1932

Preservation, utilization and properties of cranberry juice

Cecil Curtis Rice
University of Massachusetts Amherst

PRESERVATION, UTILIZATION AND PROPERTIES OF CRANBERRY JUICE

RICE - 1932

PRESERVATION, UTILIZATION AND PROPERTIES OF CRANBERRY JUICE

Cecil Curtis Rice

Thesis submitted for
the degree of
Master of Science

MASSACHUSETTS STATE COLLEGE, AMHERST
June 1, 1932

History of the Cranberry Industry

The wild native cranberry, Vaccinium macrocarpum, was found growing in America when the first colonists came to this country. The colonists used the wild cranberries in much the same way as they are used in modern times. These berries were smaller and more acid than the improved varieties of berries grown today. There are still many small areas producing the old wild type of berry. These wild berries do not bring as high prices as the improved varieties. Many of these wild berries come under the cranberry trade classification of "pie berries", small dark berries which are ordinarily not retailed, but are used largely for manufactured cranberry products.

The first attempt to cultivate the cranberry was made in North Dennis, Mass., between 1810 - 1820. It was not until 1850 that a crop of cultivated berries was successfully harvested. After much experimentation on different soils and methods of production, the acreage of cultivated cranberries increased rapidly. New Jersey started plantings in 1845, followed by Wisconsin in 1874 (3A).

Cranberry growing is localized in certain sections as well as certain countries where the peculiar soil and environmental conditions required for the crop occur. In the United States the principal producing sections are the Cape

Cod region of Massachusetts, the Pine Barren region of New Jersey, and the central and northern parts of Wisconsin. There are scattered areas in ten other states but their total acreage is not so large as that of one of the largest individual growers in Massachusetts.

Cultivated cranberries are little grown outside of the United States. Nova Scotia, Norway, Denmark and the Netherlands all have small acreages (3A).

Cranberry production in the United States averages from 500,000 to 800,000 barrels annually. There is no importation and relatively little exportation of cranberries in this country. With the comparatively recent development in commercial canning of cranberries in the form of cranberry sauce, there have been more exportations and a better distribution of shipments of cranberries in this country. An efficient growers' sales agency has greatly aided in the successful marketing of the crop.

Seasons of production vary but little. The berries are harvested from September through October. Marketing of the bulk of the crop extends from September 1st to January 1st. After this date berries are usually scarce, of poor quality and high priced, however, berries can usually be obtained until the middle of April. Cranberries are subject to various storage rots and the percentage of sound fruit diminishes rapidly after January. This necessitates frequent and expensive sorting.

The two most popular varieties of cranberries grown in the United States are the Early Black and the Howes. These cover the early and late seasons of harvesting and are among the more prolific and hardy of all the varieties. The McFarlin is one of the most highly prized quality berries. The Centerville, Centennial and Bugle varieties are grown to a considerable extent but are not so profitable from the growers' standpoint.

Massachusetts acreage in cranberry bogs is approximately 14,500 and this is nearly half of the producing acreage of bogs in the United States. The average yearly crop for Massachusetts is approximately 400,000 barrels. This represents over 60 per cent of the total crop for the United States. The average yield per acre in Massachusetts is 20 barrels per acre (5). The selling price over a period of 20 years averaged $8.50 a barrel (100 pounds).

The Cranberry Canning Industry

Among the earliest manufactured cranberry products were "Ruby Phosphate", (a cranberry syrup), and a cranberry jam packed in glass and wooden containers. These were manufactured at Wareham, Massachusetts, between 1898 and 1901. The products sold well and at a good profit, yet operations were discontinued with the death of the promoter. In 1922 at South Hanson 5,000 cases of cranberry sauce were packed.

In 1928 production in Massachusetts had reached 278,000 cases and in 1930, 350,000. The total pack for the United States being approximately 420,000 cases. A case is 24, No. 2 (21 ounce) cans.

In 1928 it was estimated that the 35,000 barrels of cranberries, which were used in the manufacture of cranberry sauce in Massachusetts, would yield an additional $600,000 profit to the cranberry industry. This was in a year when the price of berries was high. During a year like 1931, when the crop was large and the price of fruit low, the profits derived from canning are much higher.

Cranberry Juice

During the past few years a desirable cranberry juice, syrup or cocktail has been searched for. A few beverage products have been made, tried out on the consuming public and then discarded. The public is ready to accept a satisfactory cranberry syrup, or cocktail. The juice itself is tart, of good flavor and has a very attractive red color. It is very tasty when sweetened to the correct degree. The aim of any producer of this product should be to pack a juice which retains its maximum nutritive value, color, and flavor, and which will not spoil over a storage period of approximately a year.

Keeping Quality of Cranberry Juice

Preliminary Experiment

The conventional method of extracting a fruit juice is to heat the fruit in water and then to press or strain the juice from the fruit. This method liberates most of the pectin, which is water soluble, from the cell walls of the fruit. The resulting strained juice, therefore, is unusually rich in pectin. This pectin content is undesirable in sweetened cranberry juice (above 25 per cent sugar) because of the objectionable insoluble precipitate that is formed. Sometimes the sweetened juices may even form a semi-solid jelly.

The methods used in the following experiments are either deviations from the conventional method, or adaptions of methods used in the manufacture of cider. The deviations from the conventional methods are as follows: The minimum amount of cooking necessary to soften the fruit is given: the fruit cooled, and cold pressed in an effort to preserve the vitamin C which is present in the raw fruit.

The second method of extracting the juice is to grind the raw cranberries and press the ground fruit. The juice in each of the preceding instances was strained through several layers of cheese cloth to remove excess pulp which was expressed with the juice during the pressing operation.

Preparation of Cranberry Juices

The cranberries used were harvested near Wareham, Mass., during September and October, 1931. They were promptly shipped to the college and stored at 40°F. until used, normally within three months. The two most important varieties, i.e., Early Black and Howes, were used in these experiments. Evaporated cranberries, grown and evaporated at Wareham, Mass., were also used.

The juice from these fresh stored berries was extracted in two ways. The first method was by grinding the raw fruit and pressing the juice from the pomace. This pressing was done in a large manually operated screw press. Both the Howes and Early Black varieties gave a yield of six gallons juice for each barrel (100 pounds) of fruit. The color of this juice was found to be improved by storing the ground fruit in the refrigerator for a few hours before pressing. The color took on a darker, more brilliant red hue. The second method used for extracting the juice was to add water to the fruit at the rate of 6½ gallons per 100 pounds fruit. This water-fruit mixture was boiled slowly for 8 - 10 minutes to soften the fruit. This cooked fruit was then stored in the refrigerator for several hours, to cool and to improve the color, the improvement being the same as for the juice prepared in the first method. The cooled

pulp was then pressed in the same screw press used in the first method, the yield being eight gallons per barrel (100 pounds) cranberries. The cheese cloth used in both cases was a coarse heavy mesh, cider cloth. The extracted juice was then strained through two layers of fine cheese cloth.

This extracted juice was packed in two lots. The first lot was packed in glass-top, lever-seal jars, partially sealed, and pasteurized for 20 minutes at 160°F. These jars were then completely sealed, and stored in the refrigerator. The second lot was packed in metal topped vacuum seal jars, sealed under 25 inches of vacuum and pasteurized for 20 minutes at 160°. Hicks (6) states that tomato juice retains more of its vitamin C when packed and sealed under vacuum. He claims that it should also be vacuumized before sealing. This is because of air present in the juice. In cranberry juice this aerated condition of the juice does not occur and vacuum sealing should be sufficient to remove the air with its deleterious oxygen.

Source of Juice for Further Experimentation

Since the juice from both cooked and fresh-ground fruit darkens if allowed to stand before pressing, and cranberry sauce made from frozen fruit is superior in color to sauce made from fresh fruit, another method of extraction was

tried out. The frozen berries were first steamed. The thawed, soft fruit was then pressed and the juice bottled in bulk for future use. The color of this juice was the finest of any made. The astringency was similar to that of raw, pressed juice, and higher than that of heat extracted juice. The yield was 51 pounds of juice from 100 pounds of frozen fruit.

The juice from the evaporated cranberries was made up weekly and stored in the refrigerator. The method of obtaining the juice was the one advocated by the manufacturers of the evaporated fruit with this one exception, i.e., the dry berries were first ground in a food grinder equipped with a fine cutter, one ounce of ground berries were used to which were added sixteen ounces of water. The fruit was then soaked for 24 hours. During the soaking period the materials were frequently agitated. After this soaking period the fruit and juice was pressed by hand in a cheese cloth, the yield being twelve ounces of juice per ounce of original evaporated fruit.

The above described juices were used in all experiments described in this thesis.

Keeping Quality of Cranberry Juices

Both raw pressed and heat-extracted cranberry juice were packed in eight ounce bottles. Some of these juices were used in full strength, other samples were diluted with one, two, and four parts of water for each two parts of cranberry juice. Other samples, both undiluted and diluted, were sweetened to 30 per cent sugar content. All of the above juices were pasteurized at 140°F. for 20 minutes. Table I indicates the treatment given to the preceding juices.

Physical Changes

Samples of all these juices were stored at 70°and 10° F. All of the undiluted samples were also stored at 40°as well. These juices were examined organoleptically after three months, nine months and twelve months storage. At twelve months all samples were examined for sterility, and types of living microorganisms present. Spoilage agents were thus isolated and further studied.

Significant Spoilage Organisms

The results are here given in Tables II, III, IV, and V. Listed are the changes and quality of the color, clarity and flavor of the juice, as well as spoilage date. Spoilage in each case was caused either by molds or yeasts.

Table I

Raw-pressed juice and the heat-extracted pressed juices were manufactured and bottled in the following ways:

Raw Pressed Juice	Heat Extracted Juice
Undiluted, no heat treatment	Undiluted, no heat treatment
Diluted 2 : 1, no heat treatment	Diluted 2 : 1, no heat treatment
" 1 : 1, " " "	" 1 : 1, " " "
" 1 : 2, " " "	" 1 : 2, " " "
Undiluted, past. 20 min., 140° F.	Undiluted, past. 20 min., 140°
Diluted 2 : 1 " " " "	Diluted 2 : 1 " " " "
" 1 : 1 " " " "	" 1 : 1 " " " "
" 1 : 2 " " " "	" 1 : 2 " " " "
Undild., 30% sugar; no heat treatment	Undild., 30% sugar; no heat treatment
Diluted 2 : 1 " " " "	Diluted 2 : 1 " " " "
" 1 : 1 " " " "	" 1 : 1 " " " "
" 1 : 2 " " " "	" 1 : 2 " " " "
Undild., 30% sugar; past. 20 min., 140°	Undild., 30% sugar; past. 20 min., 140°
Diluted 2 : 1 " " " " "	Diluted 2 : 1 " " " " "
" 1 : 1 " " " " "	" 1 : 1 " " " " "
" 1 : 2 " " " " "	" 1 : 2 " " " " "

Table II

Effect of Storage of Cranberry Juices on Their Physical and Keeping Qualities

	Untreated Raw Cranberry Juice												Pasteurized Raw Cranberry Juice											
	Changes at Indicated Monthly Intervals												Changes at Indicated Monthly Intervals											
	Color			Clarity			Flavor			Spoilage			Color			Clarity			Flavor			Spoilage		
Storage Temp. and Dilution	3	9	12	3	9	12	3	9	12	3	9	12	3	9	12	3	9	12	3	9	12	3	9	12
	Rating			Rating			Rating			Organism			Rating			Rating			Rating			Organism		
Undiluted																								
70° F.	1	2	3	1	3	4	2	3	3			S	2	3	4	2	2	3	2	4	4			S
40°		1	2		2	3		2	2			S		2	3		2	3		3	3			S
10°		1	2		2	3		2	2			S		2	3		2	3		3	3			S
Juice to Water Ratio 2:1																								
70°	2	3	4	1	2	3	2	3	3			BG	3	4	4	2	3	3	3	4	4			S
10°		2	3		2	3		3	3			S		3	4		2	3		3	4			S
Juice to Water Ratio 1:1																								
70°	2	4	4	1	3	3	2	3	3			BG	3	4	4	2	3	4	3	3	4			BG
10°		2	3		2	3		3	3			G		3	4		3	3		3	4			
Juice to Water Ratio 1:2																								
70°	3	4	4	1	3	3	3	4	4			BG	3	4	4	2	2	3	3	4	4			S
10°		3	3		2	3		3	3			S		3	4		2	3		3	4			

1 = Excellent
2 = Good
3 = Fair
4 = Poor

B = Black mold
G = Yeast
S = Sterile

Table III

Effect of Storage of Cranberry Juice on Its Physical and Keeping Qualities

	Sweetened Raw Cranberry Juice												Pasteurized Sweetened Raw Cranberry Juice											
	Changes at Indicated Monthly Intervals												Changes at Indicated Monthly Intervals											
	Color			Clarity			Flavor			Spoilage			Color			Clarity			Flavor			Spoilage		
Storage Temp. and Dilution	3	9	12	3	9	12	3	9	12	3	9	12	3	9	12	3	9	12	3	9	12	3	9	12
	Rating			Rating			Rating			Organism			Rating			Rating			Rating			Organism		
Undiluted																								
70° F.	1	3	4	2	3	3	1	3	3			BF	2	3	4	2	3	4	2	3	3			B
40°		1	2		2	2		1	2			BG		2	3		2	3		2	3			S
10°		1	3		2	3		1	2			E		2	3		2	3		2	3			
Juice to Water Ratio 2:1																								
70°	2	3	3	3	3	3	2	3	3			BG	2	4	4	2	3	4	2	3	3			B
10°		1	3		2	3		2	2			A		2	3		2	3		2	3			BG
Juice to Water Ratio 1:1																								
70°	2	3	3	3	3	4	2	2	3			BGD	3	4	4	2	3	3	2	3	4			BGC
10°		2	3		2	3		3	4			BG												
Juice to Water Ratio 1:2																								
70°	3	4	4	3	3	4	3	3	4			CGH	3	4	4	2	3	3	3	3	4			S
10°		3	4		2	3		3	4			G												

1 = Excellent
2 = Good
3 = Fair
4 = Poor

A = Blue mold
B = Black mold
C = Yellow coccus
D = Brown coccus
E = White coccus

F = Red yeast
G = White yeast
H = Ovoid bacteria
S = Sterile

Table IV

Effect of Storage of Cranberry Juice on Its Physical and Keeping Qualities

Storage Temp. and Dilution	Untreated Heat Extracted Cranberry Juice: Changes at Indicated Monthly Intervals												Pasteurized Heat Extracted Cranberry Juice: Changes at Indicated Monthly Intervals											
	Color			Clarity			Flavor			Spoilage			Color			Clarity			Flavor			Spoilage		
	3	9	12	3	9	12	3	9	12	3	9	12	3	9	12	3	9	12	3	9	12	3	9	12
	Rating			Rating			Rating			Organism			Rating			Rating			Rating			Organism		
Undiluted																								
70° F.	2	3	4	2	3	3	1	2	2			B	2	2	3	2	3	3	2	2	3			G
40°		1	2		2	3		1	2			B		2	3		2	2		2	2			S
10°		1	2		2	3		1	2			B		2	3		2	2		2	3			S
Juice to Water Ratio 2:1																								
70°	3	3	4	2	2	3	2	2	3			BG	3	3	4	2	3	3	3	3	4			B
10°		2	3		2	3		2	2			S		3	4		2	3		2	3			S
Juice to Water Ratio 1:1																								
70°	3	4	4	2	3	3	3	4	4			B	3	4	4	2	3	4	3	4	4			B
10°		3	3		2	2		3	3			B		3	4		2	3		3	4			B
Juice to Water Ratio 1:2																								
70°	3	4	4	2	3	3	3	4	4			B	4	4	4	3	3	4	4	4	4			B
10°		3	4		2	3		3	4			S		4	4		3	3		4	4			G

1 = Excellent
2 = Good
3 = Fair
4 = Poor

B = Black mold
G = Yeast
S = Sterile

Table V

Effect of Storage of Cranberry Juice on the Physical and Keeping Qualities

	Sweetened Heat Extracted Cranberry Juice												Pasteurized Sweetened, Heat Extracted Cranberry Juice											
	Changes at Indicated Monthly Intervals												Changes at Indicated Monthly Intervals											
	Color			Clarity			Flavor			Spoilage			Color			Clarity			Flavor			Spoilage		
Storage Temp. and Dilution	3	9	12	3	9	12	3	9	12	3	9	12	3	9	12	3	9	12	3	9	12	3	9	12
	Rating			Rating			Rating			Organism			Rating			Rating			Rating			Organism		
Undiluted																								
70° F.	1	2	3	2	3	3	1	2	2	*		S	2	3	3	2	3	3	2	3	3	*		S
40°		1	2		2	3		2	2	*		S		2	3		3	3		2	3	*		S
10°		1	2		2	3		2	2	*		S		2	3		2	3		2	3	*		S
Juice to Water Ratio 2:1																								
70°	2	3	3	2	2	3	2	3	3	*		S	2	3	4	2	3	4	2	3	4	*		S
10°		2	2		2	2		2	3	*		S		2	3		2	3		2	3	*		S
Juice to Water Ratio 1:1																								
70°	2	3	4	2	2	2	3	3	4			G	2	3	4	2	3	3	2	3	3			S
10°		2	3		2	2		3	4	*		S		2	3		2	3		2	3	*		S
Juice to Water Ratio 1:2																								
70°	3	3	4	2	2	3	3	4	4			G	3	3	4	2	3	3	3	4	4			G
10°		3	3		2	2		3	4			G		3	4		2	3		3	4			S

1 = Excellent
2 = Good
3 = Fair
4 = Poor

S = Sterile
G = Yeast
* = Juice turned to jelly

The organisms other than these are simply contaminations which occurred during pressing or manipulation of the juice and which were not killed during the pasteurizing period. Organisms found in this cranberry juice are coded by letters, and their respective thermal death points are noted in Table VI.

Determination of Minimum Pasteurizing Times and Temperatures

In order to check up on the actual spoilage organisms in the cranberry juice, both raw juice and juice sweetened to 45 per cent and bottled in 8 ounce bottles were innoculated with the blue Penicillium and black Aspergillus and yeast, and pasteurized at both 160°F. and 180° for 10, 20, and 30 minutes with the results noted in Table VII.

Discussion of Results

Undiluted juices are by far superior in color, flavor, appearance and keeping quality to the diluted juices.

The color of both raw and heat extracted juices is impaired by storage over long periods of time. The diluted juice in each case is of a pink to light red color which does not appeal to the eye. The diluted juices also turn brownish in color sooner than the diluted juices.

The flavor of the juice deteriorates in about the same proportion as the change in color of the juice.

Table VI

Organisms Isolated from Cranberry Juice Used in Preliminary Experiment

Organism	Code Letter	Thermal Death Point	Action on Cranberry Juice
Blue green mold	A	160° F. for 10 min.	Actual spoilage
Black mold	B	212° F. for 10 min.	Actual spoilage
Yellow coccus	C	Did not record	Present. Could not make grow
Brown coccus	D	200° F. for 10 min.	Present but not active
White coccus	E	200° F. for 10 min.	Present but not active
Red yeast	F	180° F. for 10 min.	Present but not active
White yeast	G	180° F. for 10 min.	Actual spoilage
Ovoid bacteria	H	180° F. for 10 min.	Present but not active

Table VII

Efficiency of Pasteurization of Cranberry Juice in 8 oz. Bottles. (Crown caps).

Innoculated organism	Raw Juice						Sweetened Juice *					
	160°F.			180°F.			160°F.			180°F.		
	10 min.	20 min.	30 min.	10 min.	20 min.	30 min.	10 min.	20 min.	30 min.	10 min.	20 min.	30 min.
Mold Green Penicillium	--	--	--	--	--	--	--	--	--	--	--	--
Black Aspergillus	--	--	--	--	--	--	++	++	--	++	--	--
Yeast	--	--	--	--	--	--	--	--	--	--	--	--

++ Indicates growth
-- Indicates negative growth
* The sweetened juice (45% sugar) partly jellified during storage

Dilution appears to weaken resistance of the juice to spoilage. This might be explained by the reduction of acidity in the juice which is an active agent in the retardation of growth of microorganisms. The unsweetened juice is not appreciably affected by yeast growth. This, no doubt, is due to the small amount of sugar present in the cranberry juice plus the presence of benzoic acid. Molds are the principal spoilage agents in this juice. Sweetened juice offers a much better medium for yeast growth.

Sweetened heat extracted juice when containing from 30 - 50 per cent of sugar has a tendency to jell, which ruins it as a possible beverage, syrup or cocktail, all of which must be in a liquid condition.

From the recorded data it would appear that cranberry juice, if it is to be sweetened, should be raw pressed, to insure against jellification. Sweetened juice is desirable because the labor and uncertainty of successful preparation is less than in the case of unsweetened juice.

The minimum pasteurizing time and temperature for both sweetened and raw cranberry juices appears to be 30 minutes at 160° F. This is lower than the thermal death points would seem to indicate (see Table VI). However, consideration must also be given to the loss of oxygen in the headspace and the subsequent more rigorous conditions than were obtained in experimentation for thermal death points of the spoilage

microorganisms. The same care and aseptic precaution that can be carried out in the laboratory cannot be assured in the commercial manufacturing plant.

Canning Cranberry Juice in Tin Cans

The packing of any red colored fruit juice or other fruit products in glass is undesirable if the product is to be held in storage for over a year. Sunlight and conditions of ordinary storage will turn the juice from a bright sparkling red to a dull brownish color.

Many of the packers of orange and grapefruit juices have turned from glass to tin as a package for their product. Results have apparently been satisfactory providing the storage of the packed product was under optimum conditions of temperature and that the pack was not held for too long a time.

Cranberry sauce is packed almost entirely in tin cans. One of the disadvantages of canned cranberry sauce is that sometimes it becomes discolored, especially around the top and ends of the can and along the side seam. This discoloration is due to the formation of soluble iron from the inner surface of the can, to the reaction of the iron with the coloring matter, and with the tannin in the fruit (13). Oxygen accelerates this discoloration. All of these factors causing discoloration of cranberry sauce will have

their same effect on cranberry juice packed in tin. The most obvious result is a purplish cast in the red juice.

Chemical Properties of Cranberry Juice

Previous Studies of Fresh Cranberries

Much work has been done on the chemical composition of the cranberry. Morse (11) has examined many varieties of cranberries grown in Massachusetts and elsewhere. He carried out analyses at different times during the ripening and storage periods (11), (12) for dry matter, total acid and total sugar. These experiments have been carried over a number of years.

Nelson (17) determined the proportions of citric and malic acids occurring in cranberries. Benzoic acid is present also in quantities of .035 to .09 per cent as determined by Clague and Fellers in unpublished data. The presence of quinic acid in cranberries, noted last year, by Kohman and Sanborn (9), has been investigated by Morse (15) for several varieties of cranberries. He found the range of quinic acid found in 12 varieties of cranberries was from 0.45 to 1.1 per cent.

Caldwell (3) in his studies of astringency of apples, calls astringency a combination of tannin plus astringent non-tannin. The astringent tests which we recognize on consuming a fruit is a ratio made up of the total sugar plus astringency divided by the total acid. Astringency varies markedly among apple varieties, the

range being 7.4 to 955 micromilligrams per 100 cubic centimeters of juice. An arbitrary standard of 125 micromilligrams per 100 cubic centimeters of juice, which is the astringent value of the average eating apple, was established, and all apples with amounts greater than this were termed astringent. The method used for determination of astringency was that used for determination of tannin in distilled liquors (1).

In the following experiments described by Morse (14), (15), both Howes and Early Black varieties of cranberries were used. These analyses give a general idea of the chemical composition of the cranberry varieties which were used for the juice experiments described in this thesis.

Analyses of the fresh fruit gave the following results:

Varieties	Total Acid	Quinic Acid	Astringency	Ash	Alkalinity of Ash
Early Black	2.35%	.4	.46	~~1.58~~ .15%	2.2
Howes	2.20	.4	.61	~~1.58~~ .15%	2.2

Methods Used

The color, flavor and astringencies of the various samples of juice were tested organoleptically. A summary of the methods used follows: Specific gravity determinations were made by means of a specific gravity

spindle. Alcohol precipitate, ash, and titratable acidity were determined by using methods given in the Official and Tentative Methods of Analysis of the A. O. A. C. (2). Total soluble solids were determined by means of an Abbe refractometer.

Viscosity determinations were made by a method used to test viscosity of ice cream mixes. The recorded number being the time in seconds required to drain a 25 cubic centimeter pipet, the mouth of which had been constricted. The pipet was filled to the 25 cubic centimeter mark and drained to a mark at the beginning of the lower shank of the pipet.

The pH value of the juices was determined by use of the quinhydrone potentiometer. The results of these experiments are recorded in Table VIII.

Table VIII

Physical and Chemical Properties of Cranberry Juice

	Color	Flavor	Astringency	Specific Gravity	Total Soluble Solids*	Viscosity**	Alcohol Precipitate	Titratable Acidity***	pH	Ash
Juice #1 Raw Howes, Ground and Pressed	Good	Fine	Marked	1.025	6.3	27.15	.228%	2.15%	2.41	.11%
Juice #2 Cooked Howes-Pressed	Good	Fine	Moderate	1.017	4.75	30.65	.416	1.52	2.45	.108
Juice #3 Raw Early Blacks Ground and Pressed Vac. Packed	Fine	Fine	Marked	1.055	6.5	28.65	.168	2.78	2.35	.144
Juice #4 Cooked Early Black Pressed	Fine	Excellent	Moderate	1.0325	5.0	30.4	.396	1.53	2.55	.118
Juice #5 Raw Early Black Ground and Pressed	Good	Good	Marked	1.0600	6.8	26.6	.108	2.69	2.46	.208
Juice #6 Cooked Early Black Pressed	Good	Good	Moderate	1.0425	4.5	32.3	.496	1.71	2.54	.182
Juice #7 Cranberries Frozen, Steamed	Excellent	Good (Storage flavor)	Very Marked	1.035	5.5	28.00	.182	1.78	2.50	.122

* By Abbe refractometer
** Viscosity of water 26.2
*** Calculated as citric acid

Discussion of Results

There is very little to choose between the raw and the cooked juice as to color. Each of these has desirable characteristics of its own. The cooked juice is darker, and more purplish than the redder, brighter color of the raw juice. The flavor of the cooked juice is mellower and not so harsh as that of the raw juice which seems considerably more astringent. The specific gravities varied because of the variations in dilutions. The cooked juice was in each case more viscous than the raw juice. The alcohol precipitates for the cooked juices were all higher than for the raw juice because many cells were broken down and the pectin liberated and passed into solution, thereby giving a higher pectin content. It is interesting to note the relation of titratable acidity to pH. The acidity for all the cooked juices is low because of the dilution of the fruit juice with water. Dilution does not affect the pH value which remains between 2.41 and 2.55 for all the samples tested. The ash content for all the juices remains fairly constant with the raw juice being perhaps a trifle the higher.

The ash content of the juice is low, being about one-tenth or less, of the total ash of the cranberry. The alkalinity of cranberry ash is very low, according to

Morse (14).

Soluble solids as determined by the refractometer in the various juices tested from 4.5 to 6.8 per cent.

Determinations for alcohol precipitate and acidity were made on juice and pomace of fruit stored at 40° F. for seven months. The raw fruit was ground and pressed in a hydraulic press. The juice from 100 pounds of fruit weighed 50 pounds. The acidity of this juice was 2.2 per cent and the alcohol precipitate was 0.204 per cent. A portion of the remaining 50 pounds of pomace was prepared and tested for alcohol precipitate as directed in the Official and Tentative Methods of Analysis (2).

This juice gave an alcohol precipitate content of 0.60 per cent and an acidity of 0.32 per cent. (Calculated as citric acid). Alcohol precipitate is considered synonymous with pectin.

Study of Retention of Vitamin C in the Manufacture of Cranberry Juice

Commercially manufactured, strained cranberry sauce retains very little of the original vitamin C content of the cranberries (7). Whole fruit sauce retains from 20 - 50 per cent of the vitamin C. Obviously it is desirable to retain as much of this vitamin as possible in extracting cranberry juice. MacLeod and Booher (10) report cranberries as being a poor source of vitamin C. This work was done with berries stored from 7 to 11 months, and their highest feeding range was only 5 grams per guinea pig. Isham (8) reports that cranberries stored from 6 to 12 months lose from one-half to two-thirds of their vitamin C content. Naeslund (16) found the European cranberry, Vaccinium vitis idaea, to contain very little vitamin C.

Methods Used

The method used in determining the vitamin C content of cranberry juice was that of Sherman, Lalier, and Campbell (18). Young guinea pigs weighing 300 - 350 grams were fed a basal ration containing all the known necessary nutritive factors except vitamin C. This ration consisted of:

Baked skim milk powder, 30 parts,

A mixture of equal parts of bran and rolled oats, 59 parts,
Butter fat, 10 parts,
Sodium chloride, 1 part,
Cod liver oil, 1 part.

The ration and water were kept before the animals at all times. The animals were housed singly in cages made from 1/4 inch sand screen to allow the droppings to pass into a tray below. (Plate I)

The cranberry juice to be tested was given to the animals for six days of each week. The animals had to be force-fed by a pipet (Plate 2) due to the animals' dislike for cranberries. While this method is time consuming, it was not difficult because most guinea pigs tolerated the force-feeding very well. The animals were first weighed, fed, and weighed again. In this way each animal received an exact amount, by weight, of cranberry juice.

Negative controls were fed only the basal ration and water. These all died in from 23 to 33 days. The average survival period being 28 days. The average scurvy score was 19.

The feeding of four grams of raw fresh cranberry juice daily was found to contain sufficient vitamin C to enable guinea pigs to thrive, grow, and be fully protected from scurvy. This value was checked several times by Isham (8).

plate 1, Photograph of section of cages illustrating type of cage, food and water cups and trays.

Plate 2. Photograph illustrating method used in feeding materials by pipet. The animals when placed in a bowl on a towel become more docile.

This fresh cranberry juice was extracted daily, the berries were ground raw and the juice extracted by pressing the pulp through cheese cloth. Unfortunately, commercially sold juice cannot be extracted daily from fresh fruit. The juice must be extracted, clarified and preserved.

In the Sherman, Lamer and Campbell Method (18) for determining the protection or partial protection from scurvy by the presence of vitamin C, the animals are fed daily for a period of 90 days. If they die before the 90 days period has elapsed, they are autopsied, and carefully examined for lesions of scurvy, such as hemorrhages in the intestinal tract, muscles, and at the joints and rib junctions, and the softening and decaying of the teeth and jaw bones. Softening and enlargement of the joints also occurs. These signs of scurvy are evaluated by the Sherman scurvy score (18) which allows for a total possible score of 24. If the animals survive the 90 day period, they are chloroformed and autopsied.

In these experiments, negative controls had a mean scurvy count of 19. Animals fed the four grams of fresh raw juice daily were absolutely sound at the end of the 90 day period. (Plate 3) With these two extremes to gauge conclusions by, the following experiments were carried out. The experimental data are presented in

Plate 3. Photographs showing healthy (top) and scurvied (bottom) animals. Note apparent stupor, dull unkempt and weakened leg conditions of the scurvied animals, as compared with the alert appearance, sleek glossy coat and excellent physical condition of the healthy animal.

Table IX and Figures I, II, and III.

Vitamin C Results

While none of the juices, with the exception of raw juice, extracted daily, offered protection against scurvy, it is interesting to note that the vacuum-packed raw juice gave slightly better partial protection than vacuum-packed heat-extracted juice.

Cranberry juice as now prepared commercially by the Ocean Spray Compsny of South Hanson, gave no protection whatever. The average survival period of the guinea pigs used in this experiment was 28 days which is the same as for the negative control (8). In 1930 the guinea pigs fed the same commercial juice of that year's vintage lived 10 days longer than the guinea pigs fed on juice from the 1931 crop.

It is apparent that cranberry juices vary to some extent from year to year as to the retention of vitamin C.

There seems to be little or no retention of vitamin C in any prepared cranberry juice, which makes it necessary to prepare a product which will appeal to the taste and sight rather than to vitamin C possessed by the cranberries.

Table IX

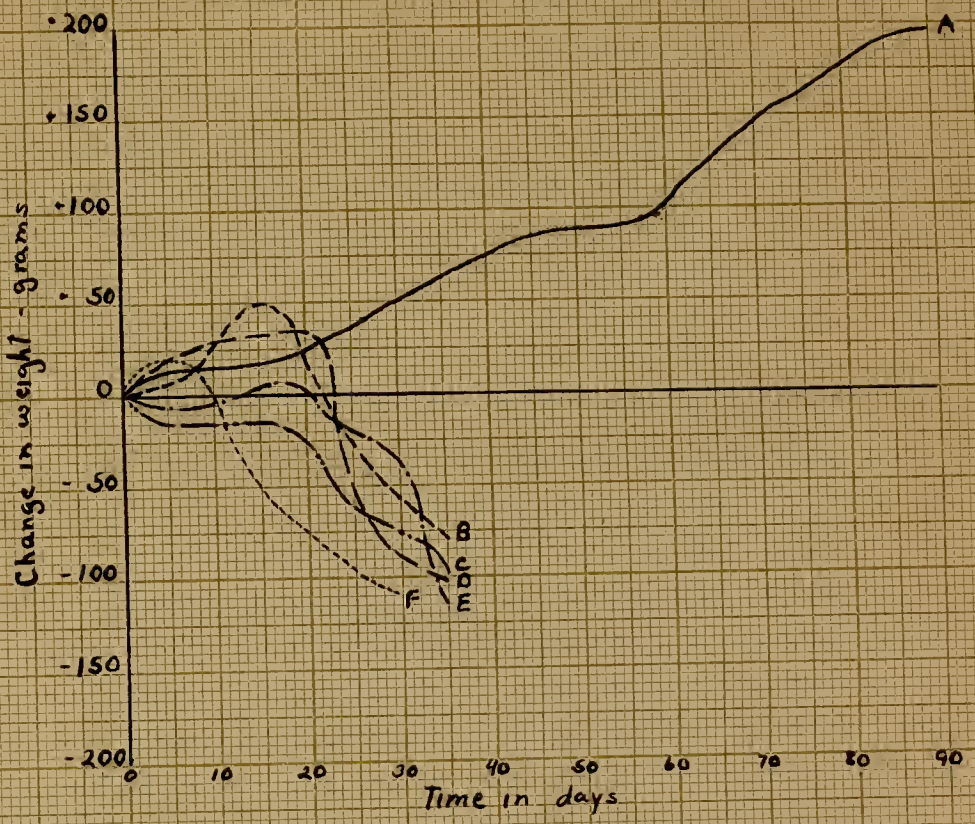
Material Used	Amount of Material	Number of Guinea Pigs	Average Life of Guinea Pigs	Average Gain in Weight Grams	Average Scurvy Score
Pasteurized raw juice	3 grams	3	35	- 73	16
Pasteurized raw juice	6 grams	3	37	-113	13
Pasteurized heat extracted juice	3 grams	3	34	- 98	16
	6 grams	3	37	-102	16
Pasteurized vacuum packed raw juice	6 grams	3	36	-140	12
Pasteurized vacuum packed heat extracted juice	6 grams	3	19	-118	9
Juice from evaporated berries	5 grams	3	31	- 88	16
Juice from evaporated berries	10 grams	3	31	-110	13
Raw cranberry juice extracted daily	4 grams	3	90	195	0
Negative control, basal ration on (no vitamin C)		3	28	-108	19

Relative values of the amount of juice expressed in fresh fruit are

6 grams raw juice were obtained from 11.8 grams berries
6 grams heat extracted juice obtained from 8.8 grams berries
10 grams juice from evaporated berries were obtained from 8.3 grams berries

Fig I

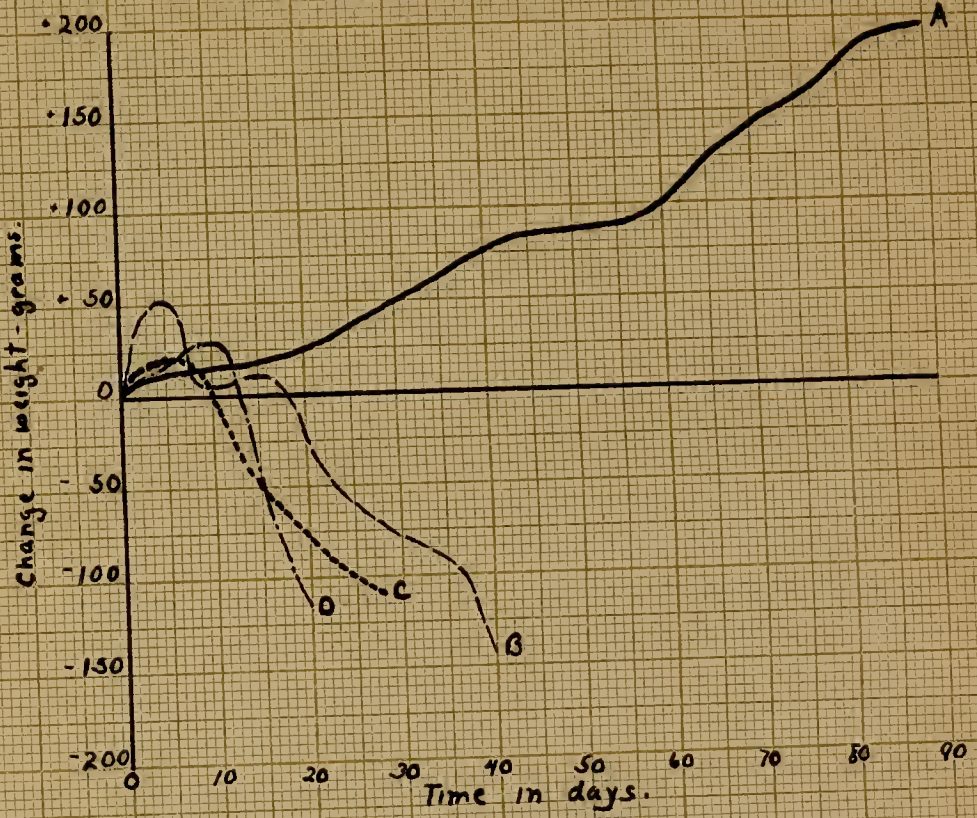
Vitamin C in Raw and Heat Extracted Pasteurized Cranberry Juices



A. Guinea pigs fed 4 grams fresh raw juice daily - Score 0.
B. " " " 3 " raw past. juice " - " 16.
C. " " " 3 " heat extracted past juice " - " 16.
D. " " " 6 " " " " " - " 16.
E. " " " 6 " raw " " " - " 13.
F. " " " basal ration only - " 19.

Fig II

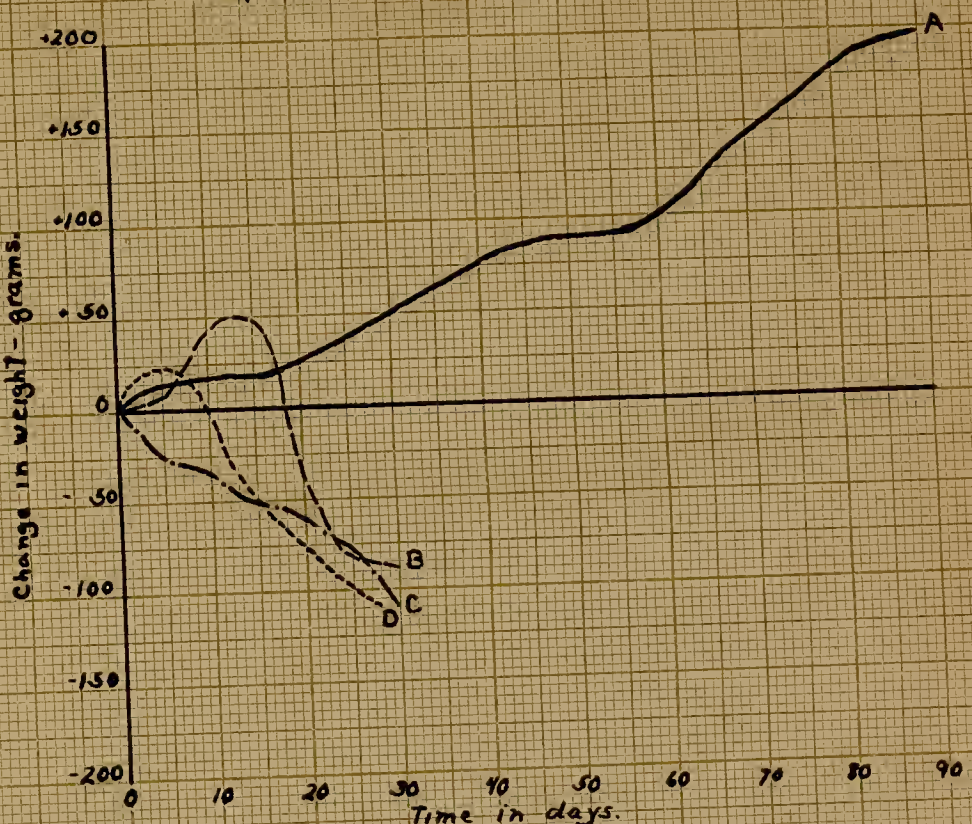
Vitamin C in Raw and Heat Extracted Cranberry Juices Packed Under Vacuum.



A. Guinea pigs fed 4 grams fresh raw juice daily - Score 0.
B. " " " 6 " past. vac. packed raw juice " - " 12.
C. " " " basal ration only. - Negative control. - " 19.
D. " " " 6 grams past. vac. pack. heat ext. juice daily - " 9.

Fig III

Vitamin C in a Juice Made From Evaporated Cranberries.



A. Guinea pigs fed 4 grams fresh raw juice daily - Score 0.
B. " " " 5 " Juice from evap. berries " - " 16.
C. " " " 10 " " " " " " - " 13.
D. " " " basal ration. Negative control - " 19.

Attention should be called to the complete work on the vitamin C content of all the different cranberry products carried on by Isham (8) contemporaneously with this investigation.

Uses for Cranberry Juice

Cranberry Cocktail

Cranberry juice cocktail is simply cranberry juice diluted and sweetened to suit the taste. Usually one part of cranberry juice requires at least two parts of water to adjust it to the most pleasing taste. This diluted juice is then sweetened to 15 per cent total sugar content. The most desirable method of manufacturing this cocktail would be in a sweetened concentrated form. This seems to be impossible unless raw pressed juice is used, because the pectin and sugar form a jelly which is insoluble and one can easily see the disadvantage of buying a potential beverage in a semi-jelly form. The two other solutions to this problem of packing for distribution are: First, to pack the finished, diluted, sweetened cocktail in the drinkable form, and second, to pack the juice as an unsweetened, undiluted concentrate which must be sweetened and diluted by the ultimate consumer. Of these two packs, the second seems the more preferable because of decreased cost of production, utilization of more fruit, and a wider range of uses as a syrup or as a blender, and because it gives the consumer a chance to satisfy his own personal taste for tartness and sweetness of the finished product.

Cranberry Syrup

This is a material which can be used for beverages or for a garnish for cakes, ice cream or puddings. It is of necessity sweeter than a cocktail and can be sweetened to nearly 70 per cent. Jellying can be partly prevented by this over-concentration of sugar and by a slight boiling period when the sugar is mixed with the cranberry juice.

Cranberry Juice Used as a Blender

The blending of fruit juices to produce a palatable beverage is often done. All punches are sweetened blends of fruit juices. Many of these have a little acid added to accentuate the flavors of the various fruits. Cranberry juice, with an acidity above 2 per cent and whose color is especially well retained when used as a blender, is one of the ideal juices for punch making. There are many combinations using cranberry juice with other fruit juices for punches. The University of Wisconsin's Extension Service publication, "Cranberries in the Diet" (19) gives a number of uses for cranberry juice as a blender. Experiments have been conducted in this department with raw cranberry juice for blending with single fruit juices and in punches with much success. The American Cranberry Exchange has also published a booklet describing several

methods and recipes for preparing cranberry beverages.

Carbonated Cranberry Beverages

A study of the uses of cranberry juice as a beverage would not be complete unless some of the juice was carbonated. In this experiment carbonation was accomplished as follows: A cranberry syrup sweetened to 45 per cent was prepared and half pint bottles were filled one-third and one-half full with this syrup. This syrup was chilled. The bottles were then filled with carbonated water and sealed at once. These bottles were then shaken to mix the syrup and the water and stored in a refrigerator. Raw unsweetened juice was also carbonated. The color of this juice was not so bright and sparkling clear as the sweetened juice.

These juices were opened and tested by eight different people. The concensus of opinion was that the sweetened juice should be diluted about midway between the two lots that were made. The unsweetened juice was diluted with about 20 per cent of water and sweetened with a cold sugar syrup. This also made a palatable beverage. In each case the person tasting the beverage thought it was a distinct improvement over the straight cranberry syrup and water combination.

Cranberry Vinegar

The possibility of utilizing cranberries as a source of vinegar has been examined (12). Satisfactory results were impossible because the total sugar content of the juice is insufficient to give enough alcohol and subsequent acetic acid to make a legal vinegar. Very little fermentation could occur because of the benzoic acid present in the juice.

General Summary

1. Cranberry juices used in this series of experiments were prepared by two methods; the first was to grind the raw fruit, allow the ground fruit to stand for several hours to gain color, and then press the juice from the pomace; the second method was to boil the fruit in water for 8 to 10 minutes, using 6 1/2 gallons of water for every 100 pounds of fruit. This cooked pulp was stored for several hours, to cool and to darken in color, and then pressed.

2. Yields from juices prepared by the above methods were 6 gallons of juice from 100 pounds of the raw pressed fruit, and 8 1/2 gallons of juice from 100 pounds of the heat treated fruit.

3. The physical and chemical properties of the raw pressed and heat extracted juices differed from each other as follows: The color of the cooked juice was more purplish than the brilliant red color of the raw juice. Early Blacks, being a darker berry, gave a slightly better colored juice than did the Howes. The flavor of both the juices was very good. The cooked juice had a more mellow flavor than the raw pressed juice. The raw pressed juice had a greater astringency and higher titratable acidity than did the heat extracted juice, the latter gave the highest alcohol precipitate (pectin), and viscosity tests. The pH content

of all the juices remained fairly constant despite the dilutions of the heat extracted juice.

4. Sufficient vitamin C to afford protection in 300 gram growing guinea pigs, was present in from 3 to 4 grams of fresh raw juice. Quantities of 6 grams of raw pressed and heat extracted juices, vacuum sealed and pasteurized for 20 minutes at 140° F., from both Howes and Early Black varieties, gave no significant protection.

Quantities up to 10 grams of juice from evaporated cranberries gave no appreciable protection.

5. Cranberry juice and products tested in 1930 gave much better vitamin C results than similar products tested in 1931, indicating that the nutritive value of the cranberry will vary from year to year.

6. The best method of bottling cranberry juice or syrup was under vacuum. Storage of juices at 30° to 40° F. gave best results. Storage temperatures much below freezing caused a separation of the color pigment in the juice. Temperatures of from 60° to 80° F. caused a rapid deteriorative change in color and flavor of the product.

7. Sealing the cranberry juice under vacuum in re-enameled, charcoal tin cans, and storage under favorable conditions, 40° F., gave practically as good a product as when packed in glass.

8. Pasteurization of the product was necessary to prevent spoilage. The minimum safe pasteurization times and temperatures were 30 minutes at 160° F., or 20 minutes at 180° F.

9. The actual spoilage agents in cranberry juices were principally molds and yeasts. Of the molds, Penicillium and Aspergillus were most important.

10. Bacteria were not significant factors in spoilage because of the high acidity and pH of the cranberry juice.

11. The spoilage and contaminating organisms were isolated and their thermal death points determined. These data were applied to the pasteurization of the juice as it would be done commercially. After incubation, the samples were then examined for growth of spoilage microorganisms.

12. Carbonated cranberry syrup seemed to be the best of the methods for utilizing cranberry juice. Cranberry syrup should contain about 40 per cent sugar and should be mixed with an equal part of carbonated water. By using raw, pressed juice, this syrup will not become semi-gelatinous.

13. Other uses for cranberry juice are for cocktails, heavy 70 per cent syrup, suitable for table or soda fountain use, and in blends for manufacturing mixed beverages or punches.

Conclusion

Attractive, tasty cranberry juice can be successfully and satisfactorily manufactured and preserved in glass or tin, if pasteurized at a temperature of 160° F. for 20 minutes. This juice contains practically no vitamin C.

Only the raw pressed juice should be packed in a sweetened form. This juice can be sweetened to 40 per cent and used either as a base for a beverage or else sweetened to 70 per cent and used as a table syrup. There are possibilities for the development of satisfactory carbonated and other cranberry beverages.

Bibliography

1. Assn. Off. Agric. Chem., Official and Tentative Methods of Analyses p. 155 (1930).

2. Assn. Off. Agric. Chem. Official and Tentative Methods of Analyses pp. 269, 265-266, 270 (1930).

3. Caldwell, J. S., Chemical Composition of American Grown French Cider Apples and other Apples of Like Character. J. of Agric. Res. 36, 391-406 (1928).

3A. Darrow, A. M., Franklin, H. J., Malde, O. G., Establishing Cranberry Fields, Farmers' Bull. 1400 (1924).

4. Fellers, C. R., From the Land of the Bean and the Cod. Canning Age. Dec. 1928. 989-993, 995, 998.

5. Franklin, H. J., Cranberry Growing in Massachusetts. Mass. Agri. Expt. Sta. Leaflet 72 (1923).

6. Hicks, C. G., Research Survey Reveals Answers to Packing and Bottling Questions. The Glass Container. Feb. 1931, 8-9, 22.

7. Isham, P. D., Fellers, C. R., Vitamin C in Cranberries, Paper read before Agricultural and Food Chemistry Sections, Am. Chem. Soc., Buffalo, September 1, 1931.

8. Isham, P. D., The Vitamin C Content of Cranberries. Thesis presented for Master's Degree. Mass. State College. (1932)

9. Kohman, E. H., Sanborn, H. H., Isolation of Quinic Acid from Fruits. Ind. and Eng. Chem. 23, 126 (1931).

10. MacLeod, G. and Booher, L., The Antiscorbutic Vitamin Content of Some Preserved Foods. J. Of Home Econ. 22, 588-593 (1930).

11. Morse, F. W., A. Chemical Study of Cranberries. Mass. Agric. Expt. Sta. Bull. 265, (1930).

12. Morse, F. W., and Jones, C. P., Chemical Studies of Cranberries During Storage. Mass. Agric. Expt. Sta. Bull. 198 (1920).

13. Morse, F. W., The Discoloration of Canned Cranberries. J. Agric. Res. 34, 889-892 (1927).

14. Morse, F. W., The Mineral Constituents of Cranberries, J. Biol. Chem. 71, (1929).

15. Morse, F. W., Unpublished data (1932).

16. Naeslund, D., Studies of the Vitamin C Content of Wild Cranberries. Acta. Med. Scand. 76, 425-436 (1931).

17. Nelson, E. K., The Non Volatile Acids of the Pears ... Cranberries...and Pomegranates. J. Am. Chem. Soc. 49, 1300-1302 (1927).

18. Sheman, H. C., Lalier, V. K., and Campbell, H. L., The Quantitative Determination or the Antiscorbutic Vitamin (vitamin C). J. Am. Chem. Soc. 44, 165-175 (1932).

19. Wis. Univ. Ext. Service., Cranberries in the Diet. Special Circular June 1928.

Acknowledgments

I wish to express my appreciation to the members of my thesis committee, Professors C. R. Fellers, F. W. Morse, and L. A. Bradley, for the helpful suggestions, advice and constructive criticisms offered in the preparation of this thesis. I am indebted to my colleague, Paul D. Isham, who was working contemporaneously with me on the study of cranberry products, for instruction in much of the meticulous detail involved in the study of vitamin C.

I further wish to thank Professor W. W. Chenoweth for his continued interest and assistance during the period this research was under way.

Approved by:

Carl R. Fellers

Leon A. Bradley

Fred W. Morse

Graduate Committee

Date May 31, 1932