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By Paul D. Isham and Carl R. Fellers

Cranberries are an important crop in Massachusetts. Nearly all of them are processed in some way before they are consumed. This study was undertaken to determine the effect of various methods of processing on their nutritive value.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

EFFECT OF MANUFACTURING AND PRESERVING PROCESSES ON THE VITAMINS OF CRANBERRIES¹

By Paul D. Isham, Research Fellow, and Carl R. Fellers, Research Professor of Horticultural Manufactures

PURPOSE

A comprehensive investigation of the vitamin content of the American cultivated cranberry, *Vaccinium macrocarpon*, was undertaken to include several varieties, seasons, storage conditions, and manufactured products such as evaporated, frozen, and canned cranberries. This is the first of a series of studies planned to investigate the effect of manufacturing methods on the nutritive value of fruits and vegetables. Only limited data are available on this general subject. Results obtained in the present investigation show the necessity of actually determining the changes which may occur in a fruit during storage, processing, and preservation.

INTRODUCTION

Since cranberries are a very important crop in Massachusetts, data relative to their vitamin content and the effect of storage, home cooking, and commercial manufacturing processes on these vitamins are very desirable. Approximately 300,000 cases or 10,000,000 pounds of cranberry sauce are produced each year. Since a pound of cranberries makes about 2.6 pounds of sauce, the cranberries used for commercial canned sauce manufacture represent close to 40,000 barrels. However, most of the fruit is consumed as sauce prepared in the home. The per capita consumption of cranberries in the United States is 0.54 pound. Cranberries are harvested in September and October and may be found on the market until late winter.

Because of confusion in nomenclature in published articles on the cranberry, and to clarify several literature citations in this paper, a very brief discussion of the botanical relationships of the cranberry is given. The common, large, cultivated American cranberry so widely consumed in this country is known as *Vaccinium macrocarpon*. European references to cranberries generally refer to other species. Most important of these is *V. Vitis-Idaea*, also known as the mountain or rock cranberry (U.S.), cowberry, foxberry (Gt. Britain, Canada), Preisselbeere (Germany), tyttebaer (Norway), lingon berry (Sweden), Kroesa (Denmark), and partridge berry (Newfoundland). This species grows on upland and rocky places rather than in swamps. The other species, *V. Oxycoccus*, is known as the moss, bog, or swamp cranberry, and also as the small or speckled cranberry. The fruit and vine of this species are smaller than either *V. macrocarpon* or *V. Vitis-Idaea*.

¹ Part of a thesis submitted by the senior author to the faculty of the Graduate School, Massachusetts State College, in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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HISTORICAL

No thorough investigation of the vitamin content of cranberries has been reported. In fact, no work has been reported on vitamins A, B, D, and G. MacLeod and Booher (22) reported the American cranberry as being a poor source of vitamin C. However, this conclusion is open to criticism, first, because the cranberries had been in storage for seven or more months and, as will be demonstrated in this paper, had undoubtedly lost much of their original vitamin C content; and second, because the experimental animals did not consume their full portion of fruit plus basal ration. Naeslund (28) investigated the vitamin C content of *V. Vitis-Idaea* in Norway and found them to be weakly antiscorbutic. He estimated the protective portion of fruit or freshly expressed juice to be more than 50 grams, with no difference in potency between the whole berry and its expressed juice. Using the same fruit, Laland (21) was unsuccessful in his attempts to isolate narcotine, believed by Rygh and his coworkers (31,32,33) to be the precursor of vitamin C. However, Dalmer and Moll (9) and Brüggemann (6) were unable to verify Rygh's results; and recently Svírbely and Szent-Györgyi (40), and also King and Waugh (18) have proved beyond question that vitamin C is closely related to or identical with hexuronic acid.²

After the completion of the vitamin C studies reported in this paper, a recent Russian investigation on *V. Oxycoccus* came to our attention. Bogoliubova (3) found that 2.5 grams of these wild cranberries, after storage for three months near the freezing point, fully protected guinea pigs from scurvy during a seven weeks' test period. However, cranberries which had lain under snow all winter or which had been alternately frozen and thawed, showed no protective action. Similarly, dried or fermented cranberries lost their vitamin C potency. She believes that cranberries are an important antiscorbutic in all northern countries and states that the value of cranberries for the treatment of scurvy in Russia was known as early as 1848. Mention is made that sailing vessels used cranberry juice as an antiscorbutic many years ago.

Bogoliubova also noted the absence of xerophthalmia in her guinea pigs, and since the oat diet was deficient in vitamin A, concluded that cranberries contained some of this vitamin. However, no data were presented.

The resistance of vitamin C to heat and oxidation is materially increased by high acidity, and the cranberry is characterized by a high acidity which averages about 2.3 per cent (calculated as citric acid). According to Nelson (29), the fixed acids are 88 per cent citric and 10 per cent malic. Mason (24) detected benzoic acid in the cranberry; this finding was verified by Griebel (17), and also in this laboratory where it was found that the benzoic acid content of 25 varieties ranged from 0.027 to 0.098 per cent. It is probable that the good keeping qualities of fresh and preserved cranberries are in part due to the presence of free or combined benzoic acid. The presence of quinic acid in cranberries was presumed by Blatherwick and Long (2) and by Quick (30). Kohman and Sanborn (20), Morse (27), and Fellers, Redmon and Parrott (15), have gathered further positive evidence of the presence of 0.38 to 1.03 per cent of quinic acid in cranberries. Unlike benzoic acid, quinic acid has no significant antiseptic properties against microorganisms.

²Recent investigations by Hahn (Ztschr. Untersuch. Lebensmitl. 61:369-411, 545-611, 1931) show that raw or cooked mountain cranberries are very poor sources of vitamin C.

The red pigment of the *V. Vitis-Idaea* cranberry has been proved by Willstätter and Mallison (41) to be the anthocyan idaein, hence is unrelated to vitamin A. By using Willstätter's technic, Morse (26) obtained 2.1 grams of idaein from 22 kilograms of American Early Black cranberries.

Of possible significance in vitamin C retention is the gas content of cranberries. The oxygen content varies from practically zero to 14 per cent depending upon the freshness of the fruit and storage conditions. A considerable percentage of carbon dioxide is always present in the tissues and voids of the fruit.

SOURCE AND PREPARATION OF SAMPLES

Fresh and Frozen Cranberries

In general the fruit was obtained from the Massachusetts Cranberry Station at East Wareham in 1930, 1931, and 1932, though samples were also furnished by the A. D. Makepeace Company, Wareham, the United Cape Cod Cranberry Company, South Hanson, and the American Cranberry Exchange, New York, N. Y.

Cranberries were harvested in September and October and held in cold storage at 40° F. in 50-pound, one-half barrel, ventilated boxes. In general, the fresh fruit and products were assayed for vitamin C within four months from the harvesting date, which corresponds to the active commercial marketing season. Early Black, Howes, and Perry Red varieties were used. The first two are the most important commercial varieties in Massachusetts and represent early and late maturing varieties. In order to determine the effect of storage upon vitamin C content, fresh cranberries from the same lot were stored at 40°, 15°, 0°, and -15° F. Thus the effect of freezing was also ascertained. The lots held at 0° and -15° F. were frozen at -30° F., in small waxed-paper cartons holding one-half pound of cranberries, by the Birdseye Multiplate Freezer. All frozen cranberries were not defrosted until just before feeding. The frozen samples included whole, sliced and sweetened, and crushed and sweetened berries, and a strained product. The samples held at 15° and 40° were in the bulk, 50-pound boxes.

The freezing of cranberries as a means of preservation has been carried on in this department since 1927 and has been practiced by the canners for several years as a means of extending the canning season. Quick-freezing of whole cranberries for the retail trade has been conducted on a limited scale since 1931.

Dehydrated Cranberries

Commercially dehydrated whole cranberries, usually called "evaporated" by the trade, were examined for vitamin activity. These berries were pricked 20 to 30 times with steel needles to allow evaporation of moisture and dehydrated for 8 to 12 hours at temperatures of 120° to 150° F. in forced-draught dryers. The moisture content is normally less than 5 per cent. One hundred pounds of fresh fruit yield about 10 pounds of dehydrated cranberries.

By grinding this product a fine red powder was obtained which served as the basis of the tests for vitamins A, B, D, and G.

Cranberry film is a dehydrated cranberry product prepared by boiling fresh cranberries in a small amount of water for two to three minutes, hot pulping, and immediately drying in a thin film on a rotating steam-heated drum dryer. The film resembles crepe paper. One hundred pounds of fresh cranberries yield about 12.3 pounds of film. The film can be used in the preparation of cranberry sauce.

Film samples were pulped and dried in air, and in nitrogen gas. The film was prepared for feeding by mixing with water in definite concentrations. In this way, desired amounts were accurately administered by pipette.

Cranberry Juice

Cranberry juice or cocktail has recently become of some commercial importance. The juice possesses a very deep red color and a characteristic flavor. It is particularly suitable for use as a blender in punches and similar beverages.

Cranberry juice was prepared by two methods and is designated "cold-pressed" and "heat-extracted." The cold-pressed juice was prepared by grinding the fresh cranberries in a food chopper and expressing the juice by means of a large hand press. The yield of juice averaged 6 gallons per barrel (100 pounds) of cranberries.

The heat-extracted juice was prepared by boiling 100 pounds of cranberries with 6.5 gallons of water for 8 to 10 minutes. The pulpy mass was cooled to room temperature and pressed. The yield was about 8 gallons per barrel of fruit. The sweetened juice was prepared by adding sufficient sugar to yield a soluble solids content of 50 per cent. Both fresh and pasteurized raw pressed juices were examined for vitamin C. Pasteurization was effected by a heat treatment of 20 minutes at 160° F. of the juice sealed in small tin cans or one-half pint bottles. One series of samples in the bottles was sealed under a partial vacuum of 25 inches of mercury.

Cranberry juice cocktail was prepared according to the recipe recommended by the American Cranberry Exchange (1). One quart of cranberries was boiled with one quart of water until soft, then strained through a cheese-cloth, the juice brought to boiling, two-thirds cup of sugar added, and the boiling continued for two minutes. This juice was filled into sterile jars, sealed, and immediately cooled.

Commercially, cranberry juice cocktail is prepared by grinding the fruit, cooking with water until soft, adding a pulp filter aid, centrifuging, making up filtrate to a volume representing two parts water to one of fruit, adding sugar to 15° Brix, heating to 180° F., and immediately filling into sterile glass containers and sealing. Frozen cranberries are preferred to fresh in the manufacture of this product.

Cranberry Sauce

Cranberries are normally consumed in the form of a cooked sweetened sauce, either strained or unstrained. The sugar content of the sauce varies from 41 to 48 per cent.

Whole-fruit, unstrained cranberry sauce was prepared according to the widely used "Ten Minute" Cranberry Sauce (1) recipe of the American Cranberry Exchange. The recipe calls for 1 pound of cranberries, 2 cups of water, and 1½ to 2 cups of sugar. The sugar and water are boiled together for 5 minutes, then the cranberries are added and boiled without stirring until the skins pop open. This usually requires about 5 minutes. This material was sealed hot in small jars and immediately cooled. Investigations on canned foods (10, 11) have shown that practically no deterioration of the vitamin C content occurs in the can even over a period of several years. All sauce was kept in the refrigerator at 33° F., and no jar was used for feeding after being open 24 hours. The surface of the material in the opened jars was kept covered with paraffin. Just prior to feeding, the sauce was pressed through a fine screen to allow its being administered by

pipette. This process is the one referred to as cold pulping or cold straining in this paper.

It was brought to our attention that cranberry sauce is often prepared in the home by cooking cranberries in water and then adding the sugar. Whole-fruit sauce was therefore prepared in this manner and treated as was the "Ten Minute" cranberry sauce.

Commercially prepared whole-fruit cranberry sauce was also examined for its vitamin C content. This material was manufactured by a method practically identical to that specified for "Ten Minute" cranberry sauce.

The strained cranberry sauce was prepared in several ways. In each case, however, the berries were pulped while at boiling or near boiling temperatures without any special precautions to prevent oxidation. Strained "Ten Minute" cranberry sauce was prepared and immediately sealed in small jars. Other strained sauce was prepared in small amounts according to commercial practice. The cranberries were boiled for two or three minutes in water, pulped while hot to remove seeds and skins, the sugar added, and the mixture concentrated in a jelly kettle to a jelly test (216° to 218° F. or 43 per cent soluble solids by refractometer). The hot liquid sauce was filled into cans and sealed without further heat treatment. As an average, 1 pound of cranberries will yield 2.6 pounds of sauce. Several brands of commercially packed strained sauce were likewise assayed.

Cranberry Jelly and Candy Filling

Cranberry jelly was prepared according to the recipe of the American Cranberry Exchange (1). This calls for 8 pounds of cranberries, 12 cups of water, and 2½ pounds of sugar. The cranberries are cooked in the water until soft, and the juice strained off through a jelly bag. The juice is measured and heated to boiling, 1 cup of sugar added for each 2 cups of juice and stirred in until dissolved, and the whole boiled briskly for 5 minutes. It is then poured into glasses and covered with paraffin. Small glasses were used, and a new one taken for each feeding.

The cranberry content of cranberry candy as such was too low to allow feeding in amounts sufficient to afford protection to the animals. Therefore, the cranberry material as it is mixed into the candy was obtained and used for feeding tests. This material was nothing other than finely chopped cranberries. It was stored, sealed in large jars, in the refrigerator at 33° F. Just prior to feeding, a suitable quantity was pressed through a fine screen while still cold, and this material used for feeding.

EXPERIMENTAL RESULTS

Vitamin C

The Sherman, LaMer, and Campbell (34) method was used, with the exception that the amounts fed were proportioned to the weight of the guinea pigs; i. e., a 400-gram animal was fed 4/3 as much as one weighing 300 grams. The animals were all young and healthy, weighed between 280 and 325 grams, and were housed in individual cages. The basal ration consisted of 58 per cent equal parts of rolled oats and wheat bran, 30 per cent of vitamin C-free baked milk powder, 10 per cent butter fat, and 1 per cent each of cod-liver oil and salt. This basal ration and water were kept before the animals at all times.

Normally three guinea pigs were used at each feeding level. At the end of the feeding period all animals were chloroformed and carefully examined for lesions of

scurvy. Negative controls died in from 26 to 36 days with an average Sherman scurvy score of 19.

Because of the dislike of guinea pigs for cranberries, it was necessary in all the vitamin C assays to express the juice and finely divided pulp from fresh, frozen, and soaked evaporated cranberries, and to force-feed the animals by pipette. All samples were freshly prepared daily immediately before feeding. In cooked and canned cranberries, the pulp freed from skins was likewise fed by pipette. In order to be assured that each animal received its full share, weighings were made before feeding and several times during the feeding process until the required weight was reached.

The results obtained on vitamin C are presented in Tables 1 to 5 and Figures 1 to 5. In general, these data are largely self-explanatory and require only brief discussion. Only certain representative results are shown in the curves, but all the data are summarized in the tables.

TABLE 1. — VITAMIN C CONTENT OF RAW CRANBERRIES

Variety	Year	Storage period	Number of guinea pigs	Amount fed daily	Gain or loss in weight average	Survival period average	Scurvy score average
		Months		Grams	Grams	Days	
Early Black	1930	2 to 5	5	10	+153	90	0
	1930	2 to 5	5	5	+134	90	0
	1930	2 to 5	2	3	+199	90	2
	1931	1 to 4	3	4	+165	90	1
	1931	7 to 8	3	10	-111	29	9
	1931	7 to 8	3	5	-112	31	12
	1932	3 to 6	3	4.5	+183	90	0, 0, 3
	1932	3 to 6	3	3.5	+30	90	4
Howes	1930	2 to 5	3	4	+123	90	0
	1930	2 to 5	3	2	+4.5	90	7
	1930	2 to 5	3	1	-58	42	12
	1930	9 to 11	3	10	+176	90	2
	1931	4 to 7	2	5	+130	90	6
	1931	4 to 7	2	3	-35	87	13
Perry Red*	1932	3 to 5	3	4.5	+290	60	0
	1932	3 to 5	3	3.5	+169	60	0, 0, 1

*Supply exhausted at 60 days.

Fresh and Frozen Cranberries

Several significant deductions can be drawn from Table 1 and Figure 1. Fresh cranberries of Early Black, Howes, and Perry Red varieties are very good sources of vitamin C, the minimum protective portion being close to 4 grams. There appears to be but little variation in vitamin C content due to differences in season or variety. For example, Early Black and Perry Red varieties differ greatly botanically, yet show similar vitamin C activity. The cranberry thus contains one-third to one-half as much vitamin C as the orange or tomato and is comparable with such foods as blueberries (14), pineapple (25), peaches (19), and some varieties of apples (12, 5).

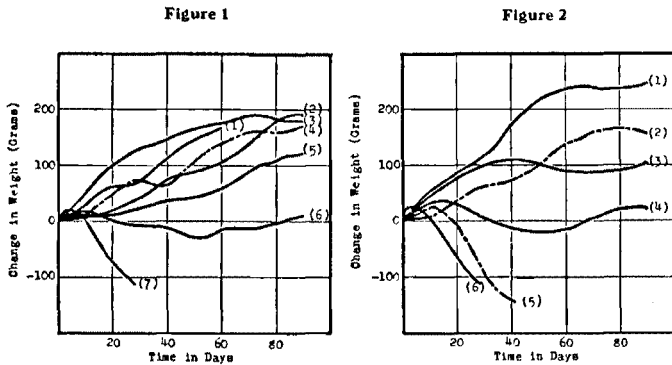


Figure 1. — Influence of Variety and Season on the Vitamin C Content of Cranberries

	Variety	Year	Grams fed daily	Scurvy score
1	Perry Red	1932	3.5	0
2	Early Black	1931	4	1
3	Early Black	1932	4.5	1
4	Early Black	1930	3	2
5	Howes	1930	4	0
6	Howes	1930	2	7
7	Basal Ration only			19

Figure 2. — Effect of Storage Temperature on the Vitamin C Content of Cranberries

	Storage Months	°F.	Grams fed daily	Scurvy score
1	7 to 9	15	5	0
2	2 to 4	40	4	1
3	7 to 9	0	5	0
4	9 to 11	15	10	12
5	7 to 8	40	10	9
6	Basal Ration only			19

From a study of Tables 1 and 2, it is evident that cranberries gradually lose vitamin C during storage at 40° F. There was little loss in Early Blacks or Howes stored under 3 months. After 4 to 6 months the loss was approximately 20 per cent; after 7 to 10 months, the loss became still greater — possibly 60 to 70 per cent in some cases. Howes keep better than Early Blacks, and this better keeping quality is reflected in better retention of vitamin C in storage. These results serve to explain why MacLeod and Booher (22) found little or no vitamin C in cranberries. Their samples had been in storage for 7 to 11 months, and the highest level fed was only 5 grams — an amount entirely insufficient to protect animals from scurvy after so long storage.

TABLE 2. — EFFECT OF STORAGE TEMPERATURE ON THE VITAMIN C CONTENT OF EARLY BLACK CRANBERRIES

Description of sample	Storage period	Storage temperature	Number of guinea pigs	Amount fed daily	Gain or loss in weight average	Survival period average	Scurvy score average
	Months	°F.		Grams	Grams	Days	
Whole fruit	2 to 4	40	3	4	+165	90	1
	7 to 8	40	3	10	-111	29	9
	7 to 8	40	3	5	-112	31	12
	9 to 11	15*	3	10	+22	90	12
	7 to 9	0	2	10	+122	90	0
	7 to 9	0	2	5	+102	90	0
	7 to 9	-15	2	10	+213	90	0
	7 to 9	-15	2	5	+246	90	0
†Crushed	7 to 9	0	2	10	+106	90	0
	7 to 9	0	2	5	+27	90	3
‡Sliced	7 to 9	0	2	10	+512	90	0
	7 to 9	0	2	5	+61	90	4.5

*Known to have been thawed and refrozen at least once.

†Frozen with added sugar — 10 g. = 7.5 g. cranberries; 5 g. = 3.8 g. cranberries.

‡Frozen with added sugar — 10 g. = 6.7 g. cranberries; 5 g. = 3.3 g. cranberries.

It is apparent from Table 2 and Figure 2 that the retention of vitamin C during storage is dependent on the storage temperature. Cranberries stored at -15° and 0° F. suffered no significant loss. Unfortunately, the cranberries in storage at 15° F. were allowed to thaw and then refreeze at least once during the storage period of 9 to 10 months. This probably explains the excessive loss of vitamin C at this temperature. However, even these cranberries retained at least twice as much vitamin C as those stored at 40° F. for the same period. The crushed and sliced cranberries to which sugar was added retained all their original vitamin C during storage at 0° F. Solidly frozen cranberries, therefore, retain fully their original antiscorbutic properties.

Dehydrated Cranberries

The vitamin C content of dehydrated cranberries, shown in Table 3 and Figure 3, varies according to the method of manufacture. Evaporated cranberries contained practically no vitamin C, while the cranberry film³ prepared in an at-

³ The name of the manufacturer will be furnished upon request.

mosphere of nitrogen suffered but a slight decrease in antiscorbutic activity. The dried film itself was fully protective at the estimated low level of 0.7 gram, equivalent to about 8.4 grams of fresh cranberries. This represents a loss of about 35 per cent. Film manufactured by the same process with no effort to exclude oxygen lost 65 to 70 per cent of the vitamin C.

TABLE 3. — VITAMIN C IN DEHYDRATED CRANBERRIES

	Number of guinea pigs	Amount fed daily	Fresh fruit equivalent	Gain or loss in weight average	Survival period average	Scurvy score average
		Grams	Grams	Grams	Days	
Evaporated cranberries	{ 3	0.83	8.3	-110	31	13
	{ 3	.42	4.2	-88	31	16
Cranberry film (pulped and dehydrated in air).....	{ 2	2	24	+164	90	0
	{ 2	1	12	+3	90	4
Cranberry film (pulped and dehydrated in nitrogen)...	{ 3	1.5	18	+118	30*	
	{ 3	1.0	12	+333	90	0
	{ 3	.5	6	+119	90	3

*Discontinued.

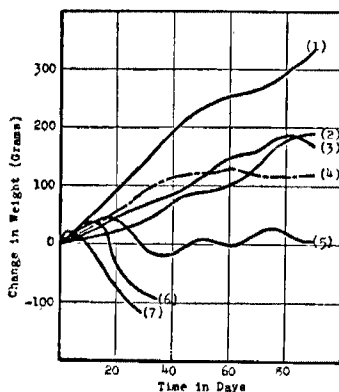


Figure 3. — Vitamin C Content of Dehydrated Cranberries

Product tested	Grams fed daily	Fresh fruit equivalent Grams	Scurvy score
1 Cranberry film prepared under nitrogen	1	5.4	0
2 Raw cranberries	4	4	0
3 Cranberry film prepared under air	2	10.8	0
4 Cranberry film prepared under nitrogen	.5	2.7	3
5 Cranberry film prepared under air	1	5.4	4
6 Evaporated cranberries	.83	8.3	13
7 Basal Ration only			19

Cranberry Juice

Cold-pressed cranberry juice was equal to the fruit in vitamin C content and when boiled in an open vessel for two minutes showed no loss. However, when either this or heat-extracted juice was bottled and pasteurized, there was very little retention of the vitamin C. This was true regardless of whether the juices were sweetened or unsweetened, or sealed in the bottles with or without vacuum. The two cranberry-juice cocktails which were examined were manufactured by heat extraction methods and likewise showed almost complete loss of vitamin C. A cocktail was prepared from cold-pressed juice and pasteurized, but this was likewise devoid of any appreciable antiscorbutic property.

TABLE 4. — VITAMIN C IN TREATED CRANBERRY JUICE AND COCKTAIL

Method of preparation	Number of guinea pigs	Amount fed daily <i>Grams</i>	Fresh fruit equivalent <i>Grams</i>	Gain or loss in weight average <i>Grams</i>	Survival period average <i>Days</i>	Scurvy score average
Cold-pressed juice						
Boiled 2 minutes	{ 3	8	8	+191	90	0
	{ 3	4	4	+192	90	0
	{ 3	4*	4	+188	90	0
Pasteurized 20 minutes at 160° F	{ 3	6	6	-113	37	13
	{ 5	4	4	-102	38	15
	{ 3	3	3	-73	35	16
Sweetened and pasteurized Vacuum sealed and pasteurized.....	5	8	4	-169	47	10
	3	6	6	-140	36	12
Heat-extracted juice						
Pasteurized	{ 3	6	6	-102	37	16
	{ 3	3	3	-98	34	16
Vacuum sealed and pasteurized.....	3	6	6	-118	19	9
Cranberry juice cocktail						
Exchange's recipe.....	{ 3	10	3.4	-165	46	15
	{ 3	5	1.7	-162	33	15
Exchange's recipe, modified:						
Hot pressed	2	10	3.4	-134	33	15
Cold pressed	2	10	3.4	-80	32	18
Commercial.....	{ 3	20	6.9	-91	40	15
	{ 3	15	5.2	-131	26	12
	{ 5	10	3.4	-117	34	14

*Plus 5 g. sugar.

These numerous examinations show that both cold-pressed and heat-extracted cranberry juices when bottled, sealed, and pasteurized retain very little vitamin C. It is possible that methods designed to avoid oxidation would be of value.

Cranberry Sauce

Since the greater proportion of cranberries are consumed in the form of cranberry sauce, a more extensive investigation of this product was carried out. The data are presented in Table 5 and Figure 5.

TABLE 5. — VITAMIN C CONTENT OF CRANBERRY SAUCE

Method of Preparation	Number of guinea pigs	Amount fed daily	Fresh fruit equivalent	Gain or loss in weight average	Survival period average	Scurvy score average
		Grams	Grams	Grams	Days	
Whole-fruit "Ten Minute" sauce	3 4 4 7	14*	8	+279	90	0
		7*	4	+82	90	2
		20	7	+42	90	2?
		10	3.5	+90	90	5
Whole-fruit sauce (sugar added last).....	2	10	3.5	-99	90	3
Hot-strained "Ten Minute" sauce	3 3 3 3	8*	4.5	-49	52	9
		20	7	+39	83	10
		15	5.3	-92	33	8
		8	2.8	-134	38	10
Hot-strained sauce.....	5 5 5	20	7	-70	25	11
		10	3.5	-164	38	18
		8	2.8	-62	57	17
M. S. C. canned strained sauce.....	5 5	26	9.1	-146	31	16
		13	4.6	-148	31	15
Commercial strained sauce 1	2 2	20	7	-50	29	12
		10	3.5	-61	33	13
Commercial whole-fruit sauce 1 (1930)	3 3	20	7	-58	38	14
		10	3.5	-23	35	16
Commercial whole-fruit sauce 1 (1931)	3	12	4.2	-60	65	5
Commercial strained sauce 1, vacuum packed.....	2 2	20	7	-58	50	17
		10	3.5	-52	52	15
Commercial strained sauce 2.....	2 2	20	7	-73	37	17
		10	3.5	-48	33	16
Strained sauce, frozen and stored 9 months at 0° F.	2 2	12	9.6	-16	70	9
		6	4.8	-128	62	14
Jelly (Exchange's recipe)	3	12	6	-156	40	12
Cranberry candy filling....	2 2 2 2	10	10	-80	36	16
		6	6	-157	35	14
		5	5	-103	47	18
		3	3	-122	36	15

*Made without sugar.

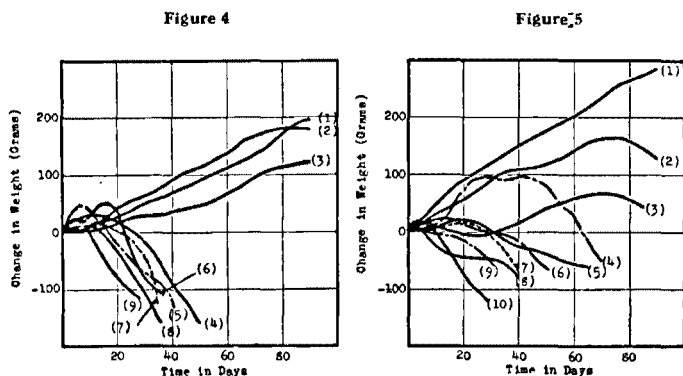


Figure 4. — Vitamin C in Cranberry Juice Prepared by Different Methods

Method of preparation	Grams fed daily	Fresh fruit equivalent Grams	Scurvy score
1 Cold-pressed, boiled 2 minutes	4		0
2 Cold-pressed, boiled 2 minutes, plus 5 grams sugar	4		0
3 Cold-pressed, untreated	4		0
4 Cranberry juice cocktail (1)	10	3.4	15
5 Cold-pressed, vacuum packed, pasteurized	6		12
6 Heat-extracted and pressed, pasteurized	6		16
7 Cold-pressed, pasteurized	6		13
8 Cranberry juice cocktail (2)	10	3.4	14
9 Basal Ration only			19

Figure 5. — Vitamin C Content of Whole-Fruit and Strained Cranberry Sauce

Method of preparing sauce	Grams fed daily	Fresh fruit equivalent Grams	Scurvy score
1 Whole-fruit sauce without sugar	14	8	0
2 Whole-fruit "Ten Minute" sauce	10	3.5	5
3 Hot-strained "Ten Minute" sauce	20	7	10
4 Strained sauce, frozen and stored at 0°F	12	9.6	9
5 Commercial whole-fruit sauce (1)	12	4.2	5
6 Commercial strained sauce (1), vacuum packed	20	7	17
7 Commercial strained sauce (2)	20	7	17
8 Fresh, hot-strained sauce	20	7	11
9 Commercial strained sauce (1)	20	7	12
10 Basal Ration only			19

Whole-fruit cranberry sauce prepared in small amounts according to much used recipes (1,23) was found to retain approximately 80 per cent of the vitamin C of the cranberries. In order to make it more palatable to the animals, whole-fruit sauce was prepared without sugar, and the same percentage loss occurred. The time of adding sugar did not alter the results. Commercially packed whole-fruit sauce contained little vitamin C. Samples of two years' packs were assayed, one showing complete destruction and the other a 30 to 40 per cent retention.

Hot-strained cranberry sauce (1) retained a small part of the original vitamin C of the cranberries — possibly 20 per cent. However, five samples of strained sauce prepared by commercial methods retained only traces of vitamin C. Three of these samples were obtained from leading cranberry-sauce manufacturers; the other two were prepared in this laboratory.

One sample of strained sauce was prepared by cooking the cranberries to soften them, cooling, pulping, adding the sugar, and packing in one-pound waxed-paper cartons. The cartons were frozen at -30° F. and stored at 0° F. This sample retained only 10 to 15 per cent of the original vitamin C content of the cranberries.

Summarizing, whole-fruit sauce retains fully three-fourths and strained sauce less than one-fourth of the vitamin C of the fruit. Pulping has a decidedly harmful effect upon the antiscorbutic property of cranberries.

Cranberry Jelly and Candy Filling

Table 5 shows that true cranberry jelly is practically devoid of vitamin C, the experimental animals living but little longer than the controls. The guinea pigs very much disliked this sticky sweet product and they were force-fed only with difficulty.

Cranberry candy filling, consisting mainly of finely chopped cranberries packed in glass jars without heat treatment, showed only very slight antiscorbutic activity. If the fresh berries were chopped and used immediately for candy filler, no doubt a much higher percentage of the vitamin C would be retained.

Vitamin A

The technic developed by Sherman and Burtis (37) and Sherman and Munsell (36) was used in this investigation. Litters of young rats, 28 days old, were placed on a vitamin A-free diet consisting of vitamin-free casein 18, salt mixture 4, irradiated dried brewers' yeast 10, sodium chloride 1, and cornstarch 67 parts. When the body stores of vitamin A were depleted, the rats were placed in individual cages and fed the vitamin A-free diet supplemented by finely ground dehydrated cranberries which were substituted for an equal weight of starch in the diet. One rat from each litter was continued on the vitamin A-free diet as a negative control. Accurate records were kept of the quantity of food consumed and of the weight of the animals. On death or at the termination of the experimental period of 42 days, the rats were autopsied and carefully examined for lesions characteristic of vitamin A deficiency. The data are presented in Table 6.

It is apparent that the quantity of cranberry required to produce unit growth of 3 grams per week is probably slightly over 0.5 gram daily or 8 per cent of dried cranberry in the diet. This would place the vitamin A content of fresh cranberries at about 0.2 unit per gram. These deductions do not allow for possible vitamin A losses during the drying process; hence it is possible that raw cranberries may be richer in vitamin A than is indicated in the dried product. Recent findings (16)

indicate that losses do occur during drying and storage. Fruits comparable to cranberries in vitamin A content are apples, orange juice, and peaches (38).

TABLE 6.— VITAMIN A IN CRANBERRIES

Dried cranberry in diet	Amount of diet consumed daily	Amount of dried cranberry daily	Fresh fruit equivalent	Survival period average	Gain or loss in weight average	Remarks
<i>Per Cent</i>	<i>Grams</i>	<i>Grams</i>	<i>Grams</i>	<i>Days</i>	<i>Grams</i>	
10	7	0.7	7.0	42	+25.1	Complete protection
5	6.5	.33	3.3	42	+5.8	Very slight xerophthalmia in one rat
2.5	6.5	.16	1.6	40	-.4	Slight xerophthalmia—pus in one rat
1	6	.06	.6	38	-8.8	Xerophthalmia — pus in three rats
0	6	0	0	22	-26	Severe xerophthalmia and copious pus

Vitamin B (B₁)

In the vitamin B investigations the method suggested by Sherman and Spohn (35) and modified by Chase (7) was employed. Healthy young rats, 28 days old, were placed in metal cages with raised wire-screen floors and fed a vitamin B-free diet consisting of vitamin-free casein 18, salt mixture 4, butter fat 8, cod-liver oil 2, autoclaved yeast 15, and starch 53 parts. The animals continued to gain for about two weeks. When growth ceased, their diet was supplemented by dried cranberry powder which was incorporated in the diet in definite proportion, replacing an equal weight of starch. Accurate records were kept of the weights of the animals and the amount of food consumed. The data are presented in Table 7.

TABLE 7.— VITAMIN B (B₁) IN CRANBERRIES

Dried cranberry in diet	Amount of diet consumed daily	Amount of dried cranberry daily	Fresh fruit equivalent	Survival period average	Loss in weight average	Remarks
<i>Per cent</i>	<i>Grams</i>	<i>Grams</i>	<i>Grams</i>	<i>Days</i>	<i>Grams</i>	
15	8	1.2	12.0	16	-20.5	No better than controls
5	7	.35	3.5	18	-14.7	No better than controls
0	8	0	0	15	-18.9	Definitely neuritic

From these data, it is apparent that the material used contained no vitamin B. Even when cranberry powder comprised 15 per cent of the diet, it did not benefit the animals. Here, of course, even more than with vitamin A, losses might have occurred during the drying. But if a significant amount of vitamin B had been present in the raw cranberries, an amount of the dried material equivalent to 12 grams of fresh cranberries daily should have given at least some protection.

Vitamin G (B₂)

Vitamin G assays were conducted according to the method developed by Bourquin (4). Normal young rats, 28 days old, were placed in metal cages with raised wire-screen floors and fed the vitamin G-free diet consisting of purified casein 18, salt mixture 4, butter fat 8, cod-liver oil 2, and cornstarch 68 parts. The cornstarch carried the alcoholic extract from 50 grams of whole wheat for each 100 grams of diet. The animals were continued on this diet until they ceased growing. At this time the diet was supplemented with dried cranberry which was incorporated

in the diet, replacing an equal weight of starch. Accurate records were kept of the weight of the animals and of the food consumed. The data are presented in Table 8.

TABLE 8. — VITAMIN G (B₂) IN CRANBERRIES

Dried cranberry in diet	Amount of diet consumed daily	Amount of dried cranberry daily	Fresh fruit equivalent	Survival period average	Gain or loss in weight average	Remarks
<i>Per cent</i>	<i>Grams</i>	<i>Grams</i>	<i>Grams</i>	<i>Days</i>	<i>Grams</i>	
25	8	2.0	20.0	42	+0.3	No better than controls
15	8	1.2	12.0	42	+ .8	No better than controls
0	8	0	0	42	-1.3	Negative controls

These data indicate that cranberries contain very little, if any, vitamin G. Dried cranberry equivalent to 20 grams of fresh cranberry daily caused no significant increase in weight over the controls. Here again some destruction of the vitamin may have occurred during the drying process, but considering the large amount fed, there can be no more than a slight trace present in fresh cranberries.

Vitamin D

The method of testing for vitamin D was that developed by Steenbock and Black (39). Young rats were weaned when they weighed between 45 and 50 grams at about 24 days of age. They were placed on the Steenbock No. 2965 ration consisting of yellow corn 76, wheat gluten 20, calcium carbonate 3, and sodium chloride 1 part. The animals developed rickets in from 28 to 40 days. At this time dried cranberry was added at the rate of 15 and 25 per cent of the diet. This was fed to the animals for a ten-day period, at the end of which X-ray photographs were taken, then the animals chloroformed and line tests carried out. Negative controls were carried to indicate that spontaneous healing had not occurred, and positive controls which received cod-liver oil, in order to allow comparisons.

Animals on both amounts of cranberry showed no improvement over the negative controls. Hence, it was concluded that cranberries contain no significant amounts of vitamin D.

SUMMARY

The American cultivated cranberry, *V. macrocarpon*, is a very good source of vitamin C, the minimum daily protective amount for guinea pigs being 3.5 to 4.5 grams. Varietal differences were slight.

There was a gradual loss of vitamin C in cold storage. However, the loss was only slight during the active marketing season. After four to six months the loss was approximately 20 per cent, and after seven to ten months 60 to 70 per cent. Good keeping quality seemed to be associated with good vitamin C retention.

Inasmuch as vitamin C in cranberries, apples, and possibly other fruits decreases during storage of the fruit, this point must be considered in making vitamin C assays.

Freezing did not injure the antiscorbutic properties of whole, sliced, crushed, or sweetened cranberries. Temperature of freezing and temperature and length of storage had little effect. There was some evidence, however, that thawing and subsequent freezing lowered the vitamin C content.

Evaporated whole cranberries were very deficient in vitamin C. Dehydrated cranberry pulp (film) when prepared in an atmosphere of nitrogen gave full protection from scurvy at the 0.7 gram level, equivalent to a retention of 65 per cent.

Fresh or boiled cold-pressed cranberry juice with or without added sugar was nearly equal to the fruit in vitamin C content. However, when either cold-pressed or heat-extracted juice was bottled and pasteurized, most of the vitamin C was lost. Vacuum sealing of the bottles did not aid in retaining this vitamin.

Whole-fruit sweetened cranberry sauce prepared by several formulas retained 75 to 80 per cent of the fruit's vitamin C. On the other hand strained sauce usually retained less than 20 per cent. The pulping or straining process had a decidedly deleterious effect upon the antiscorbutic vitamin.

When clear cranberry juice was made into jelly, the latter contained no significant amounts of vitamin C. Similarly, cranberry candy filling was very low in vitamin C.

Dehydrated cranberries contained 2 units per gram of vitamin A. Assuming that no loss occurred during dehydration, fresh cranberries would thus contain at least 0.2 unit per gram.

No significant amounts of vitamins B (antineuritic), D (antirachitic), and G (antipellagic) were found in cranberries.

In conclusion it is clear that handling and manufacturing methods may greatly alter the nutritive value of cranberries and cranberry products.

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