THE VITAMIN C CONTENT OF COMMERCIALLY CANNED SAUERKRAUT PRODUCED UNDER KNOWN CONDITIONS [1]

By HELEN T. PARSONS, *associate professor*, and CAROLYN HORN, *industrial fellow*, *Department of Home Economics, Wisconsin Agricultural Experiment Station* [2]

INTRODUCTION

In a previous paper [3] the antiscorbutic value of six brands of commercially canned sauerkraut was shown to vary widely. The vitamin C content of two of these brands compared very favorably with specially fermented fresh raw sauerkraut tested by Clow, Marlatt, Peterson, and Martin,[4] while the poorest brand contained from one half to one third as much vitamin C as the best brands. Because of the lack of uniformity in the methods used in the manufacture of the sauerkraut tested, it was not possible to determine what factor or set of factors was responsible for the loss of antiscorbutic vitamin in the poorer brands. The cooperation of 4 of the 6 commercial packers who had contributed to the previous experiment was welcomed, therefore, in producing samples of canned sauerkraut under controlled conditions, as nearly uniform as feasible in all four factories. The packers who had produced the two highest scoring brands, A and B, the previous year, did not share in the present experiment.

Earlier observation [5] that bulk sauerkraut, as purchased, may be very poor in antiscorbutic potency was confirmed by the experiments of Lawrow and Jarussowa [6] who tested a market lot of sauerkraut which they kept in a wooden keg. The juice fed was prepared by first draining off and discarding the brine, and then squeezing the chopped sauerkraut in a cloth by hand. Thirty cubic centimeters of this juice fed daily gave complete protection against scurvy in guinea pigs, but 20 cubic centimeters gave only partial protection. The author estimated that the sauerkraut itself, without the brine, contained about 70 percent of the concentration in the juice tested.

[1] Received for publication Feb. 27, 1933; issued October 1933. This study was made possible through an industrial fellowship fund given to the University of Wisconsin by the National Kraut Packers' Association. The research carried out under the fund was organized and executed by members of the university staff in the university laboratories.

[2] Thanks are due to Dr. W. H. Peterson, Department of Agricultural Chemistry, and Dr. E. B. Fred, Department of Agricultural Bacteriology, for valuable assistance in planning the research; to W. I. Berg and other members of the research committee of the National Kraut Packers' Association for outlining the detailed procedures to be followed in the manufacture of the sauerkraut and securing the cooperation of the four sauerkraut packers; and to the packers themselves for their courtesy in supplying the data on the manufacturing procedures used. Thanks are also due Dorothy Adgate and Corrine Hogden for assistance in the preparation of the solutions, in calibration, and in chemical determinations. All solutions were checked by the senior author.

[3] CLOW, B., PARSONS, H. T., and STEVENSON, I. THE VITAMIN C CONTENT OF COMMERCIALLY CANNED SAUERKRAUT, TOGETHER WITH SOME OBSERVATIONS ON ITS VITAMIN A CONTENT. Jour. Agr. Research 41: 51–64, illus. 1930.

[4] ——— MARLATT, A. L., PETERSON, W. H., AND MARTIN, E. A. THE VITAMIN C CONTENT OF FRESH SAUERKRAUT AND SAUERKRAUT JUICE. Jour. Agr. Research 39: 963–971, illus. 1929.

[5] ELLIS, N. R., STEENBOCK, H., AND HART, E. B. SOME OBSERVATIONS ON THE STABILITY OF THE ANTISCORBUTIC VITAMINE AND ITS BEHAVIOR TO VARIOUS TREATMENTS. Jour. Biol. Chem. 46: 367–380, illus. 1921.

[6] LAWROW, B. A., and JARUSSOWA, N. SAUERKRAUT ALS C-VITAMINTRÄGER. Biochem. Ztschr. 229: 115–127, illus. 1930.

PLAN OF EXPERIMENT

As it was desirable that the details of the method employed in producing the canned sauerkraut should be in accordance with the best commercial practice, an outline of the processes necessary to be controlled in the experiment was drawn up by members of the Departments of Home Economics, Agricultural Chemistry, and Agricultural Bacteriology of the University of Wisconsin and submitted to a research committee of the National Kraut Packers' Association for their decision as to the exact procedure to be followed. Specific detailed instructions were then sent to each of the four factories. The points covered in the instructions are indicated by the details under item in table 1. Machine canning, which presumably would give the most nearly accurate control possible in commercial practice, was employed by three of the plants. The fourth plant, however, was particularly interested in hand packing, and inasmuch as large quantities of commercial sauerkraut are packed by hand, it was thought that the inclusion of this method would make the samples more nearly representative of commercial sauerkraut and furnish a valuable control. Except for this one variation in the method of canning, an attempt was made to secure the highest degree of uniformity possible throughout the four factories.

TABLE 1.—*Condensed reports of the four sauerkraut companies on methods employed in manufacturing and canning the brands used in present experiments*

CUTTING

Item	Month	Brands [a]			
		C_2	E_2	F_2	D_2
Variety of cabbage used		All Seasons	All Seasons	Believed to be mostly Glory of Enkhuizen.	All Seasons 70 percent, All Head, Glory of Enkhuizen.
Salinometer readings at time of filling tank.		15° F	November 15° F March, 19° F	15° F	November, 16.5° to 15° F. April, 15°.

TEMPERATURE

Room temperatures during fermentation	November December January February March	68°	72° to 48° F 61° to 38° F 38° to 20° F 53° to 30° F 62° to 54° F	55° to 70° F. (range for entire time).	56° to 44° F. 63° to 46° F. 58° to 36° F. 62° to 48° F. 59° to 50° F.
Temperature of the cabbage at time of cutting.		Estimated to be 45° to 50° F.	42° to 44° F	47° to 56° F	44° to 46° F.
Temperature of sauerkraut during fermentation.	November December January February March	55° F. (estimated)	56° to 48° F 48° to 44° F 43° to 30° F 40° to 30° F 49° to 44° F	70° to 61° F 70° to 66° F 65° to 55° F	56° to 44° F. 55° to 49° F. 54° to 42° F. 51° to 46° F. 53° to 50° F.
Temperature of cold sauerkraut at time of canning.		46° F	45° to 49° F	65° F	51° F.

[a] Listed in order of vitamin C concentration.

TABLE 1.—*Condensed reports of the four sauerkraut companies on methods employed in manufacturing and canning the brands used in present experiments*—Continued

ACIDITY

Item	Month	Brands					
		C_2	E_2	F_2	D_2		
					Top	Middle	Bottom
					Percent	*Percent*	*Percent*
Average acidity of fermenting sauerkraut for each month, expressed as lactic acid	November				0.72	0.68	0.74
	December				1.25	1.24	1.30
	January				1.31	1.32	1.32
	February				1.52	1.54	1.57
	March				1.66	1.67	1.69
Acidity of the bulk sauerkraut as it goes into the can.		2.16 percent / 1.98 percent [b]	1.46 percent [c] / 1.46 percent [b]	1.66 percent	[c] 1.72	[c] 1.72	[c] 1.76
Total acidity, expressed as percentage lactic acid, in the canned sauerkraut (average for 20 determinations for each brand).		1.47 percent	1.14 percent	1.40 percent	1.39 percent.		
Highest reading of acidity in cans [b]		1.49 percent	1.22 percent	1.43 percent	1.43 percent.		
Lowest reading in acidity in cans [b]		1.45 percent	1.10 percent	1.37 percent	1.36 percent.		
Reduction in acidity during canning		29 percent	22 percent	16 percent	20 percent.		
pH of canned sauerkraut [b]		5.2	5.2	5.2	5.2.		

CANNING

Length of fermentation		121 days	130 days	92 days	145 days.
Date of opening tank and canning		March 6	March 17	February 19	April 2.
Time in preheating tank		Estimated to be 6 minutes	Approximately 20	4 minutes	10 minutes.
Temperature of sauerkraut as it leaves preheating tank and is put into cans.		180° F	132°–137° F	110° F	130° F.
Method of packing		Machine	Machine	Hand	Machine.
Additional brine or water used in canning		Mixture of about 3 barrels salt water to each 15 barrels of sauerkraut in preheating vat.	Mixture of 5 percent brine and 95 percent pure water added in automatic filler.	Hot salt brine (not sauerkraut brine) in preheating vat.	Approximately 3 ounces water added to each can in the filler.
How the amount of brine added is determined.			To control acidity (tests at various intervals).	Added to keep up the heat	

Time in exhaust			5 minutes	5 minutes	7 minutes.
Temperature in the can before sealing		Average 178° F	146° F. bottom 140° F. center 186° F. outside	120° F. center	140° F. center. 184° F. outside.
Cooking after sealing		None	None	Cooked in rotary Anderson and Barngrover continuous rotary cooker for 10 minutes; center of can after cooking was 165°.	None.

SOLID AND LIQUID CONTENTS OF COMMERCIALLY CANNED SAUERKRAUT

Average weight of the drained solid content of sauerkraut in 16 or more cans of each brand.		681 grams	675 grams	669 grams	717 grams.
Average weight of liquid in 16 cans of each brand.		103 grams	131 grams	138 grams	89 grams.
Additional liquid required to completely fill cans of sauerkraut:					
A, range		28 to 55 cubic centimeters	28 to 46 cubic centimeters	25 to 56 cubic centimeters	37 to 60 cubic centimeters.
B, average of the six determinations made for each brand.		38 cubic centimeters	39 cubic centimeters	42 cubic centimeters	43 cubic centimeters.
Reduced pressure in cans of sauerkraut; average of three determinations for each brand.		8 pounds	12.1 pounds	11.6 pounds	12.8 pounds.

[b] Acidity tests made at University of Wisconsin. Average acidity of C_2 was 2.07 percent.
[c] Figures for last determination of acidity in fermentation tank.

EXPERIMENTAL PROCEDURE

The details of the care of the experimental animals and the feeding of the doses of sauerkraut were identical with those employed by Clow, Parsons, and Stevenson.[7]

Standard solutions and calibrated glassware and thermometers were furnished to the four companies by the Department of Home Economics of the University of Wisconsin.

The hydrogen-ion content of the canned sauerkraut was determined by means of a Leeds and Northrup potentiometer with a quinhydrone electrode.

Total acidity was determined by titrating with N/10 sodium hydroxide 10 cc of sauerkraut juice after the addition of 15 cc of water and 1 cc of a 1 percent solution of phenolphthalein and after a few seconds of boiling.

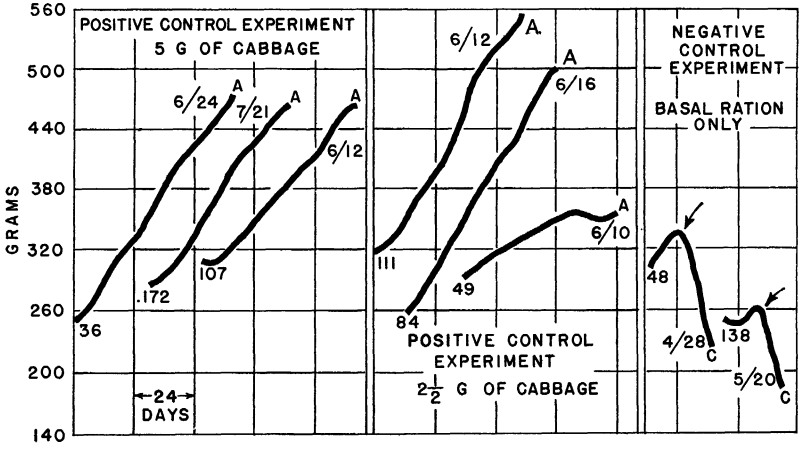

FIGURE 1.—Control experiments on vitamin C. In the positive control experiment, the animals received 5- or 2½-g doses of raw cabbage daily. In the negative control experiment, the animals were fed the basal ration alone; arrows above the weight curves indicate the point at which pronounced scurvy became evident. The month and day of the month on which autopsy was performed are indicated near the end of the weight curve of each animal. Autopsy symbols are as follows: A, no sign of scurvy; A?, possibility of scurvy; A−, slight but definite signs of scurvy; B+, moderate scurvy; B, B−, C+, and C, increasing degrees of scurvy.

Determinations of the solid contents of the cans of sauerkraut were made as follows: Each can of sauerkraut, upon being opened, was rapidly spread on a 9 by 4 inch piece of wire gauze of ¼-inch mesh, suspended in a metal pan into which the juice drained. The total weight of sauerkraut and juice was determined during the 2-minute period allowed for the juice to drain. At the end of this period, which was determined by a time clock, the wire gauze containing the sauerkraut was removed from the pan, and the weight of the juice alone was ascertained. The weight of the total solids was then determined by difference.

RESULTS

Each of the four brands of sauerkraut tested in these experiments is identified in this report by the same letter assigned to it in the study carried out previously [7] and an inferior figure 2 is added to indicate the

[7] CLOW, B., PARSONS, H. T., and STEVENSON, I. See footnote 3.

second series of experiments in the present study. The sequence of letters therefore indicates the rank of the brands in the relative concentration of vitamin C in the first study, but not, in each case, in the second study.

In carrying out the set of instructions in the four factories, some unavoidable variations occurred because of such incidents as failure of the sauerkraut to attain the required acidity in an expected time in certain of the tanks. On the whole, however, the processes of manufacture were decidedly more nearly uniform in the four factories than for the six brands tested during the preceding year, and much more detailed information was secured in the present experiment. The data for the manufacture of the four brands of sauerkraut are given in table 1.

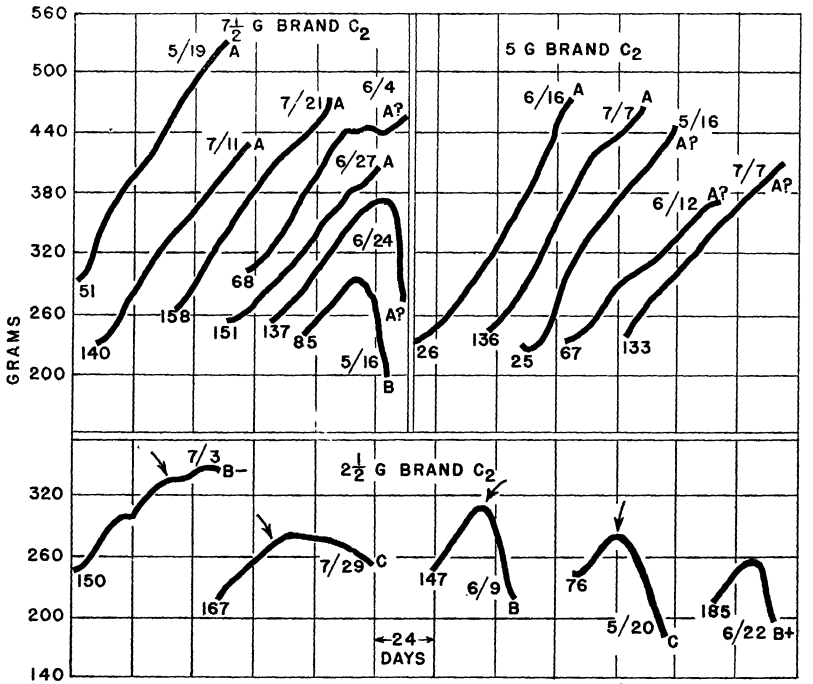

FIGURE 2.—Growth of guinea pigs and degree of protection from scurvy afforded them by 7½-, 5-, and 2½-g daily doses of commercial sauerkraut, brand C2. For explanation of symbols see figure 1.

One hundred and thirty-one guinea pigs were used in the experiment, but only 80 are included in this report. No arbitrary selection was made of the data, however, inasmuch as all animals are included except those which were discarded for the following reasons: Failure to eat the daily portion of sauerkraut; refusal to eat the basal ration, with resultant starvation; and the presence of intercurrent abnormalities such as infected lungs or liver. In a few instances such as no. 137, figure 2, and nos. 83, 88, and 92, figure 4, the growth curves indicate some abnormality not connected with a deficiency of vitamin C, but since no specific pathological condition was detected on autopsy, the records of these animals were retained in order to make the report entirely impartial.

A problem arose in connection with attempting to secure quantitative intake of the 10- and 7½-g doses of brands F_2 and D_2, respectively, not heretofore encountered. In former experiments, the only pronounced cases of scurvy occurred on relatively small doses of sauerkraut where quantitative intake was easy to secure. In the present experiment the two brands mentioned were found to have such a low vitamin C content that it proved impossible, except in five instances, to induce quantitative intake of the 10- or 7½-g daily portions after scurvy became pronounced. At the onset of scurvy the gums and

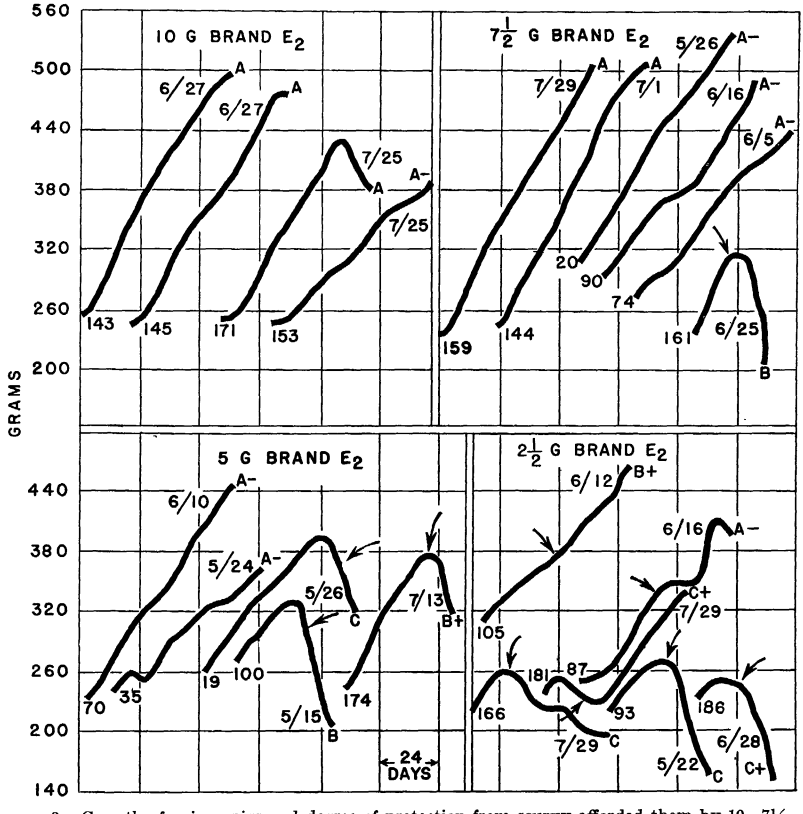

FIGURE 3.—Growth of guinea pigs and degree of protection from scurvy afforded them by 10-, 7½-, 5-, and 2½-g daily doses of commercial sauerkraut, brand E_2. For explanation of symbols see figure 1.

teeth of guinea pigs usually become tender and painful, and as a result both the total food intake and the body weight decline, as a rule. In all cases where the consumption of the daily dose of sauerkraut became irregular before the onset of scurvy, the animals were discarded. But in the case of the guinea pigs on large doses of these two brands of sauerkraut it was necessary to include the records of all animals which consumed their doses quantitatively up to the time of the appearance of severe scurvy, and to indicate the intervals of irregular intake by broken lines on the graphs. The results of the feeding experiments are presented in figures 1 to 5, inclusive.

CONTROL EXPERIMENTS

In the negative control experiment where only the basal ration was fed, both of the animals developed signs of pronounced scurvy in 16 days. The first signs of incipient scurvy occurred in 7 days.

In the positive control experiment, the six animals fed the basal ration with the addition of either 5 or 2½ g of cabbage daily were fully protected from scurvy and, except in the case of no. 49, responded with excellent growth.

The growth curves and incidence of scurvy of guinea pigs on the 7½-, 5-, and 2½-g portions of sauerkraut brand C_2 per day (fig. 2) were practically identical in this study, in which the sauerkraut was produced under controlled conditions, and that made previously under the routine procedures of the factory [8]. Protection from scurvy

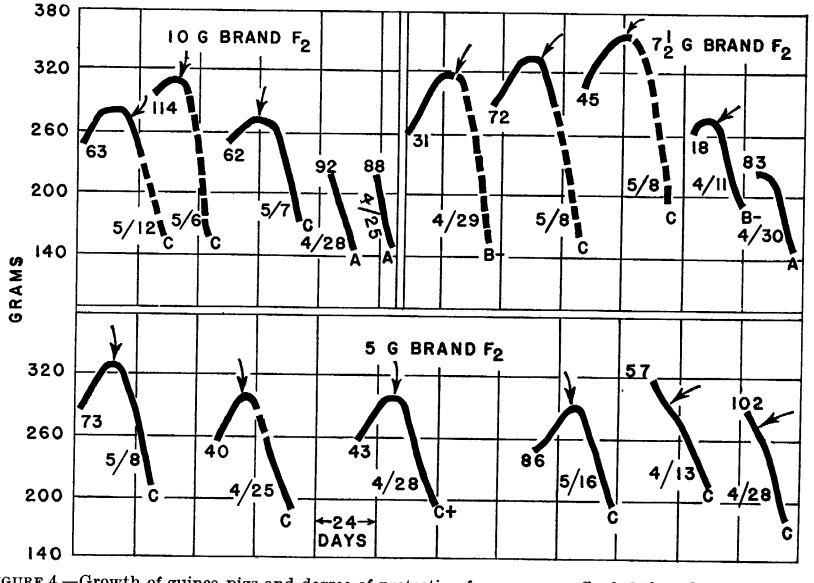

FIGURE 4.—Growth of guinea pigs and degree of protection from scurvy afforded them by 10-, 7½-, and 5-g daily doses of commercial sauerkraut, brand F_2. Broken lines indicate periods of failure to eat quantitatively the doses offered. For explanation of symbols see figure 1.

was somewhat better on the 7½-g level in last year's experiment in comparison with the present results, but was correspondingly slightly poorer on the 5- and 2½-g levels.

The protection from scurvy afforded by brand E_2 is approximately the same as for brand E from the same factory, tested previously. The results on the higher doses are slightly inferior in the present experiment but are better on the 2½-g level.

The results of the present experiments on brands F_2 (fig. 4) and D_2 (fig. 5) compare very unfavorably with those obtained in the former study on brands D and F from the same factories. In the records presented in figures 4 and 5 there is almost no indication to be found of the presence of vitamin C in the sauerkraut, even at a

[8] CLOW, B., PARSONS, H. T., and STEVENSON, I. See footnote 3.

level of 10 g daily. By a comparison with the negative control experiment in figure 1, it may be seen that scurvy occurs, on an average, as soon when these brands of sauerkraut, at even 7½- or 10-g levels, are fed daily with the basal ration, as when the basal ration is fed alone. In the case of guinea pigs 83, 88, and 92 which were fed brand F_2 and which did not develop scurvy, death ensued so quickly from some unknown cause that the symptoms of scurvy would not have become evident in so short a time had the animals been fed the basal ration only.

No data were secured for a 2½-g daily dose of brand F_2 inasmuch as the negative results of the higher levels were available before this dose was started, and it was quite evident that it would be superfluous to feed the lower amount.

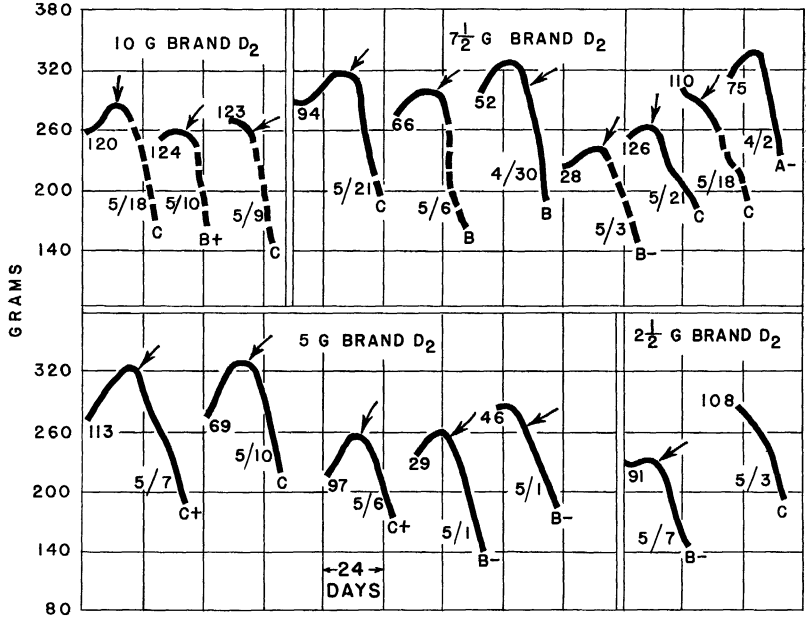

FIGURE 5.—Growth of guinea pigs and degree of protection from scurvy afforded them by 10-, 7½-, 5-, and 2½-g daily doses of commercial sauerkraut, brand D_2. Broken lines indicate periods of failure to eat quantitatively the doses offered. For explanation of other symbols see figure 1.

Although no difference can be seen in the degree of failure to protect from scurvy between brands F_2 (fig. 4) and D_2 (fig. 5), the latter is given a lower rating in the list because of the greater difficulty in inducing the guinea pigs to eat this brand, and the number of failures of animals on it for unexplained reasons. Brand D_2 was also the only one in which some of the cans showed dark streaks in the sauerkraut and even swells and leakage during the course of the experiment. These cans were, of course, rejected, and the material used for feeding was only from cans of good appearance.

DISCUSSION

Of the 4 brands of commercial sauerkraut produced under known, and somewhat uniform conditions, 2, brands C_2 and E_2, were found to contain a significant amount of vitamin C. Indeed, the richer of

these 2, brand C_2, is fairly comparable in antiscorbutic value with the specially fermented raw sauerkraut tested by Clow, Marlatt, Peterson, and Martin.[9] Furthermore, these 2 commercial brands duplicated very closely the antiscorbutic value of the sauerkraut manufactured the previous year by the same two packers, respectively, under their routine factory conditions.[10] The other 2 brands, on the other hand, showed no demonstrable antiscorbutic potency even when fed at a 10-g level. Consumption of larger doses by the guinea pigs was not obtained, but these experiments show that if these 2 brands contain any antiscorbutic vitamin it is at least less than one fourth the amount in the 2 richer brands.

In view of the striking differences found in the vitamin C content of the 4 brands, it is of interest to compare the details of manufacturing procedure in the different plants as they are listed in table 1.

The variety of cabbage is identical only in the two richer brands. While no experiments have been reported on variations in vitamin C content of different samples of fresh raw cabbage, it is known that variety is a factor in the vitamin C content of certain fruits. Bracewell, Hoyle, and Zilva [11] have shown that one variety of English cooking apple is outstandingly superior in vitamin C content to all the other varieties tested by them. However, if All Seasons cabbage were strikingly richer in antiscorbutic vitamin than the other varieties used in these experiments, it would be expected that brand D_2, containing 70 percent of this variety, would be more nearly like brands C_2 and E_2 in antiscorbutic potency than like brand F_2. In regard to length of fermentation, temperature of fermenting vat, degree of acidity, and processes of canning, there seems to be no one factor common to both brands F_2 and D_2 as compared with brands C_2 and E_2, to account for the differences found between these two groups. It is known that vitamin C is particularly sensitive to conditions of low acidity or of alkalinity in the presence of heat. However, brand E_2, which had an outstandingly low acidity in the fermentation vat and in the can, was 1 of the 2 richer brands. Again, these 2 richer brands were the ones subjected to the greatest dilution by water or salt brine during canning, as indicated by the percentage of reduction in acidity between the fermenting vat and the sealed can. It is true that the average unfilled space in the cans of the richer brands was slightly less than in the other 2, but the degree of variation among individual cans of all 4 brands makes this appear of little significance as a gage of possible oxidation within the can after sealing.

It would seem that the differences in vitamin C content of the 4 brands must be attributable to some unidentified factor or factors which were not controlled in this experiment, but which are perhaps dependent on the regular procedure in manufacture in the different plants, inasmuch as 2 of the brands studied practically duplicated their former vitamin C content, and another brand which was previously at the bottom of the list was 1 of the 2 in which no vitamin C was demonstrated in the present experiment.

[9] CLOW, B., MARLATT, A. L., PETERSON, W. H., and MARTIN, E. A. See footnote 4.
[10] ——— PARSONS, H. T., and STEVENSON, I. See footnote 3.
[11] BRACEWELL, M. F., HOYLE, E., and ZILVA, S. S. THE ANTISCORBUTIC POTENCY OF APPLES. Biochem Jour. 24: 82-90. 1930.

SUMMARY

A study of 4 brands of commercial sauerkraut manufactured under known and fairly comparable conditions showed that 2 of these brands practically duplicated their previous antiscorbutic content, when observed under routine conditions of the factory. The other 2 brands did not show any antiscorbutic potency when fed at even a 10-g level, a record much inferior to previous results on the same brands, although 1 of these brands made an especially poor record, also, in the previous test.

No satisfactory correlation can be traced between the comparative vitamin C content in the four individual brands on the one hand, and variations in processes of manufacture on the other.

U. S. GOVERNMENT PRINTING OFFICE: 1933