22.4	1.24	0.061	0.245	0.988
180	6	0	0	21	+++	10.0	1.8	29.8	2.08	0.620	28.1	—	20.6	1.24	0.055	0.290	0.939
180	8	0	0	20	+++	9.3	2.8	30.9	1.92	0.593	27.8	1.68	19.7	1.18	0.056	0.257	0.941
180	8	4	–	22	+++	9.1	—	30.0	1.89	0.565	—	—	19.7	—	—	—	0.913
190	2	0	0	25	+++	10.8	6.2	32.2	2.38	0.767	27.8	1.70	23.1	1.18	0.060	0.271	1.002
190	4	0	0	16	+++	4.2	1.3	30.2	2.08	0.630	25.4	1.80	20.9	1.37	0.065	0.276	0.955
190	6	0	0	15	+++	6.1	2.2	31.5	2.22	0.699	28.6	1.47	19.8	1.30	0.056	0.257	0.983
190	8	0	0	13	+++	3.6	1.8	29.9	2.17	0.650	28.9	1.79	19.4	1.21	0.054	0.276	0.898
200	2	0	0	19	+++	9.8	2.5	31.2	2.13	0.650	28.6	1.63	20.9	1.18	0.065	0.266	1.011
200	2	4	–	27	+++	9.6	—	30.8	1.96	0.603	26.5	—	19.1	1.17	0.072	0.290	0.978
200	4	0	0	12	+++	0	1.2	30.2	2.33	0.702	28.0	1.64	20.6	1.21	0.060	0.270	0.925
200	6	0	0	12	++	0	1.3	32.9	2.17	0.749	29.5	1.74	17.0	0.98	0.053	0.282	1.001
200	8	0	0	8	+	0	1.3	31.0	1.96	0.607	27.9	1.57	18.7	1.16	0.042	0.246	0.886
200	8	4	–	15	++	0	—	31.8	2.50	0.795	25.5	—	17.9	1.18	0.054	0.283	0.941
210	2	0	0	7	+	3.0	2.6	30.4	2.50	0.759	27.0	1.71	19.2	1.34	—	0.270	0.950
210	2	4	–	14	++	3.4	—	30.8	2.08	0.640	28.2	—	17.1	1.20	0.054	0.262	0.955
210	4	0	0	5	0	0	2.6	32.9	2.70	0.888	25.1	1.73	17.0	1.35	0.052	0.282	1.073
210	6	0	0	6	0	0	2.6	30.2	2.38	0.720	26.2	1.73	17.5	1.13	0.048	0.250	0.953
210	8	0	0	6	0	0	3.0	30.5	2.38	0.725	—	—	16.5	—	—	—	0.898
210	8	4	–	–	–	0	—	29.7	2.17	0.645	26.3	1.70	14.9	1.25	0.044	0.266	0.898

*On fresh weight basis. Harvested September 23, 1946. Approximate average size No. 4.
†See page 6 for meaning of abbreviations.

viously described with peas and snap beans. In this case the ascorbic acid content of the freshly blanched sample was also lower than would be indicated from the behavior of the other samples and thus some loss due to "thermal maceration" might have occurred in these lima beans by the time the zero-time samples were fixed for analysis. The samples which received a severe blanching of 8 minutes at 210° showed a considerable loss of ascorbic acid during the subsequent 4-hour holding period. We have no explanation for this phenomenon.

Changes in total sugars, crude fiber, alcohol-insoluble solids, nitrogenous fractions, and ash

As expected, the loss of sugars increased as the length of blanching treatment and the temperature of the blanching water were increased, but it is felt that the extent of sugar losses (mostly below 20 per cent) and the irregularity of the results make a detailed discussion of these results unwarranted. The same holds for the results obtained on crude fiber and alcohol-insoluble solids.

The results obtained on the nitrogenous fractions are interesting. The bulk of losses in this fraction occurred in the alcohol-soluble nitrogenous fraction and only upon prolonged blanching was any loss from the alcohol-insoluble nitrogenous substances observable. However, while the proportion of loss in the alcohol-soluble fraction reached over 25 per cent in a number of instances, the absolute amount of this constituent (0.07 per cent, on fresh weight basis) is too small to have any known practical significance.

Within the ranges studied, the lengthening of the blanching period accentuated the losses of ash constituents more than the elevation of the blanching temperature. This is in harmony with the observations on peas and beans.

Discussion

The desirability of blanching vegetables before canning is now generally accepted. At the same time it is also clear that the blanching operation will remove or destroy some of the vitamins and nutrients originally present in vegetables. The problem, therefore, is to find blanching conditions which will give the most desirable product from the quality standpoint with the least harm to the vitamins and nutrients.

The present study also endeavored to assess the effects of the

blanching operations on the losses which might occur during the holding of blanched vegetables before canning. Ascorbic acid and some other chemical constituents were used as indicators of changes which may occur.

Changes in the activities of three enzymes were used to show the extent of thermal treatment which the individual vegetable particles have received during blanching.

With the exception of a single commercial-size experiment on snap beans, no canning tests were made on the blanched vegetables since it is now well established that the major loss of ascorbic acid in vegetables occurs before the product is sealed and processed.

In harmony with various reports in the literature, the experiments reported here show that the effect of blanching on the various enzymes investigated depends, in addition to the blanching treatment itself, on the kind of vegetable, particle size, maturity, and likely some additional but as yet little understood factors. However, the general statement may be made that catalase and ascorbic acid oxidase are relatively easy to inactivate in the vegetables studied. In the case of catalase, heat treatments of 180° F for 6 minutes or 195° F for 2 minutes (in the case of one lot of snap beans) were sufficient to completely inactivate this enzyme. On account of the somewhat irregular "base" values, the results are more difficult to evaluate in the case of ascorbic acid oxidase. Yet, it is clear that a heat treatment only slightly in excess of that required in the case of catalase will usually inactivate ascorbic acid oxidase.

The peroxidase required much more severe thermal treatment and to inactivate it completely and permanently required in the case of peas, heating to 190° F for 3 minutes; in the case of snap beans, to 210° F for at least 4 minutes; and in the case of lima beans, to 210° F for 4 minutes. It is believed that the differences observed were caused by the different particle sizes and particle shapes in the three vegetables studied. Of course, these will seriously affect the rate of heat penetration.

In practically every instance observed in this study, a short blanch at a higher temperature resulted in less loss of ascorbic acid than a longer blanch at a lower temperature. As was observed in connection with the individual experiments, an increase in the temperature of the blanch usually resulted in little accentuation of the ascorbic acid losses while prolonging the blanching caused increased losses of ascorbic acid. While this observation agrees with the major

conclusions of several previous investigations dealing with the effects of blanching, it is believed that an important cause of loss of ascorbic acid, namely, the occurrence of "thermal maceration" in the tissue (7,21), has been insufficiently emphasized in the past. Since accentuated losses of ascorbic acid occur in underblanched vegetables, it is desirable to pass through the region where "thermal maceration" occurs as rapidly as possible. This can be most effectively accomplished by the use of high blanching temperatures. In addition to the lesser extents of extraction of vitamins and nutrients during high-short blanches as compared with low-long blanches, this constitutes another argument in favor of the application of blanching temperatures as high as practicable.

Summary

Peas, snap beans, and lima beans were blanched on a pilot plant scale at various temperatures and for different lengths of time. The progress of the inactivation of the enzymes catalase, peroxidase, and ascorbic acid oxidase was followed and the changes which occurred in several chemical constituents were determined. To clarify the nature of these changes, blanched peas were held at room temperature for several hours and samples removed periodically for analyses.

Of the enzymes studied, catalase was easiest to inactivate, peroxidase was the most stable, while ascorbic acid oxidase showed an intermediate heat lability between catalase and peroxidase. No relationship could be established between the inactivation of any of the enzymes and of various chemical changes.

Dry matter and unit weight changes in peas during blanching indicate a progressive loss of solids and a simultaneously increased imbibition of water. Prolonged blanching increased the removal of solids while the blanching temperature was only of minor importance as exemplified by the changes in sugar content. The degree to which solids were affected by blanching peas varied from large losses of sugar and alcohol-soluble nitrogenous compounds to negligible changes, if any, in alcohol-insoluble solids and crude fiber.

The loss of ascorbic acid from peas during blanching is caused both by the destruction of ascorbic acid by some enzyme system, or systems, in the pea and by leaching. In this study the loss of ascorbic acid in raw or adequately blanched peas during holding for 2 hours at room temperature was negligible. At certain intermediate tem-

peratures (critical temperatures) where the heating was inadequate for enzyme inactivation but sufficient to cause "thermal maceration", the ascorbic acid losses during holding were rapid and extensive. In the present experiments peas blanched at 160° F for 1 to 7 minutes and at 175° F for 1 minute showed this phenomenon of "thermal maceration". Where losses were due to leaching as indicated by stable ascorbic acid values during holding, the length of the blanch determined the extent of loss more than did the water temperature.

Extensive losses of ash constituents from peas and snap beans were observed during blanching. Again, the length of the blanching treatment appeared to have a greater influence on the extent of ash removal than did water temperature. Calcium, an important ash constituent, increased with all blanching treatments, undoubtedly by the combination of various constituents of the tissues and the calcium in the wash and blanching waters.

In beans, catalase showed a varying degree of heat resistance, in one case being completely destroyed at 165° F in 6 minutes and in other cases requiring 4 minutes at 180° F for total inactivation. Peroxidase was extremely heat resistant in beans, invariably requiring 4 to 5 minutes of heating at 210° F for complete inactivation. Ascorbic acid oxidase required a temperature of 180° F for 4 to 6 minutes for complete inactivation.

Observations on crude fiber, alcohol-insoluble solids, dry matter, ash, and total nitrogen of snap beans revealed that some of the changes in these constituents were caused by imbibition of water rather than by leaching. Approximately half of the apparent losses of sugars were real. Blanching caused a small fraction of the soluble nitrogen to be converted to the insoluble state. Total calcium is increased by a contribution from the blanching water.

After the tissue has been disrupted by heat ("thermal maceration"), the ascorbic acid of snap beans is especially liable to enzymic oxidation in under-blanched material and to non-enzymic oxidation in adequately blanched beans. These two types of oxidation were well demonstrated by holding the blanched beans at room temperature. No corresponding losses of ascorbic acid occurred in unblanched snap beans.

The less extensive experiments conducted on lima beans indicated a smaller extent of loss of ascorbic acid from this vegetable than from peas or snap beans. Considerable losses occurred in the alcohol-soluble nitrogenous fraction during blanching.

A single commercial-scale experiment with raw, blanched, and canned snap beans indicated no significant differences in ascorbic acid and thiamine or in quality of two lots of beans blanched for 4.5 minutes at 185° F and for 1.5 minutes at 212° F.

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