THE EFFECT OF VARIOUS METHODS OF EXTRACTION ON THE COMPOSITION OF FRUIT JUICE.

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INTRODUCTION

While jelly-making has been a frequent household activity for many years, it is only recently that it has been recognized as a process involving important chemical principles which are worthy of serious research. The chemistry of jelly-making finally attracted the attention of research chemists whose work has been directed chiefly to controlling the methods used commercially. The household process has been most thoroughly investigated by Miss N. E. Goldthwaite, at the University of Illinois, and by Miss Kate Daum, at the University of Kansas. In addition, the Department of Home Economics at this institution has carried on a number of short studies on the subject which have not been published. This latter material has been used freely as a basis for the present study.

Cranberries are seldom made into a clear, transparent jelly as are other fruits. It is a delicious jelly which housewives may profitably add to their supply for it gives variety to the menu and is especially appetizing and attractive with certain foods. Cranberry sauce is frequently made and recipes for certain forms of cranberry jelly may be found but they suggest preparing it by straining through a sieve or colander, which allows seeds and pulp from the fruit to appear in the product which is therefore a marmalade and not a jelly. The infrequent use of cranberry jelly is probably due to the fact that it presents difficulties which have not been understood. It was with the aim of eliminating these difficulties by applying the general chemical and physical principles of jelly-making to this fruit that the present study was undertaken.

REVIEW OF LITERATURE

Principles of Jelly Making.

Of all the home products favorably affected by the application of precise methods, jelly is among those most improved because the making of fruit jelly is strictly a chemical and physical process, every part of which must be exactly controlled if an ideal product is to result. (Stoker)

Definition of Jelly.

Jelly has been defined as "The product obtained by so adjusting the concentrations of acid, pectin, sugar, and water in a fruit juice in such a relationship with each other that the result is a clear, transparent, mass which will quiver and not flow when shaken and which retains a sharp or slightly rounded edge when cut." (Stoker)

Goldthwaite (16) says that, "Ideal jelly is a beautifully colored, transparent, palatable product obtained by so treating the juice that the resulting mass will quiver and not flow, when removed from the mold; a product with texture so tender that it cuts easily with a spoon and so firm that angles thus produced retain their shape; a clear product that is neither gummy, sticky or tough. This is that delicious appetizing substance, a good fruit jelly."

Colloidal Nature of Jellies.

Jelly is a concentrated colloidal solution. It is usual to refer to the particles in suspension as the disperse or internal phase and the medium in which they are suspended as the continuous or external phase. The continuous phase is the more concentrated and in jelly is a network of pectin. The disperse phase is made up of drops of liquid, or fruit juice in suspension.

The colloidal particles are so small that they cannot be seen with an ordinary microscope so an ultra-microscope is used. (27) A beam of light is sent through the solution horizontally and then the particles are seen as bright spots through the microscope.

The concentration of colloidal solutions is generally very dilute, containing only a fraction of one percent of solid in suspension. These particles are kept in suspension due to the fact that they are electrically charged and therefore repel each other. They may be precipitated almost immediately if they are brought in contact with some electrolite, ie. a few drops of a solution which will cause a change in the electrical charge.

Grigg and Johnstin (18) say that the colloidal particles in water solutions are often thought to bear negative charges because the precipitation of pectin from water solutions is brought about by metallic ions, lead ions being the most effective. They say however, that in electrolyzing water-pectin sols free from electrolytes, the pectin has been found to deposit on the cathode which indicates a positive charge. When the addition of alcohol produces a soft gel there is no doubt but that the pectin is a negative colloid for it forms as a solid gel on the anode when electrolyzed.

Essential Substances.

Chemically jelly is a mixture of acid, water, sugar, and pectin. These substances must be present in proper proportions if a desirable jelly is to be formed.

Pectin.

Occurence.

One of the most important constituents of the fruit juice is pectin. It is found in the middle lamellae of all cell-walls and serves as the cementing tissue between them. Pectic substances (34) are most abundant in the parenchymatous tissue of vegetables and fruits. Pectin has an affinity for certain dyes such as methylene blue and ruthenium red, so its presence may be determined by this staining reaction. With some dyes it may be detected in all tissues and also as a covering of the intercellular cavities.

Chemistry of Pectin.

Pectin is closely related to starches and plant gums and is usually classed as a polysaccharide. There are three classes of polysaccharides, the trisaccharides, the tetrasaccharides and the colloidal polysaccharides. Pectins are found in the last group. The following outline helps to classify pectins in relation to other carbohydrates. (27)

Monosaccharides

Bioses, trioses, tetroses, pentoses, hexoses, heptoses, octoses and nonoses.

Disaccharides

Lactose, maltose, saccharose, trehalose, melibiose.

Polysaccharides

Trisaccharides

Tetrasaccharides

Colloidal polysaccharides

Hexosans
Fructosans - inulin
Glucosans - starch, dextrine, glycogen
Mannana
Galactans

Pentosans - gums, pectin

Hexosans - Pentosans lignocellulose, hemicellulose.

There are three recognized pectic substances. The mother substance called pectose or protopectin or pectinogen, the secondary substance called pectin and pectic acid. By hydrolysis protopectin is converted into pectin, and pectin into pectic acid. This is brought about by enzyme action (pectase) in nature and by dilute acids in the laboratory.

The chemistry of pectin and the construction of its molecule are still obscure. Protopectin, an insoluble substance is made soluble by being converted into pectin. This occurs in the ripening of fruits by enzyme action. It may also be brought about by boiling in water; by being in contact with alcohol; by treatment with dilute acids or salts of the acids which form soluble calcium salts such as ammonium oxalate, ammonium tartrate or sodium carbonate.

Sucharipa (33) believes there is no distinct line between protopectin and pectin and the cell-wall. He says "the free pectin layer merges into the protopectin without a sharp line of demarcation and the latter merges into the cellulose wall." He bases this statement upon an experiment he performed in which pure protopectin was hydrolyzed with hot ammonium oxalate which caused pectin to be given off. The remaining material was washed in distilled water treated with alcohol and dried. It was then dissolved in Schweitzer's reagent which oxidized the cellulose and left lignin and inorganic matter undissolved. Thus by hydrolysis he showed that both pectin and cellulose were present in the pure protopectin.

He also tried to determine how the pectin and cellulose were linked together in the protopectin. He found that the free pectin, or the pectin in the fruit juice, differed in its methoxyl content from that hydrolyzed from the pure protopectin. Tutin (37) believes that protopectin or pectinogen is identical with soluble pectin. The tissues containing the supposedly insoluble pectin or protopectin do not allow sufficient water to come in contact with the sparingly soluble substance. He believes that where the tissues will allow plenty of water to permeate, all the protopectin present will be dissolved. The process is very slow so some authorities believe that the protopectin is slowly being converted into soluble pectin.

Pectin, the soluble substance, which is the step between protopectin and pectic acid is called by von Fellenberg, the methyl ester of pectic acid. When (36) pectin is neutralized with sodium hydroxide it is saponified and yields methyl alcohol. Clayson, Norris and Schryver (35) believe that this methyl alcohol obtained by the treatment of protopectin with alkali has no relation to pectin. Carre and Haynes (8) believe it is a calcium ester because it may be precipitated by addition of N/10 sodium hydroxide and calcium chloride after neutralization with acetic acid.

Chodnew (21) gave pectin the formulae of C H O which he based upon combustion figures. The work of Ehrlick in 1917-23 showed on hydrolysis of pectin substances, arabinose, galactose and galacturonic acid were obtained. Manji, Paton and Ling (36) 1925 found the chemical properties were explained by a formulae involving a six-number ring the sides of which represented, arabinose, galactose and four molecules of galacturonic acid. An analysis of pectin by Schryver (36) showed carbon, hydrogen and oxygen in proportions indicating the presence of two hexose groups and one pentose group. Since arabinose is a pentose and galactose a hexose there seems to be a close agreement between these authors as to some of the groups making up the pectin molecule. However, the actual constitution of the pectin molecule is not known.

Pectic acid (28) is only slightly soluble in water and will not form a jelly with acid and sugar. Upon treatment with acids it breaks down into arabinose, galactose, galacturonic acid and other compounds.

Arabinose	Galactose	Galacturonic acid
CH_2OH	CHO	CHO
HOCH	HCOH	HCOH
HOCH	HOCH	HOCH
HCOH	HOCH	HOCH
CHO	HCOH	HCOH
	HCOH	COOH
	H	

Pectin content of fruit juices for jelly.

Amount of pectin.

The percentage of pectin necessary for jelly-making varies with the percentage of acid and sugar present. Lal Singh (31) believes that 0.5% - 1.5% pectin is best for jelly making. He also says that "jellies having 2% or less pectin are normal and show no distinct taste of pectin, but when the pectin is raised to 2.75% a crust like formation appears which is stiffer and less sweet than the lower portion of the jelly. This is even more evident as the concentration increases."

Baker (2) believes that 0.97% pectin is optimum for jelly. He made a series of jellies with pectin varying from 0.5-2.0 gms. per 100 gms. of sugar, the pH. was kept constant at 3.19. He found that 1.49 gms or 0.97% pectin was best for jelly. His figures are based upon the finished jelly.

Campbell (5) performed an experiment in which the acid and sugar were kept constant but the pectin was varied. As a result of his work he says that a pectin content of 1.25% produces a fine commercial jelly and 1.0% or 0.75% produces a delicate quality resembling home made jelly.

It is important to have a correct percentage of pectin because an excess of pectin causes a tough, cloudy, jelly and an insufficient amount, a thin weak jelly.

If a juice contains too little pectin more may be added by mixing with a fruit juice which is rich in pectin or by adding one of the commerical pectins. If there is too much pectin the juice may be diluted, but care must be taken that the acidity is not greatly reduced. However, if this should happen more acid may be added.

Acid.

A second important constituent of jelly making is the acid content of the juice. Acid brings about the setting of the jelly and within certain limits the rate of setting increases as the acidity increases; it also inverts part of the sugar, brings out the flavor of the juice and balances the sweet taste of the sugar.

Acidity of Fruits

Fruits are grouped in relation to their acidity as low, medium and high. Fruits low in acid are apricots, peaches, pears, strawberries, raspberries. Those having an average amount of acid are ripe apples, blackberries, oranges, grapefruit, loquat, most plums, California grapes, sour cherries and quinces. Fruits rich in acid are sour apples, crab apples, currants, lemons, cranberries, sour plums and eastern varieties of grapes.

Kinds of Acid in Fruit.

There are different kinds of acids occurring in the fruit. The ones that are most common are malic acid, (H C H O) which is found in apples, currants, pears, berries, pineapples, and cherries. Tartaric acid is found mainly in grapes. Citric acid, (H C H O) occurs in the juice of lemons, oranges, and currants. Acetic acid is also found. (39) It is not originally present in the juice but results from the fermentation of sugars and starches. Tartaric acid is probably the most efficient acid in fruit juices, citric least, and malic between. (Tarr) (35)

Amount of Acid.

The acidity of the juice may be expressed as total acidity, which is the percent of free acids present, or as active acidity, that is, the hydrogen-ion concentration.

Titratable Acid.

The free acid or titratable acid is usually expressed in terms of tartaric, citric, or sulphuric acid. The amount of free acid necessary to make an ideal jelly varies with the fruit as shown by Goldthwaite's (17) work. She found that an excellent jelly could be made from the following fruits. The acid is calculated as sulphuric.

sour apples	0.86%	acid	excellent
currants	1.892%	acid	excellent
blueberries	1.332%	acid	excellent

Percent of Titratable Acid for Jelly Formation.

Cruess and McNair (11) found that juices containing 0.50% acid as tartaric or citric did not jell, but by increasing the acidity to 0.70% or 0.80% jelly was always formed. They state that the range of optimum acidity is from 0.50% to 1.0%. Singh (31) used juices whose acidity was as low as 0.05% calculated as citric acid, and as high as 4.05%. Campbell (5) states that an acidity of 0.30% calculated as sulphuric makes good jelly, the minimum being 0.27% and the maximum being 0.50%.

Poore (29) made a series of jellies in which the pectin and sucrose were kept constant and the acid varied. A good jelly was obtained with as low as 0.045% acid. The 0.5% acid jelly was considered the best tasting.

Hydrogen-ion Concentration.

The free acidity of a juice is not a constant or reliable factor upon which to base the resulting jelly made from a certain juice. Tarr (33) says that the formation of jelly cannot be correlated with total acidity but that there is a direct relation between jelly formation and active acidity or hydrogen-ion concentration. He finds that within a pH or 3.46 to 3.1, the higher the hydrogen-ion concentration the stiffer the jelly. Other investigators come to similar conclusions, for instance, Filken (44) found that above a pH of 3.55 jelly formation did not occur. As the pH decreased from 3.55 to 3.0 the strength of the jelly became greater and below 3.0 jelly became weaker and syneresis developed. Jameson (19) believes that the active acidity of a juice should range between a pH of 3.0 and 3.54. She finds that too high a concentration gives syneresis and too low means jelly failure. Baker (2) says that the minimum jelly formation varies around a pH of 3.7 for organic acids and pH of 3.55 for inorganic acids. These workers seem to agree that jelly formation requires a pH between 3.0 and 3.54.

The hydrogen-ion concentration of fruit juices depends upon the kind of acid present in the juice. Tarr (34) says that "the character of the acid present is of as much importance as the total amount. Jellies that are made from fruits as apples in which there is considerable malic acid usually require less acid than do those jellies that are made from citrus fruits in which citric acid predominates."

The hydrogen-ion concentration is also effected by substances in the juice known as "buffers" which prevent the dissociation of acids. Pectin is one, salts of the various acids is another, and there are others, but their effects are slight.

Tarr (35) makes this very interesting comment in regard to hydrogen-ion concentration of a juice. "The formation and character of the jelly depends in a large degree upon the hydrogen-ion concentration. There is a wide variation in total acidity and there may be variations in the particular acids. The "buffer effect" whether exerted by pectin, or salts of other substances may be either great or little, yet the hydrogen-ion concentration at which jelly formation occurs is practically constant."

Modification of the Acid Content of Fruit Juice.

If a fruit contains a low percent of acid it may be increased by the addition of some organic acid such as tartaric or citric. Cruess and McNair (11) used citric acid but Baker (2) used tartaric, for he says "of the acids most common in fruits tartaric produces the strongest and most desirable jelly."

If the acidity of a juice is too great for jelly-making it may decreased by dilution with water, dilution with apple juice or by deacidification. (10) This latter method was used by Cruess in the production of fruit juices for bottling but was adapted in this laboratory and applied to juices to be used in jelly making. The procedure is as follows: The juice is divided into two portions, "a" being three fourths, and "b" one fourth, of the total. This is heated to the boiling point and allowed to stand for twenty-four hours. It is then filtered and added to "b". This reduces the acidity to one fourth of the original juice. Other reductions may be made by suitable modifications of the method. The effect of reducing the acidity of the juice is shown in the following table.

Juice	Sp. Gr.	% acid	Jelly
Original juice	1.025	0.922	clear, firm, syneresis
Diluted with water	1.015	0.881	2, delicate, slight synersis.
Diluted juice further diluted with apple juice	1.025	0.623	beautiful color, texture and flavor.
Original juice deacidified with precipitated chalk (Cruess Method)	1.025	0.600	good jelly, without syneresis.

* (Stoker) (39)

Deacidification may also be accomplished by neutralizing the acid with sodium hydroxide or sodium carbonate ($NaHCO_3$), but the flavor of the jelly is impaired by this method.

Sugar

Sugar is the third important constituent in jelly making. There is some sugar in fruit juices. Goldthwaite (16) reports having made a jelly by boiling down the fruit juice with no addition of sugar. The resulting jelly was very tough. Sugar is necessary if a tender jelly is to be formed. Cruess and McNair (11) state that, "the addition of sugar is necessary to raise the concentration of the solids sufficiently to cause jellying of the pectin. The amount of sugar necessary depends upon the pectin and acid concentrations but the amount used normally is controlled by the concentration of sugar necessary to prevent fermentation and molding."

Determination of Sugar Concentrations

There are two ways of determining when the concentration of sugar is such that jelly will result. One method is that of using a thermometer. When sugar is added to the fruit juice there is a greater concentration of dissolved solids, which causes a rise in the temperature at which the liquid will boil. If a good jelly results when the juice and sugar are boiled at 103 C that means, at that temperature, the concentration of solids has increased to the jellying point.

Percent	Boiling Point
10	100.4
20	100.6
40	101.
50	102.
60	103.
70	106.5
80	112.
90.8	130.

(Brown)

According to this table of Browns (4) which shows the relation between boiling temperature and the percent of sucrose in solution jellying temperatures of from 103° to 105° C would range from 60 to 70% sugar.

The second method is one suggested by Parloa (27) in which a saccharometer is used. A saccharometer is a hydrometer used to read concentrations of sugar solutions. She says "when the syrup gauge registers 25 the proportions of sugar is right to combine with the pectin bodies to form a jelly."

Jellies are made with either cane or beet, granulated sugar. Goldthwaite (16) says that beet sugar yields slightly less jelly but that there is no difference in the texture. This statement as to yield is not confirmed however by any other writers. Sucrose is a disaccharide with the formulae C H O . It yields, on hydrolysis two monosaccharides, levulose and glucose, both C.H O . These simple sugars are known as invert sugar. This reaction takes place when sucrose is boiled with the dilute acids of fruit juices. The amount of inversion depends upon the length of time the sugar and juice are boiled together and also upon the acidity of the juice. If there is little inversion there is greater crystallization. The amount of inversion necessary to make a good jelly is not known.

Other sugars used for Jelly.

Jellies may be made from sugars other than sucrose. During the war, Miss Lucille Wheeler Adams and Ethel Loflin, in the experimental kitchen of the United States Food Administration, made jellies from honey, corn syrup, glucose and sorghum. They found that these sugars may be used in jelly to replace part or all of the sucrose sugar. The product, however, was a little darker and the texture slightly less tender.

Goldthwaite (17) finds that fructose makes a firm jelly but it cannot be substitued for d-glucose for it causes crystallization.

Amount of Sugar

The amount of sugar needed to cause formation of jelly, according to Goldthwaite depends upon the amount of pectin in the juice and the quantity of water used in extracting the juice. She states that fruits needing little water in extraction require more sugar for jelly formation. Lal Singh (31) believes that the percent of acid, also influences the amount of sugar needed to form jelly. He says "within certain limits the greater the acidity of the juice the lower the amount of sugar necessary to form jelly". He found that no jellies with 65% sugar or higher showed any tendency to mold while jellies with less than 65% molded in most cases.

Cruess and McNair (11) determine the percentage of sugar necessary to form jelly by calculating the amount of sugar it will take to bring the juice to 65° Brix. They use the following formula:

$$(65^\circ - a)\ v/35 \text{ equals } S$$

a - Brix of juice
v - volume of juice
S - gms. of sugar necessary to bring to 65° B.

Baker (2) reports an experiment which shows the effect of varying percentages of sugar upon the resulting jelly. He used one gram of pectin, 10 cc. of 0.1 tartaric acid, diluted to 120 cc. This was brought to a boil and 100 gms. of sugar added. When the jellies reached a certain weight they were taken off the stove. The weight of the jellies varied from 120 gms. to 165 gms. Jelly of 120 gms. or containing 83.33% sugar did not resemble jelly but was caramelized, sticky and gummy. When the jelly weighed 144 gms. so containing 69.44% sugar it was at the optimum point. Less than this amount produced jellies which were sticky and cloudy in appearance.

Cruess (10) finds, as a result of his experiments that in order to make jelly a juice must contain 55% to 65% sugar. He says "the boiling must continue until the required concentrations of sugar is reached, this will mean a concentration of 55% or over."

Goldthwaite (16) performed an experiment in which varying amounts of sugar were used. She found that impaired the flavor and texture. She believes that the reason there is so much jelly failure, is that too large a proportion of sugar is used. She says "too little rather than too much sugar should be the rule."

Poore (29) studied the effect of the variation of sucrose on the consistency of jelly and found that "jellies produced were good when they contained 50 to 65% sucrose, but the consistency of jellies containing more or less was poor." He used 0.5% acid and 0.25% pectin. The water was either increased or decreased so that the resulting jelly weighed about 50 gms. His results are shown in the following table:

Poore - Variation of Sucrose

Sucrose %	Consistency	Sucrose %	Consistency
40.0	Sirup	35.6	Sirup
43.5	Fair jelly	39.1	Sirup
48.9	" "	43.5	Barely jellied
53.2	" "	50.0	Good Jelly
64.0	" "	60.0	" "
65.3	" "	65.3	Fair jelly
68.6	" "	68.0	" "
74.5	Very viscous sirup	70.6	Barely jellied
80.0	" " "	74.5	Very viscous sirup
		76.9	Very viscous sirup

Jameson (19) agrees with Poore for she says, "the sugar may be decreased to 50% and a good jelly will result".

Campbell (5) determined the amount of sugar that would produce the best commercial jelly by running a series of experiments in which the original juice was the same throughout but the amount of sugar added varied. To one gallon of juice he added 2,3,4,5,6,7,8,9,10, and 11 lb. of sugar. His results showed that the lot containing five lbs. of sugar per gallon of juice was best for commercial use, but that the lot containing six pounds of sugar per gallon had the best flavor. He concludes that as the sugar is increased the jelly becomes more delicate. This is true to a certain extent. He also states that an excess of sugar produces a soft jelly and that an insufficient amount results in a firm tough product.

Crystallization.

Crystallization often occurs in jellies. This is due to either a surplus amount of sucrose, a low acid content, or a low pectin content in the juice. Cruess (10) believes that if the jelly is boiled down so that it does not contain more than 70% sugar crystallization will not take place.

Relation of pectin and sugar.

Lal Singh (31) performed an experiment in which the acid was kept constant but the pectin and sugar were varied. The pectin concentration of a juice was determined and then successive tests were made with this juice until the minimum amount of sugar necessary to cause jelly formation was found. The following table shows the results of his experiments.

Exp.	Pectin %	Sugar present in finished product at lowest sugar conc. for jellying.
1	0.5	No. jelly at any concentration.
2	0.75	" " " " "
3	0.9	45%
4	1.0	62%
5	1.25	54%
6	1.5	52%
7	1.75	49.5%
8	2.75	48%
9	4.2	45%
10	5.5	43%

He concludes that within certain limits the higher the percent of pectin in the juice the lower the amount of sugar required to form jelly. Especially is this true of jellies containing 0.5 -- 1.5% pectin. He makes the important statement that after a certain concentration of pectin is reached an excess added remains inactive or undissolved.

He also believes that a juice rich in pectin will take less sugar. He finds that by increasing the pectin in a juice 0.9 -- 1.5% a jelly maker may save 15% of his sugar.

Poore (29) in studying the effect of variation of pectin and sucrose on the consistency of jelly while the acid was kept constant constant concluded that if the percentage of pectin is gradually increased from 0.25% to 0.93% the proportion of sugar decreases 41%.

Baker (2) found that for one gram of pectin a sugar concentration of 69.44% produces the maximum jelly strength. If the pectin be increased to 2 gms. the optimum jelly strength appears at 66.66% concentration of sugar. So he concludes "a definite pectin--sugar ratio must be maintained for a certain pH. in order to obtain a jelly of optimum strength.

Relation of Acid and Sugar.

Lal Singh (31) has made an interesting study of the relation of acid and the minimum sugar concentration necessary to produce a jelly. He used a juice whose pectin content was 1.5%. The percentage of acid was varied and only enough sugar was added to cause the juice with the varying percent of acid to jell.

Exp.	Total citric acid content in percent.	Sugar required barely to cause jelling. grams.
1		
1	0.05	75
2	0.17	65
3	0.30	61.5
4	0.55	56.5
5	.75	
6	1.05	53.5
7	1.2	
8	1.55	52.
9	1.75	
10	2.05	50.5
11	2.55	
12	3.05	50.00
13	3.55	
14	4.05	50.0

He found that there is a definite relation between the amount of acid present and the amount of sugar necessary to form jelly. Between certain limits the greater the acidity of the juice the lower the amount of sugar necessary. The relation is especially marked when the acidity is low. From about 0.1% acidity to about 1.7% acidity almost 20% of the sugar was saved. If the acidity is increased 2% or beyond the sugar percentage necessary for jellying was not materially decreased. So it is more economical to increase the acidity of the juice to the maximum limit, compatible with the taste, in order to economize on sugar.

Time of Adding Sugar

It has been the usual practice, to add the sugar to the juice before the cooking process is began. This method is likely to cause a loss in flavor, a darkening of the color and caramelization of the sugar. (Cruess)

An experiment performed by Cruess and McNair (11) compared the method of adding sugar at the beginning and oiling to the jelly forming stage, with that of adding enough sugar to bring the juice to a concentration of 65° Brix at once, and heating only enough to dissolve the sugar. They say that the latter method is the best because prolonged boiling with sugar results in loss of flavor and aroma.

Goldthwaite (16) compared boiling the sugar and juice together for the full time, with that of adding hot sugar when the juice was half cooked, and adding hot sugar during the last four minutes of cooking. She believes that adding sugar when the juice is half cooked is best. She findsthat the time of adding sugar not only influences quality of the resulting jelly but also the quantity. She says "the yield of jelly is greater if sugar is added toward the end of the cooking process."

This short process is more economical than the long because, Goldthwaite says, "by the long method much sugar is lost in the skimmings."

Temperature and Time of Boiling

Length of time of boiling.

The length of time of boiling a fruit juice to the jelly stage depends Goldthwaite says, upon the amount of sugar, pectin and probably acid present, for instance, increasing the amount of sugar decreases the time of boiling. She believes that from ten to thirty minutes is necessary.

Baker also studied the effect of the time of boiling on the resulting jelly. He first tried the effect of boiling the pectin and acid together for varying lengths of time previous to the addition of sugar. The period of boiling varied from 0--12 minutes. His results showed a marked decrease in jelly strength with increase in the time of boiling pectin solutions. He then tried the effect of boiling with sugar. The sugar was added just after the pectin-acid mix began to boil. His results show that there is no detrimental effect from increased boiling after sugar is added.

Miss Grace Williams as a result of experiment on cranberry jelly says that "The shorter the time for boiling the jelly the more tender, bright and clear the product."

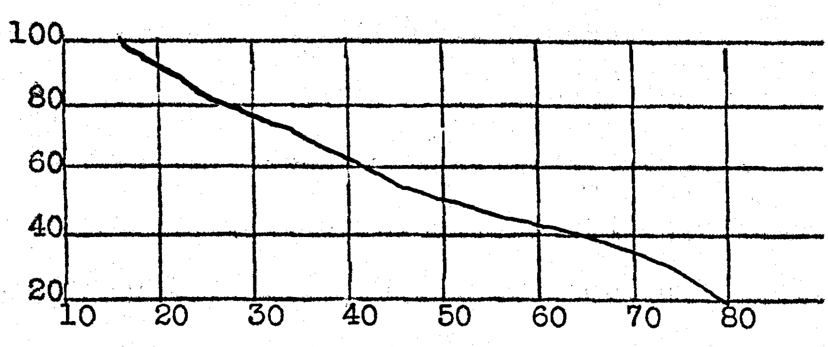
Final Boiling Temperature.

The temperature of a boiling juice indicates the percentage of dissolved solids in that juice. As the concentration increases the temperature rises. The final temperature is a very dependable means of knowing when the acid, sugar pectin and water content of the juice are right for jelly formation. This final temperature does not vary much for the different fruits, but does vary with the fruit juices.

Cruess and McNair (11) tried to find the reason for the change in flavor and aroma of fruit juices during cooking. They believed that the change was due to hydrolysis and to loss by volatilization. A series of experiments were run in which the fruit was crushed, heated to a certain temperature, and pressed. The resulting juice was cooked, with sugar to the same temperature at which it had been extracted. The temperatures varied from 60° to 100° C. A second series was run to note the loss of flavor by hydrolysis. The same temperatures were used but the jellies were made in a 500 cc. flask to which was attached a reflux condenser. The jellies made by these two methods were compared. It was found that jellies made under a reflux condenser were superior in flavor and aroma to those, made to the corresponding temperature, in an open kettle. However, jellies made at a high temperature, that is, 85° - 105°

had less of the fresh fruit flavor than those at room temperatures 60°- 75°.

Baker (2) in doing a series of experiments on the effect of temperature on jelly strength, in jellies produced below the boiling point, found that an increase in temperature causes decrease in jelly strength. The acid, sugar and pectin of his juice were kept constant. They were one gram of pectin; ten cubic centimeters of N/10 tartaric acid and one hundred grams of sugar. The temperature was varied from 2° to 80° C. His results showed a steady decrease in jelly strength with increase of temperature up to 60° C. After this temperature was reached a further increase caused a decided decrease in jelly strength. The following table shows his results.



Temperature in degrees Cent.
(Baker)

This conclusion was also reached by Fellers and Griffiths, (15) who used the Bloom Gelometer in testing the strength of jellies. A number of tests were made on fruit jellies held at different temperatures. They say that "the jelly strength decreased rather uniformally with increasing temperatures between 10° and 30° C., the decrease being approximately one gram per degree." So with increase in temperature there is decrease in strength, as determined by jelly strength testers.

A fruit juice will usually jell when it reaches 103 C - 105 C. Goldthwaite says "hot juice which will jell on colling has a temperature of 103 C." Cruess and McNair (11) place the temperature a degree or so higher than Goldthwaite does for they say "juice boiled to 104°--105° C or 65--70% dissolved solids will, at this concentration, form jell." Perhaps they are giving the temperature for a stiffer jelly than Goldthwaite for Cruess (10) states in another article that "when juice reaches 221 F or 105° C. it has reached the stiff jelly stage, 219° is best for household use."

Preparation of Fruit Juices.

The extraction of fruit juice preparatory to jelly making is a process which has a decided influence upon the resulting jelly. The methods of extracting the juice and the amount and kind of substances obtained has not been studied extensively.

The method of extracting the juice may be varied; such as by heating the fruit in a double boiler, without addition of water, by boiling it in an open kettle with various amounts of water, by boiling it rapidly at a high temperature, or slowly at a low temperature and by making several extractions from the same fruit pulp.

Goldthwaite (16) says the best way to extract the juice is to "cook it out"; with a juicy fruit, by adding only enough water to prevent burning and with a less juicy fruit by adding enough water to cover it. She uses about 200 cc. of distilled water for, four to five quarts of fruit and allows this to simmer slowly and then mashes and drains the pulp through a cheese cloth. She makes further extractions by cooking the remaining pulp with a large supply of distilled water, allowing it to simmer, and then drain it as before.

Parloa (27) used four quarts of water to eight quarts of fruit and suggests that the jelly will be clearer and finer if the fruit is simmered gently and not stirred during cooking. She also says that it should be drained through a cheese cloth, flannel or felt bag, without pressure.

The proportions of water used in making extractions affect the pectin and acid content of the resulting jelly. It takes more skill to make jellies from fruits to which a large quantity of water must be added than from juicy fruit, due to the fact that the pecent of pectin, solids, and acid are lower in proportion to the amount of water used, this may be overcome, however, by concentrating the juice.

There are other factors besides the amount of water used which will influence the constituents of the fruit juice. This is illustrated by Poore's (29) work which shows that the amount of pectin extracted from a fruit will depend upon the temperature at which fruit is extracted and the acidity of the fruit. Though his work was done on the extraction of pectin from fruit rinds, his results are doubtlessly applicable to the extraction of pectin from the fruit itself. He did a series of experiments on extractions to determine the effect of temperature, time of heating and acidity on quantity and quality of the jelly. The first involved the extraction of pectin from lemon peel in which 0.1% citric acid was present. The time of heating was varied from fifteen minutes to three hours. Results showed that heating the pectin for the three hours at 98° C. produced the largest amount of pectin. He next tried the effect of varying the acidity. The lemon peel was heated for three hours at 70° C and the percent of acid was varied; 0.09, 0.04, .36 and .37. He found that while 0.37% acid produced the most pectin it was not as good for jelly as the pectin produced with 0.09% and 0.04% acid. So he tried the effect of low acidity on the quality of the product. Pectin from orange peel was extracted at 98° C in a slightly acid solution (at least 0.1%) yielded a fair quantity of good quality pectin. Further experiments were made to find the proper acidity and the feasible number of extractions which may be used. He found that pectins of high jellying power are obtained when at least 0.1% of acid is present and that the quantity of pectin extracted increases with the increase of acid. He also found that after two extractions the pectin is of inferior jellying quality. He says, "a third extraction yields enough pectin to warrant the extra cost if it were not a poor quality, but the fourth and fifth are not of economic value."

As a result of Poore's (29) work it is shown that, not only the amount of water used in extraction, but also the temperature at which the juice is extracted, the acidity of the fruit, and the number of extractions, all influence the kind and amount of constituents. obtained.

The total amount of these dissolved substances may be estimated by the specific gravity of the juice but the proportions of the various kinds of substances must be determined by chemical methods. It is the purpose of this study to determine the percent of these substances obtained from various methods of cranberry juice extraction, and their effect upon the jelly made from them.

Concentration of the Juice.

The effect of the various cooking methods may be seen in the concentration of the fruit juice, which may be indicated by its specific gravity. This is determined either by a hydrometer having a suitable range, or by the more delicate, Westphal balance. The specific gravity measures the amount, but not the kind of solids in the juice.

Specific Gravity Varies.

The concentration of a fruit juice suitable for jelly-making has been found to vary with the different types of fruit as indicated in the following table:*

Cranberries	1.010 - 1.025
Currants	1.016 - 1.030
Apples	1.025 - 1.050
Crab apples	1.026 - 1.054
Grapes	1.050 - 1.084

It will be noted that with each fruit as well as with the different types of fruit there is a rather wide range of concentration that may be used. This is due to the differences in the kinds and amounts of substances extracted from the fruit as juice. The specific gravity of a pure water solution containing 1% pectin and 0.5% tartaric acid (accepted amounts for a jelly) is 1.0059. If the specific gravity of this solution is compared with those in the preceding table, the effect of other substances in the fruit juice is quite evident.

Fruits having a specific gravity of 1.010 - 1.025 but are high in both pectin and acid as are currants and cranberries can be made into jelly. On the

*Unpublished data, Home Economics Dept. Univ. of Kansas.

other hand, fruits which contain a large amount of other substances such as sugar, must have a higher specific gravity eg. 1.050 - 1.085. If the specific gravity is low it may be raised with the addition of acid, pectin or sugar and a jelly will form if the right proportions are kept. If the specific gravity is high and jelly does not form it is probably due to the fact that the dissolved solids are mostly sugar with little acid and pectin, as in the juice of ripe grapes.

EXPERIMENTAL WORK

Purpose of this Study.

Cranberries, when considered as a jelly making fruit are unique in many respects. For instance, they seem to furnish a jelly making substance in such a proportion that jelly can be made from a very dilute juice. However, they also possess such a high acid content that syneresis is of very frequent occurrence. It was with the idea of determining the effect of various methods of extraction on the composition of the juice and its jelly making powers that this study was undertaken.

The cranberries used for this experiment were bought at the local stores in March. The maturity of these berries may have influenced to some extent the content of the extractions. The berries were washed, sorted and placed in the refrigerator until used.

Method of Cooking

For extracting the juice equal amounts of berries and distilled water were used. A kettle of the same size was used for each experiment in order to keep the evaporation surface as nearly alike as possible.

The time of boiling was controlled from the time when the juice reached 100° C. The water was kept constant during the cooking process and the resulting juices made up to uniform volumes.

Determination of specific gravity

In the first experiments the specific gravity was taken with both the hydrometer and Westphal balance. The two determinations always agreed with each other so nearly that both were not used with all subsequent experiments. The specific gravity of distilled water was taken each time before that of the juice in order to make the readings as accurate as possible.

Determination of Total Solids.

The method used for the determination of total solids was an adaptation of Leach's method for the determination of moisture. He suggests using a one to ten gram sample which should be placed in a tared, platinum dish. If a large quantity of water is present he suggests letting the sample simmer on a water bath. It is then placed in a gas heated air oven. The temperature should be the highest possible that will not affect the constituents. The samples are dried to constant weight.

In the preliminary experiments, 10 cc. of juice were used. The pans were heated, cooled, and weighed. The juice was then measured into them and evaporated on the water bath. The samples were dried in the oven at 110° C for an hour cooled an hour, weighed and heated again. This process was repeated several times. Constant weight was not obtained by this method. The solids weighed less after each heating, showing that decomposition was taking place.

After some experimentation, the final method adopted as as follows: The evaporating dishes were heated in the oven at 100° C for a half hour. They were then cooled in a dessicator for half an hour and weighed. Five cubic centimeters of the fruit juice were measured with a pipette, placed in the dishes and evaporated on a water bath. When all of the liquid had been evaporated the pans were placed in the oven at 100° C for two and one-half hours. At the end of this time they were placed in the dessicator for an hour to cool. They were weighed, reheated for one-half hour, cooled and weighed again. At the end of the second heating they weighed practically the same as at the first weighing. All of the determinations were made in duplicate.

Determination of Acidity

Titratable Acidity.

Titratable acidity was determined by titration with N/10 NaOH. The apparatus used included a graduated 50 cc burette, 5 cc. pipette, three 250 cc. flasks, glass stirring rods with phenolphthaline as an indicator. The juice was diluted one in ten cubic centimeters as suggested by Daum. Twenty cubic centimeters of the original juice were used. The procedure was as follows: Four cubic centimeters of the original juice were measured with a pipette into a 250 cc. flask. To this 50 cc. of distilled water were added. The diluted juice was then placed in each of two flasks. Four drops of phenolphthaline were added to each. The diluted juice was titrated with N/10 NaOH. Calculations for the amount of acid present were as follows.

If it requires

2.46 cc. of N/10 NaOH to neutralize 20 cc. of 1-10 dilution of juice

.246 cc. of N/1 NaOH will neutralize 20 cc. of 1-10 dilution of juice

2.46 cc. N/1 NaOH will neutralize 20 cc. whole juice

then 2.46 cc. divided by 20 cc. equals 1.23 cc. acid (N/1) in 1 cc. juice.

In order to express this data as tartaric acid, the following calculations are necessary.

$$H_2C_4H_4O_6 + 2\ HaOH = Na_2C_4H_4O_6 + 2\ H_2O$$

$$\text{or } \frac{\text{tartaric acid in gms.}}{\text{2 sodium hydroxide in gms.}} = \frac{150}{80}$$

To find the weight of tartaric acid per cc. of juice the following ratio is used.

If 1 cc. of N/1 NaOh contains .04 gms. NaOH then 150 gms. of $H_2C_4H_4O_6$: 80 gms. 2(NaOH) as X;.04

x = .075

If it requires .23 cc. N/1 NaOH to neutralize 1 cc. of juice

Then three are .123 cc. x .075 gms of tartaric acid in each cc. of juice or .0092.

The percent of acid is then, the grams of acid divided by the weight of the juice. If the weight of 1 cc. is 1.0156 gms. the juice is then .908% acid.

Hydorgen-ion Concentration.

The H-ion concentration of the juice was also determined. The LaMotte color standards were used for this purpose. The LaMotte standards consist of a series of enclosed glass tubes containing a dye which show the color of acids and alkalies at the various pH values, when states indicators are used.

Procedure.

Into two test tubes is placed one cubic

centimeter of fruit juice and nine cubic centimeters of distilled water. One half cubic centimeters (0.5 cc.) of the dye or LaMotte indicator is added to one of the test tubes. A LaMotte standard containing the same kind of dye as used in the fruit juice is placed in the test tube holder with the other two test tubes and also a test tube of distilled water. They are so arranged that the LaMotte standard containing the dye is placed in front of the diluted fruit juice containing no dye. The juice containing the dye is placed in line with the test tube of distilled water. Thus in looking through the two groups of test tubes one is looking through dye, juice, and distilled water. If, under these conditions the color in the juice containing the dye is the same as the color of the LaMotte standard, it has the same pH.

Pectin Determination.

Pectin is an extremely hard substance to determine quantitatively. There is no definite, approved method for determining it in fruit juices. Different workers have used varying methods. Alcohol will precipitate pectin but it also brings down impurities with it.

Ashmann and Hooker (1) have worked out a method of determining pectin based upon the fact that acidity develops when pectin is saponified in the cold. The amount of HaOH it takes to neutralize this acid gives the amount of pectin present. The pectin solution is treated with NaOH and allowed to stand 12 hrs. The sodium pectate produced is acidified with HCl. From the number of cubic centimeters of alkali combined with pectin during saponification the amount of pectin is calculated. The following ratio is used:

NaOH : Pectin as weight of alkali combined : X.

Emmett & Carre (14) precipitated pectin with 95° alcohol. They used pectin solutions with varying dilutions. Twenty-five cc. of the solution were treated with 100 cc. of 95% alcohol. They say, as a result of their work that "the alcohol precipitation is untrustworthy, because too many impurities are dragged down and there is a less precipitation of alcohol with increasing dilutions. A concentration of .04% pectin is not precipitated".

They next tried precipitating pectin with acidified alcohol. Twenty-five cubic centimeters of pectin solution were used. The alcohol was acidified with HCl, by using N/1.25 HCl in 95% alcohol and the volume made up to 100 cc. Results showed that acidified alcohol precipitates pectin completely at nearly all dilutions. This precipitate does not give directly a measure of the pectin content of the solution due to the fact that it is difficult to wash the precipitate free from HCl without bringing about a solution of the pectin. Since pectin solutions contain substances like oxalates which are precipitable by calcium it has been found best to precipitate the pectin first with acid alcohol and then after washing the preipitate with more acidified alcohol, to dissolve it and reprecipitate as calcium pectate.

There is another method suggested by Carre and Haynes (8) by which pectin is estimated as calcium pectate. A preliminary determination of the amount of pectin present is taken. A quantity of the solution which will yield o.02 - 0.03 grams of calcium pectate is neutralized and diluted. A hundred cubic centimeters of N/10 NaOH are added and the mixture is allowed to stand at least an hour, or over night, which is better. The pectin is precipitated as calcium pectate after the addition of 50 cc. of N/10 acetic acid and M $CaCl_2$. If precipitation has been properly carried out filtration will take place rapidly and subsequent washing be easy. Washing is done repeatedly with boiling water until the filtrate gives no indication of chloride with silver nitrate. It is then filtered into a small fluted filter and finally transferred to a Booch crucible. Precipitate is dried to constant weight at 100° C. for 12 hours.

Stoker (40) tried a much simplier method than these and seemed to have very satisfactory results. She made detenminations of pectin in certo and in apple juice. Her work as done in duplicate and very close checks were made. The method she used was as follows: The fruit juice was weighed out into a beaker. An equal volume of absolute alcohol was added. After an hour the precipitate was filtered off and dissolved in boiling distilled water. It was then cooled, reprecipitated with alcohol, and allowed to stand twenty-four hours, filtered and reprecipitated as before. The last precipitate was thoroughly washed, dried to constant weight at 70°- 80° C. Then ashed and reweighed.

This method except for the ashing, was tried in these experiments. Four tests were run on each of two juices. The result was very unsatisfactory. The amount of pectin obtained from the same juice varied widely and often the pectin had gained weight after evaporation of moisture. An attempt to dry the filter papers to a constant weight proved impossible for they gained in weight while being weighed. An effort was made to dry out the air in the scales by placing a beaker of sulphuric acid in the case. Though every precaution was taken it seemed impossible to prevent the absorption of moisture. This was undoubtedly due to some extent to the exceedingly damp weather prevailing at this time.

It was desired that some method might be used which did not involve the weighing of filter paper and required as little handling as possible. The more the pectin was handled the greater the percentage of loss and probable error.

A method found in Leach "Food Chemistry" was tried. His procedure as as follows: To 10 cc. of juice 20 cc. of 95% alcohol are added. This is allowed to stand over night. It is then filtered and washed with 80% alcohol. The precipitate is washed off the filter paper with hot distilled water into a weighed platinum dish. This is evaporated to dryness in a water bath and then heated in the oven to constant weight.

Duplicate samples of juice were tried by this method. The results were again, very unsatisfactory.

A method suggested by Campbell (5) was

tried next. It was the method finally adopted for it proved much more satisfactory than the others, the percentage of error being decidedly less. His method is as follows: To 180 cc. of 95% alcohol, 10 cc. of filtered juice are added dropp by drop, drom a pipette, with vigorous stirring. It is filtered immediately and dissolved in boiling distilled water. It is then evaporated to dryness and heated for two hours in a dry air oven at 70° C.

For the determination of pectin in the cranberry juice used in this study Campbell's method was used, though it was slightly modified. Ten cubic centimeters of juice were concentrated to five. The juice was then placed in the refrigerator for a half hour or until it was thoroughly chilled. It was then poured into 90 cc. of 95% alcohol, filtered and dissolved in distilled water. The dissolved pectin solution was placed in the evaporating dishes which had been previously heated, cooled and weighed. The pectin solution was allowed to evaporate on a water bath and was then placed in an oven at 70° C for two hours. Duplicates were run on every juice, close checks were obtained.

Calculations.

To obtain the percentage of pectin in the original juice it was necessary to divide the grams of pectin obtained from the 10 cc. of juice by the weight of that juice. For instance, if there are .0454 grams of pectin in 10 cc. of juice and the juice has a specific gravity of 1.0156 then there will be .0454 grams divided by 10.156 grams or .447 percent pectin.

The percentage of pectin in the total solids is obtained as follows. The grams of pectin in 10 cc. are divided by the number grams of solids in 10 cc. If there are .0454 grams of pectin in 10 cc. and .3588 grams of solid there will be 12.6% pectin. In other words, the total solids contain 12.6% pectin or 12.6% of the total solids is pectin.

Table I

The first experiment was made to determine the specific gravity, acidity, amount of total solids and pectin in cranberry juice from 100 gms. of cranberries boiled with 100 cc. of distilled water for varying lengths of time, namely five minutes, ten minutes, thirty minutes and forty minutes. The results are shown in the following table. (Table I) In order to keep the liquid at a constant volume it was necessary to add the following amounts of water during cooking, 5a received 100 cc.; 5b received 186 cc.; 5c received 250 cc.; and 5d received 480 cc. In spite of this precaution there was a difference in the volume of the resulting juice. The residue was therefore, carefully washed with enough water to make the juice up to the required amount.

It is interesting to note that as the time of boiling is increased the specific gravity increased and the weight of the residue decreased. This apparently indicates a more extensive disintegration of the cell walls and more complete extraction of soluble material which is confirmed by further analysis.

It will be noticed that the specific gravity rises with the increased time of boiling, ranging from 1.0105 to 1.0153. The amount of total solids obtained when boiled ten minutes rather than five minutes, only .0030 grams, a small increase when boiling forty instead of twenty minutes, (.0062 grams) but there is a more decided increase when boiled twenty minutes instead of ten minutes, (.0140 grams). This would seem to indicate that most of the solids are extracted in the first twenty minutes of boiling. In other words, the average amount of solids in 10 cc. of juice by 5 or 10 minutes boiling is .2688 grams, and by 20 to 40 minutes boiling .3458 grams, which is equal to an increase of 28 percent. Again too, it should be noted that the greater part of this increase occurs in the twenty minute period.

Table I.

Effect of Increased Time of Boiling on the Composition of Fruit Juices

(Basis: one gram of fruit yields one cc. juice.)

Exp. No.	Method	Time of Boiling min.	Amount of Juice Extracted cc.	Weight of Residue gms.	Specific Gravity	Ph	Weight in Grams			Percentage		
							Solids in 10 cc.	Pectin in 10 cc.	Acid per cc.	Solids %	Pectin %	Acid %
4a	Continuous	5	54	100.7	1.0105	3.0	.2658	.0187	.00855	2.6	.185	.846
4b	"	10	59	96.6	1.0108	3.0	.2718	.0204	.00054	2.8	.2018	.540
4c	"	20	79	95.0	1.0147	3.0	.3398	.0260	.0055	3.36	.256	.650
4d	"	40	70	76.8	1.0153	3.0	.3518	.0186	.00756	3.46	.183	.744

Table II

The second experiment was made to determine the specific gravity, acidity, amount of solids and the pectin content of cranberry juice from eight hundred grams of berries. The time of boiling is the same as that of the preceding experiment. However, the total length of time during which the fruit was in contact with the juice was greater because of the time required to raise the larger mass to the boiling point.

The results show that the specific gravity rises with the extended time of boiling. Those juices boiled ten and twenty minutes are practically the same in the amount of solids present as represented by the specific gravity. This is also borne out in the total solids determination, thus, 5b has .2124 grams per 5 cc. of juice and 5c has .2125 grams. The amount of pectin in 10 cc. steadily increases with the length of time of boiling, however the difference between that boiled twenty minutes and that boiled forty minutes is greater than the difference between any of the others. The amount of acid also increases, but the increase is slight. The largest increase being, again as in the pectin, between that boiled twenty and forty minutes.

Table II.

Effect of the Time of Boiling on the Composition of Fruit Juices Obtained from 800 grams of Berries.

Exp. No.	Method	Time of Boiling min.	Amount of Juice Extracted cc.	Weight of Residue gms.	Specific Gravity	Ph	Weight in Grams			Percentage		
							Solids in 10 cc.	Pectin in 10 cc.	Acid in 1 cc.	Solids %	Pectin %	* Acid %
5a	Continuous	5	612.	716.5	1.0156	2.8	.3548	.0454	.009225	3.53	.447	.908
5b	"	10	769.	694.5	1.0190	2.8	.4248	.0546	.00945	4.16	.535	.925
5c	"	20	810.	683.	1.0199	2.8	.4250	.0615	.00995	4.18	.603	.975
5d	"	40	990.	607.	1.0218	2.8	.4926	.0755	.011325	4.82	.739	1.108

Table III

Table III gives a comparison of the results obtained when extracting juice from small, (100 gms.) and large (800 gms.), quantities of fruit. The specific gravities differ decidedly. Juice from the one hundred grams in every case have a lower specific gravity than that extracted under similar conditions using eight hundred grams of fruit.

The percents of total solids present are also lower in every case when extracted from the smaller quantity, as is the percent of pectin and acid. This is probably due to the fact that it took a longer time to heat the eight hundred grams of cranberries to the boiling point, than it did the one hundred grams. Probably substances were being extracted during this pre-boiling period.

The total length of time during which the water and fruit are in contact is apparently one of the most important factors. In later experiments this pre-boiling period was noted and found to be from ten to twelve minutes.

Table III

Comparison of the Amount of Solids, Pectin and Acid Obtained from 100 and 800 grams of Cranberries.

Exp. No.	Time of Boiling min.	Weight of Berries gms.	Specific Gravity	Ph	Weight in Grams			Percentage		
					Solids in 10 cc.	Pectin in 10 cc.	Acid in grams	Solids %	Pectin %	Acid %
4a	5	100.	1.0105	3.0	.1329	.0187	.00855	2.6	.185	.876
5a	5	800.	1.0156	2.8	.1794	.0454	.009225	3.53	.447	.908
4b	10	100.	1.0108	3.0	.1359	.0204	.000546	2.68	.2018	.540
5b	10	800.	1.0190	2.8	.2124	.0546	.00945	4.16	.535	.925
4c	20	100.	1.0147	3.0	.1699	.0260	.0066	3.36	.256	.65
5c	20	800.	1.0199	2.8	.2125	.0615	.00995	4.18	.603	.975
4d	40	100.	1.0153	3.0	.1759	.0186	.00756	3.46	.183	.744
5d	40	800.	1.0218	2.8	.2463	.0756	.011325	4.82	.739	1.108

Table IV

Table IV shows the results of experiment four which is the second extraction from the fruit numbered 5a, b, c, d. Half of the fruit left from that experiment was used, the other half being reserved for experiment 12. In 5a there was 370 gms. pulp, 5b, 361 gms., 5c, 341.5 and 5d 289.5. Each pulp was boiled for the same length of time as in the preceding experiment. That is, the five minute pulp was boiled another five minutes, the ten minute a second ten minutes, etc. The extracted juice was measured and the specific gravity, total solids, acidity and pectin content determined.

The specific gravity of this second extraction is much lower than that of the first extraction. This is also true of the solids, pectin and acid present. This is to be expected since much of the soluble material had been extracted in the first process. The longer the pulp was cooked the more solids in the juice, is true of this extraction as well as of the first. One might expect 5d which was cooked the longest in the first extraction might show less solid present than a pulp which had not been cooked so long in the preceding extraction.

There is a greater increase in solids

extracted, between the twenty and forty minute periods than between any other two. There is also a greater increase in acid and pectin in the forty minute period over the twenty minute than between any other two extractions.

Table IV

Effect of Increased Time of Boiling on the Composition of Fruit Juice Obtained from a Second Extraction.

(Basis: one gram of pulp yields one cc. juice.)

Exp. No.	Method	Weight of Pulp gms.	Time of Boiling min.	Amount of Juice Extracted cc.	Weight of Residue gms.	Specific Gravity	Ph	Weight in Grams: Solids in 10 cc.	Weight in Grams: Pectin in 10 cc.	Weight in Grams: Acid per cc.	Percentage: Solids %	Percentage: Pectin %	Percentage: Acid %
$5a_1$	Successive	370.	5	340.	278.5	1.0085	2.8	.1886	.0236	.00435	1.87	.234	.431
$5b_1$	"	361.	10	314.	273.5	1.0085	3.0	.1980	.0290	.00435	1.96	.287	.431
$5c_1$	"	341.5	20	376.	246.	1.0102	3.0	.1994	.0312	.004545	1.99	.309	.453
$5d_1$	"	289.5	40	238.	268.5	1.0109	3.0	.2316	.0412	.00525	2.29	.407	.519

Table V

Table V, shows the results obtained from the third extraction of pulps 5a,b,c,d. The pulp was the same as that used in the preceding experiment. The volume by weight of pulp and water were equal. If there were 246.6 grams of berries, then 246.6 cc. of distilled water were used. An attempt was made to keep the water level the same during the cooking. The weight of the residue was taken as in the other experiments. It was found that the longer the pulp had been on the stove the smaller the weight of the residue. Determinations of specific gravity, acidity, pectin content and total solids were made.

The results show that in this extraction the ppecific gravity is greater as the time of cooking decreased. The juice which was cooked five minutes had a higher specific gravity than the one cooked forty minutes. This is what would be expected for the juice booked five minutes this time had, in all three successive extractions been cooked only fifteen minutes. The ten minute pulp had been cooked thirty minutes; the twenty minute, forty minutes; and the forty minutes a hundred and twenty minutes or two hours. This is confirmed by the decrease also, in total solids and acid. The solids and pectin decrease in the first three extractions but increase in $5d_2$ instead of decreasing.

Table V.

Effect of Increased Time of Boiling on the Composition of Fruit Juice Obtained from a Third Extraction.

Ext. No.	Method	Time of Boiling min.	Amount of Juice Extracted	Weight of Residue	Specific Gravity	pH	Weight in Grams			Percentage		
							Solids in 10 cc.	Pectin in 10 cc.	Acid per cc.	Solids %	Pectin %	Acid %
$5a_{12}$	Successive	5	231	163.7	1.0093	3.0	.1958	.0329	.003975	1.95	.365	.393
$5b_{12}$	" "	10	237	165.4	1.0081	3.0	.1688	.0241	.0033	1.67	.239	.327
$5c_{12}$	" "	20	332	112.4	1.0074	3.0	.1512	.0248	.002925	1.50	.246	.290
$5d_{12}$	" "	40	230	95.0	1.0071	3.0	.1614	.0278	.002925	1.60	.276	.290

Table VI.

Table VI summarizes the solids obtained from the three extractions, boiling for the four different lengths of time, that is for five, ten, twenty, and forty minutes. More solids are obtained as the time of boiling is continued, but the amount of increase is not as great as might be expected. For instance, boiling a pulp for five minutes, three different times gives over 70% as much solids as boiling forty minutes three different times. The percentage of solids present increases with increased boiling in the first and second extractions, but decreases with increased boiling in the third extraction, indicating that the pulp was being exhausted. The weight of the remaining pulp decreases with increased boiling time. This would be expected. In extractions one and two the specific gravity rose as the weight of the remaining pulp decreased, showing that there were more solids in the juice with decrease in amount of pulp, but of the third extraction the specific gravity decreased as the weight of the remaining pulp decreased.

Escept for 5a, there is a decrease in specific gravity with each extraction. That is, 5b has a higher specific gravity than $5b_1$, and the latter higher than $5b_{12}$. This shows that the amount of solids extracted is not the same for equal lengths of boiling time. The first five minutes extracts more solid matter than the second, five minutes. The first ten minutes gives more solid than the second ten minutes, et cetera. So the percentage of solid extracted is inversely proportioned to the length of time of cooking.

Table VI

Relative Amounts of Solids in Successive Extractions.

Ext. No.	Method	Yield of Juice cc.	Specific Gravity Westphal	Time of Boiling min.	Total Solids: Grams in 10.cc.	Total Solids: Percent	Total Solids: Solids in Total Yield	Total Solids: Grand Total	Solids per 100 gms. of Fruit
5a	Successive	800	1.0156	5	.3588	3.53	28.68		
5a$_1$	" "	370	1.0085	5	.1886	1.87	6.97		
5a$_{12}$	" "	271	1.0093	5	.1958	1.95	4.21	34.86	4.35
5b	Successive	800	1.0190	10	.4248	4.16	34.01		
5b$_1$	" "	361	1.0085	10	.1980	1.96	7.13		
5b$_{12}$	" "	246	1.0081	10	.1688	1.67	4.14	45.28	5.66
5c	Successive	800	1.0199	20	.4250	4.18	34.11		
5c$_1$	" "	341	1.0093	20	.1994	1.99	6.84		
5c$_{12}$	" "	233	1.0074	20	.1512	1.50	3.50	44.39	5.54
5d	Successive	800	1.0218	40	.4926	4.82	39.40		
5d$_1$	" "	289	1.0109	40	.2316	2.29	6.40		
5d$_{12}$	" "	226	1.0071	40	.1614	1.60	3.64	49.73	6.21

Table VII.

Table VII shows the relative amounts of pectin and acid from the successive extractions of group five.

It will be noticed that there is a steady increase in the amount of pectin extracted as the time of boiling increases. There is practically the same amount of increase in solids between the five and ten minute periods and between the ten and twenty minute periods, respectively.500 grams and .583 grams, but between the twenty and forty minute periods there is a much larger gain, that is 1.289 grams.

In comparing the amount of pectin received from the different boiling periods, it is noticed that the pectin received from the three extractions of 5b is .0058 grams greater than 5a; that 5c is .0098 grams greater than $5b_1$, and that 5d contains .0277 grams more than 5c. In the same manner the amount of acid from the combined extractions of the like boiling periods increases with increased boiling, except for 5a, which is probably due to an error. So in studying the combined extractions, it seems that the highest percentage ofmpectin is obtained in the forty minutes period. The increase in the forty minutes over the twenty is greater than the increase between any of the other periods. This is also true of the acid, the highest percentage obtained is that of the forty minute boiling.

Table VII

Relative Amounts of Pectin and Acid in Successive Extractions.

Ext. No.	Method	Time of Boiling min.	Specific Gravity	Pectin: Gms. in 10 cc.	Pectin: Per cent	Pectin: Pectin in total Yield	Pectin: Grand Total	Pectin per 100 gms. Fruit	Acid: Acid in 10 cc.	Acid: Per cent	Acid: Acid in Total Yield	Acid: Grand Total	Acid per 100 gms. Fruit
$5a$	Successive	5	1.0156	.0454	.447	3.63			.00922	.908	7.378		
$5a_1$	" "	5	1.0085	.0236	.234	.871			.00435	.431	1.605		
$5a_{12}$	" "	5	1.0093	.0329	.365	.998	5.499	.687	.003975	.393	1.075	10.058	1.232
$5b$	Successive	10	1.0190	.0546	.535	4.361			.00945	.905	7.377		
$5b_1$	" "	10	1.0085	.0290	.287	1.044			.00435	.431	1.57		
$5b_{12}$	" "	10	1.0081	.0241	.239	.594	5.999	.749	.0033	.327	.812	9.759	1.219
$5c$	Successive	20	1.0199	.0615	.603	4.91			.00995	.975	7.955		
$5c_1$	" "	20	1.0093	.0312	.309	1.093			.00454	.453	1.559		
$5c_{12}$	" "	20	1.0074	.0248	.246	..579	6.582	.822	.00292	.290	.683	10.197	1.274
$5d$	Successive	40	1.0218	.0756	.737	6.024			.011325	1.108	9.057		
$5d_1$	" "	40	1.0109	.0412	.407	1.192			.00525	.519	1.521		
$5d_{12}$	" "	40	1.0071	.0278	.276	.625	7.841	.980	.00292	.290	.660	11.238	1.404

Table VIII.

Table VIII is a summary showing the relative amounts of solids, pectin and acid per 100 grams of fruit. It also shows the amount obtained from each sample of a given quantity of juice. For example, 800 grams of berries which have been boiled for five minutes, yield 28.68 grams of total solids; 3.63 grams of pectin and 7.37 grams of acid. In other words, 800 cc. of this juice contains 28.68 grams of solid; 3.63 grams of pectin and 7.37 grams of acid. The total amount of these three constituents obtained from boiling the pulp three times is also given. So a comparison may be made with the following table which gives the amount of solid, pectin and acid obtained when the pulp is cooked the same length of time but for a continued period.

Table VIII

A Comparison of the Amount of Solids, Pectin and Acid Obtained from Successive Extractions of a Fruit Juice.

Exp. No.	Method	Time of Boiling min.	Specific Gravity	Yield of Juice	Solids: In Total Yield	Solids: Grand Total	Solids: Solids per 100 gms. fruit	Pectin: In Total Yield	Pectin: Grand Total	Pectin: Pectin per 100 gms fruit	Acid: In Total Yield	Acid: Grand Total	Acid: Acid per 100 gms fruit
5a	Successive	5	1.0156	800.	28.68			3.63			7.378		
$5a_1$	"	5	1.0185	370.	6.77			.871			1.605		
$5a_{12}$	"	5	1.0093	271.	4.21	34.86	4.35	.998	5.499	.687	1.075	10.058	1.232
5b	Successive	10	1.0190	800.	34.01			4.361			7.377		
$5b_1$	"	10	1.0085	361.	7.13			1.044			1.57		
$5b_{12}$	"	10	1.0081	246.	4.14	45.28	5.66	.594	5.999	.749	.812	9.759	1.219
5c	Successive	20	1.0199	800.	34.11			4.91			7.955		
$5c_1$	"	20	1.0093	341.	6.84			1.093			1.559		
$5c_{12}$	"	20	1.0074	233.	3.50	44.39	5.54	.579	6.582	.822	.683	10.197	1.274
5d	Successive	40	1.0218	800.	39.40			6.024			9.057		
$5d_1$	"	40	1.0109	289.	6.40			1.192			1.521		
$5d_{12}$	"	40	1.0071	226.	3.64	49.73	6.21	.625	7.841	.980	.660	11.238	1.404

Table IX.

Table IX shows the amount of pectin, acid, total solids and the specific gravity of cranberry juice extracted from four hundred grams of cranberries, by the continuous method, using the same length of time as the sum of all the periods for the first, second and third extractions. That is 6a (total time 15 minutes) is to be compared with 5a and $5a_1$ plus $5a_{12}$ in each of which the boiling period is five minutes.

There is a steady increase in the amount of solids, with an increase in the time of boiling. This is true also of the pectin and acid content. However, the increase is not directly proportional to the length of time. For instance, the pulp boiled one hundred and twenty minutes has only a little over twice as many grams of solids as the one boiled fifteen minutes, instead of eight times as much, though it was boiled eight times as long. There is a greater difference between the thirty minute and the sixty minute extractions than between any other successive steps. That is between the fifteen and thirty minute there is a gain of .0213 grams of solids; between thirty and sixty minutes, .0862 grams and between sixty and one hundred and twenty a gain of .0694 grams.

In comparing the one hundred and twenty minute and the sixty minute extractions we find that the last sixty minutes of the one hundred and twenty minutes extracts only .085 grams of solids per 5 cc. of juice.

Table IX

Effect of the Time of Boiling on the Composition of Fruit
Juices Obtained from 400 grams of Berries.

Exp. No.	Method	Time of Boiling min.	Amount of Juice Extracted	Weight of Residue	Specific Gravity	pH	Weight in Grams			Percentage		
							Solids in 10 cc.	Pectin in 10 cc.	Acid in 1 cc.	Solids %	Pectin %	Acid %
6A	Continuous	15	272.	245.1	1.0124	2.8	.2780	.0161	.0068	2.72	0.159	.672
6B	" "	30	214.	265.2	1.0152	2.8	.3206	.0648	.00855	3.15	0.638	.842
6C	" "	60	365.	208.5	1.0239	2.8	.5130	.0931	.01065	5.01	0.9092	1.040
6D	" "	120	490.	176.6	1.0297	2.8	.6518	.1413	.01342	6.32	1.275	1.285

Table X.

Table X represents the results of boiling eight hundred grams of cranberries for fifteen, thirty, forty and one hundred and twenty minutes. This was a continuous extraction, the time being the sum of the periods used in the three extractions of experiment 5a, b, c, and d.

It was found that the specific gravity increased as the time of boiling increased. The amount of total solids and acid also increased. It was also noticed that after the first thirty minutes, the amount of solids extracted was not enough to warrant the extra time used. The greatest amount of solids are extracted during the first fifteen minutes, namely .3546 grams per 10 cc. With an added fifteen minutes of boiling .0514 grams per 10 cc. are extracted and with thirty minutes .0094 grams per 10 cc. are extracted. This shows that the amount extracted after the first fifteen minutes is exceedingly slight and does not pay for the extra cooking.

The pectin extracted runs quite similar to this. Most of the pectin is extracted during the first fifteen minutes, namely .0468 grams per 10 cc. of juice; in the next fifteen minutes .0168 grams are extracted and in the last sixty minutes .0203 grams per 10 cc. are extracted.

The acid is irregular, for from a pulp boiled thirty minutes, more is extracted than from that boiled sixty minutes or fifteen minutes. This may be due to the fact that all acids do not boil out of a pulp at the same time. Some acids may be harder to extract than others, hence our varying content.

Table X.

Effect of the Time of Boiling on the Composition of Fruit Juices Obtained from 800 grams of Berries.

Exp. No.	Method	Time of Boiling min.	Amount of Juice Extracted	Weight of Residue	Specific Gravity	pH	Weight in Grams			Percentage		
							Solids in 10 cc.	Pectin in 10 cc.	Acid in 1 cc.	Solids %	Pectin %	Acid %
7A	Continuous	15	564	554	1.0158	2.6	.3546	.0468	.00855	3.49	.460	.849
7B	" "	30	654	447	1.0177	2.6	.4060	.0636	.01005	3.98	.625	.987
7C	" "	60	663	475	1.0185	2.6	.4152	.0677	.00945	4.07	.664	.927
7D	" "	120	850	421	1.0221	2.6	.4756	.0880	.010275	4.60	.860	1.005

Table XI.

Table XI gives a comparison of the results obtained when four hundred and eight hundred grams of cranberries are boiled for fifteen, thirty, sixty and one hundred and twenty minutes.

For the long boilings, that is, sixty or one hundred and twenty minutes, the specific gravity of the four hundred gram extractions are higher than the eight hundred grams, while the specific gravity for the fifteen and thirty minute extractions are greater for the eight hundred gram extractions and less for the four hundred gram extractions. The grams of total solids are greater in the four hundred tnah for the eight hundred in the longer boiling periods, but in the shorter lengths of time there is less in the four hundred than eight hundred gram extractions. Again, there is more acid in the small extractions for the longer periods of time than in the large extractions. The large quantities have more acid extracted during the fifteen and thirty minute periods than do the small ones.

The inconsistencies shown between 6c and 7c, and between 6d and 7d as compared with 6a and 7a, and 6b and 7b, cannot be explained. It is possible that there might be some variations in the sample of fruit used, although every precaution was taken to eliminate this error. The determination of pectin and acid would seem to indicate that there was no error in the determination of total solids.

Table XI.

Comparison of the Amount of Solids, Pectin and Acid
Obtained from 400 and 800 grams of Cranberries.

Exp. No.	Time of Boiling min.	Weight of Berries gms.	Specific Gravity	pH	Weight in Grams			Percentage		
					Solids in 10 cc.	Pectin in 10 cc.	Acid per gm.	Solids %	Pectin %	Acid %
6a	15	400	1.0124	2.8	.2780	.0161	.0068	2.72	.159	.672
7a	15	800	1.0158	2.6	.3546	.0468	.00855	3.49	.460	.849
6b	30	400	1.0152	2.8	.3206	.0648	.00855	3.15	.648	.842
7b	30	800	1.0177	2.6	.4060	.0636	.01005	3.98	.625	.987
6c	60	400	1.0239	2.8	.5130	.0931	.01065	5.01	.9092	1.040
7c	60	800	1.0185	2.6	.4152	.0677	.00945	4.07	.664	.927
6d	120	400	1.0297	2.8	.6518	.1413	.01342	6.32	.1275	1.206
7d	120	800	1.0221	2.6	.4706	.0880	.010275	4.60	.860	1.005

Table XII.

Table XII gives a comparison of the amount of solids, pectin and acid per 100 grams of fruit if boiled for 5, 10, 20, and 40 minutes in 100, 400 and 800 gram quantities.

Results show an increase in the amount of these substances obtained from the three lots. The largest amount of solids, acid and pectin, with the exception of one case, is obtained from the longest boiling period. The increase in the forty over the twenty minute period is probably not enough to warrant the extra time, especially is this so in group four and seven. It seems that with 100, and 400 gram quantities, the largest percent of material is extracted within the first twenty minutes, though more is extracted with longer boiling, it is not enough to pay for the extra time. This is not true of the 800 gram quantities, which extract more between the twenty and forty minute periods than between any of the others.

With the acid, the highest percent of increase between the different extractions in group four is the forty minute over the twenty minute, but the gain in only .0850 grams of acid per 100 grams of fruit so there is not enough to warrant the extra twenty minutes of boiling. A similar thing is true of the sixth group. The greatest percent of gain is forty minute over the twenty but it is only .0490 grams per 100 grams of fruit so does not pay for the extra time. The acid of the seventh group is irregular, the pulp boiled ten minutes having greater acid than that boiled five minutes, and also greater than that boiled twenty minutes. This was not true of the other 800 gram extractions. In it the acid extracted gradually increased with the increased time of boiling. The greatest percent of increase being, as in the 100 and 400 gram extractions, in the forty minute extraction. Most of the acid is extracted however, in the first five minutes. The amount gained by continued boiling is very slight. For instance, in group six, .6802 grams of acid per 100 grams of fruit are cooked out in the first five minutes; .1746 grams more are cooked out in the second five minutes, and only .2100 grams more are cooked out in the next ten minutes, and .2592 in the next twenty minutes.

Table XII.

Showing Amount of Solids, Pectin, and Acid per 100 Grams of Fruit.

Exp. No.	Method	Time of Boiling min.	Specific Gravity	Yield of Juice cc.	Solids		Pectin		Acid	
					In Total Yield	Solids from 100 gms. Fruit	In Total Yield	Pectin per 100 gms. Fruit	In Total Yield	Acid per 100 gms. Fruit.
4a	Continuous	5	1.0105	100	2.657	2.657	.0187	.1869	.8546	.8546
4b	"	10	1.0108	100	2.70	2.70	.0204	.2031	.5485	.5485
4c	"	20	1.0147	100	3.390	3.390	.0260	.2596	.6595	.6595
4d	"	40	1.0153	100	3.512	3.512	.0186	.1859	.8560	.8560
6a	Continuous	5	1.0124	400	11.09	2.772	.0161	.1359	2.721	.6802
6b	"	10	1.0152	400	12.79	3.197	.0641	.6475	3.419	.8548
6c	"	20	1.0239	400	20.55	5.132	.0931	.9305	4.259	1.0648
6d	"	40	1.0297	400	26.07	6.265	.1413	1.2780	5.292	1.3240
7a	Continuous	5	1.0158	800	28.364	3.540	.0468	.4172	6.899	.8627
7b	"	10	1.0177	800	32.403	4.050	.0636	.6360	8.035	1.004
7c	"	20	1.0185	800	33.248	4.156	.0677	.6745	7.543	.9828
7d	"	40	1.0221	800	38.022	4.752	.0880	.8791	8.217	1.0270

Table XIII.

Table XIII gives a comparison of the amount of solids, pectin and acid extracted from 100, 400 and 800 grams of berries boiled five, ten, twenty and forty minutes, or fifteen, thirty, sixty and one hundred and twenty minutes.

It will be noticed that there is an increase of pectin, solids and acid with increase, time of boiling as well as increased amount of berries used.

In the solids of group four, there is a greater increase between the ten and twenty minute extractions than between any other successive extractions of this group. This is also true of the solids in group six. The smallest increase is between the five and ten minute group. The greatest is between the ten and twenty minutes. This is not true of the solids of group seven for here it is noticed that the smallest increase is between the ten and twenty minute groups. The increase between five and ten and between twenty and forty are practically the same. That is between the ten and twenty the increase in .845 but between five and ten and twenty and forty it is 4.623 and 4.774 respectively.

It is found that the average percent of increase of the solids obtained from 400 grams of fruit over that of 100 grams of fruit is 18.76% while that of 800 grams over 400 grams is 52.24%. The increase of 7a and 7b is 39% each, while that of 7c and 7d is 61 and 68% respectively. So there is a greater percentage of increase in that boiled twenty and forty minutes than that boiled five and ten minutes.

The increase in pectin in four a,b,c, and d, is similar to that of the solids in this group. In group six the greatest increase seems to be between the five and ten minute groups, the increase between the ten and twenty and forty being similar. In group seven the increase in pectin is like that of the solids. The smallest increase being between the ten and twenty minute groups and practically the same amount of increase obtained between the five and ten minute groups and the twenty and forty minute groups.

There seems to be a greater percent of increase of solids between the 400 and 800 gram extractions than between the 100 and 400 gram extractions. The amount of increase of pectin within the group is similar to that of the solids.

The percent of acid steadily increases in each group with the different lengths of time of boiling. There are two exceptions however, 4a, is higher than 4b, instead of being smaller. In group seven the juice pulp boiled twenty minutes has less acid than that boiled ten minutes, instead of more. These differences may be due to the theory that some acids are extracted more readily thn others

Table XIII.

Comparison of Solids, Pectin and Acid Obtained
from 100, 400, and 800 grams of Berries.

Exp. No.	Time of Boiling	Yield	Specific Gravity	Solids			Pectin			Acid		
				Gms. in 10 cc.	Percent	Solids in Total Yield	Gms. in 10 cc.	Percent	Pectin in Total Yield	Gms. in 10 cc.	Percent	Acid in Total Yield
	min.	cc.										
4a	5	100	1.0105	.2658	2.67	2.657	.0187	.185	.1869	.0855	.846	.8546
4b	10	100	1.0108	.2718	2.68	2.70	.0204	.2018	.2031	.00546	.540	.5485
4c	20	100	1.0147	.3398	3.341	3.390	.0260	.2560	.2596	.066	.650	.6595
4d	40	100	1.0153	.3518	3.460	3.512	.0186	.1830	.1859	.0756	.744	.8560
6a	15	400	1.0124	.2780	2.74	11.09	.0161	.159	.6438	.068	.672	2.721
6b	30	400	1.0152	.3206	3.15	12.79	.0648	.638	2.5900	.0855	.842	3.419
6c	60	400	1.0239	.5130	5.02	20.55	.0931	.9092	3.7220	.1065	1.040	4.259
6d	120	400	1.0297	.6518	6.33	26.07	.1413	1.275	5.1120	.1342	1.285	5.292
7a	15	800	1.0158	.3546	3.543	28.364	.0468	.460	3.738	.0855	.849	6.899
7b	30	800	1.0177	.4060	3.987	32.403	.0636	.625	5.088	.1005	.987	8.035
7c	60	800	1.0185	.4152	4.086	33.248	.0677	.664	5.410	.0945	.927	7.543
7d	120	800	1.0221	.4756	4.65	38.022	.0880	.860	7.033	.10275	1.005	8.217

SUMMARY.

For the study of the effect of methods of extraction on the quality of cranberry juice, equal portions by weight of fruit and distilled water were used. The portions of fruit weighed, in different series, respectively, 100 grams, 400 grams, and 800 grams. The lengths of the boiling periods were, five, ten, twenty, and forty minutes for most of the experiments in which successive extractions were made, and fifteen, thirty, sixty, and a hundred and twenty minutes in those using the continuous method.

Specific Gravity.

That the specific gravity increases directly with the length of time of boiling is shown by the following figures:

Time of Boiling min.	Serial No.	Minimun Specific Gravity	Serial No.	Maximun Specific Gravity
5	4a	1.0105	5a	1.0156
10	4b	1.0108	5b	1.0190
15	6a	1.0124	7a	1.0158
20	4c	1.0147	5c	1.0199
30	6b	1.0152	7b	1.0177
40	4d	1.0153	5d	1.0218
60	7c	1.0185	6c	1.0239
120	7d	1.0221	6d	1.0297

In general, the higher specific gravities were obtained when larger quantities of fruit were used, although there are some inconsistencies which could not be explained unless they were due to variations in the quality of the fruit sample. This view is supported by the fact that each series within itself is consistent and confirms the statement that increase in time of boiling, other conditions being equal, increases the specific gravity of the resulting juices.

Jelly has been made with cranberry juice as low as 1.010 Sp.g.; a specific gravity of 1.015 has been preferred by others (Stoker). Above this, the juice seems to be too concentrated for best results. From the above data it would seem desirable to boil for 15 to 20 minutes for a one-pound lot or for from 5 to 15 minutes for a two-pound lot.

Total Solids.

As is to be expected, the total solids also increased with the length of time of boiling and follow the same curve as the specific gravities.

Time of Boiling min.	Minimun %	Maximun %
5	2.67	3.53
10	2.68	4.16
15	2.74	3.54
20	3.34	4.18
30	3.15	3.97
40	3.46	4.82
60	4.09	5.02
120	4.66	6.33

A few inconsistencies appear here as in the specific gravities and are probably to be explained on the same grounds. The experiments indicated that the largest precent of solids obtained is extracted in the first five or ten minutes. The additional amount obtained by increased boiling is small. From the 100 and 400 gram extractions the percent of increase was very slight after the first twenty minutes boiling. In the 800 gram extraction boiled 5, 10, 20, and 40 minutes the greatest percent of increase in total solids was obtained when the pulp was boiled forty minutes instead of twenty minutes as in the former amounts. In the 800 gram extractions which were boiled 15, 30, 60, and 120 minutes the greatest amount of solids extracted was during the first fifteen minutes, however the largest percent of increase was obtained when the pulp was boiled 120 minutes.

The percent of total solids obtained per 10 cc of juice was lower when extracted from small quantities of fruit such as 100 or 400 grams than from a large quantity such as 800 grams. Four hundred grams of fruit gave 18.70% more solids than does 100 grams boiled for the same lengths of time with the same proportions of water and fruit. Eight hundred grams gave 52.24% more solids than does 400 when treated under the same conditions. This is probably due to the fact that it takes longer for the larger quantity to heat to the boiling temperature and substances are being extracted during this pre-boiling period which is 10 to 12 minutes.

The amount of solids extracted is not the same for equal lengths of time of boiling for much more is extracted in the first five minutes than in the second five minutes, and so on with the other extractions. The decrease in amount of solids obtained with continued boiling is not protportional to the length of time of boiling, that is, the proportional amount of solids obtained from a juice boiled twenty minutes instead of ten minutes may not be the same as that boiled thirty or forty minutes.

Solids in Successive Extractions.

In the above section the data presented has dealt with the first extraction only. When a second extraction is made, it is found that there is a marked decrease (about 50%) in the amount of total solids found in the juice. There is a similar decrease in the third extraction.

Pectin.

In studying the pectin content of a juice it was noticed that the amount of pectin obtained by the different extractions followed the same trend that the solids took, that is, extractions giving increased solids also gave increased pectin. This would be expected for pectin is part of the solid material extracted.

The greatest percent of pectin is extracted in the first ten or fifteen minutes of boiling. This is true of the 100, 400, and 800 gram quantities. For those juices boiled 5, 10, 20, and 40 minutes, ten minutes are best and of those boiled 15, 30, 60, and 120 minutes, fifteen minutes is optimum.

There is an increase in pectin with increase in the time of boiling. After the first 10 ot 15 minutes when most of the pectin is extracted the largest additional amount is extracted during the forty or one hundred and twenty minute periods. For instance, in group seven, the largest amount of pectin (.0468 grams per 10 cc) is extracted during the first fifteen minutes. During the second 15 minutes .0168 grams per 10 cc are extracted, during the following thirty minutes .0041 grams per 10 cc are extracted and in the last sixty minutes .0203 grams per 10 cc are extracted. The amount of pectin obtained after the first 15 minutes is not enough to warrant the extra time of boiling. The longer the pulp is boiled the more pectin obtained but after a certain length of time, added boiling is not economical.

In a third extraction of a fruit juice there is a decrease in pectin with increase in boiling time. This is due, of course, to the fact that the pulp boiled the shorter lengths of time have the larger percent of pectin left in them, so with each extraction there is a decrease in the amount of pectin obtained.

Acid.

Acid also makes up a part of the solid material found in the fruit juices. The amount of an acid obtained in these extractions ranged from .246% to 1.27% calculated as tartaric. The juices having the least acid were those of the third extractions, while those having the most were in juices extracted from larger extractions (800 grams) of fruit and boiling for 15, 30, 60, or 120 minutes. As a rule, there seems to be increased grams of acid with the increased amount of fruit. There are exceptions however, such as, in group seven, where the 10 and 40 minute boilings are higher in acid than the 5 and 20 minute. Also in group four, that boiled 40 minutes, has the same amount of acid as that boiled five minutes. There are different kinds of acids in fruits, perhaps some of them boil out more readily than others, thus causing these differences.

The largest percent of the acid is extracted during the first few minutes of boiling. For instance, in group five .00922 grams of acid per ten cc were extracted in the first 5 minutes, during the following 5 minutes .00024 grams per 10 cc were extracted, during the next 10 minutes .005 grams per 10 cc were extracted, and in the last 20 minutes .00137 grams per 10 cc were produced. This means that during the first five minutes .00184 grams of acid were being extracted per minute. In the second five minutes .000408 grams per minute, in the next ten minutes .0005 grams per minute, and during the last twenty minutes .000685 grams per minute. This shows that there is a steady increase in the amount extracted, with the length of boiling time.

The number of extractions made on a pulp also influence the amount of acid in the juice. As the number of extractions continue the amount of acid increases. For instance, "5c" contains .00995 grams of acid per 10 cc, the second extraction of this pulp contains .00454 grams per 10 cc and the third contains .00292 grams per 10 cc.

Hydrogen-ion Concentration.

The hydrogen-ion concentration of a juice seems to become greater as the quantity of fruit used, increases. Thus group four (400 grams) has a pH of 3.0; group six (400 grams) a pH of 2.8, and group seven (800 grams) a pH of 2.6.

In reference to successive extractions, it is observed that those pulps boiled the shortest time have the greatest pH. This may be due, in part to the length of the boiling period, but it is most probably due to the fact that the greatest percent of the acid comes out during the first five minutes of boiling. This was also true of the titratable acidity. So, it appears that we have a relatively higher percent of titratable acid and a higher pH with a short time of boiling than with a long time of boiling.

It has been observed that as the specific gravity of a juice increases, the time of boiling increases but the weight of the pulp decreases. This indicates an extensive integration of the cell walls and a complete extraction of soluble material.

Continuous versus Successive Methods of Extraction.

The greater efficiency of the successive method compared with the continuous by comparing the total amounts extracted from 100 grams of fruit by the two methods:

Total Yield per 100 grams of Fruit.

Time of Boiling	Solids		Pectin		Acid	
min.	Continuous	Successive	Continuous	Successive	Continuous	Successive
15	3.54	4.35	.417	.687	.863	1.232
30	4.05	5.66	.636	.749	1.000	1.219
60	4.15	5.54	.674	.822	.983	1.274
120	4.75	6.21	.879	.980	1.027	1.404

In every case the amounts of total solids and of pectin and acid are greater in totals extracted by the successive extraction method than by the continuous when the total time was the same ranging from a 22% increase in the shortest process to a 30% in the longest. A larger volume and a more dilute juice is secured by the successive method owing to the amounts of water necessary for the several extractions. The volume of the juice averaged about 50% more by this method.

The residues from the continuous extractions still contain enough flavor substances to make them desirable for use as a basis for jams and marmalades. The residue from the successive extractions is so exhausted as to have little value.

Significance of Specific Gravity.

The close relationship between the specific gravity and the solids, pectin and acid is shown in the following table:

(See next page)

Exp. No.	Specific Gravity	Percentage Solids %	Pectin %	Acid %	pH
4a	1.0105	2.60	.185	.876	3.0
4b	1.0108	2.68	.201	.540	3.0
6a	1.0124	2.72	.159	.672	2.8
4c	1.0147	3.34	.256	.65	3.0
6b	1.0152	3.15	.638	.842	2.8
4d	1.0153	3.46	.183	.744	3.0
5a	1.0156	3.53	.447	.908	2.8
7a	1.0158	3.54	.46	.84	2.6
7b	1.0177	3.99	.625	.987	2.6
7c	1.0185	4.09	.664	.927	2.6
5b	1.0190	4.16	.535	.925	2.8
5c	1.0199	4.18	.603	.975	2.8
5d	1.0218	4.82	.739	1.108	2.8
7d	1.0221	4.65	.860	1.005	2.6
6c	1.0239	5.02	.909	1.040	2.8
6d	1.0297	6.33	1.275	1.285	2.8

If the samples are arranged in three groups - indicating weak, medium and strong juices - it will be noticed that the percent of solids increases regularly with the increasing specific gravity. They follow the same curve. The pectin and acid also increase steadily, but in these there are a few inconsistencies.

The juice represented in the first group of this table would probably be too weak for making a very optimum jelly, the pectin especially, is very low. The juice of the last group is too concentrated for the best jelly, that of the middle group would be best.

CONCLUSIONS.

1. The longer the time of boiling a juice, the greater the grams of solids extracted but the less the percentage obtained per unit of time. In the first five minutes more solids are obtained per minute than in the second five minutes, et cetera.

2. When several extractions are to be made of the same pulp, boiling for ten minutes for each extraction is best, for the greatest percent of solids seems to be extracted this way.

3. When making a continuous extraction upon small quantities of fruit, that is, 100 or 400 grams, boiling for twenty minutes is optimum, for during this time the greatest percent of solids is obtained.

4. When making a continuous extraction upon a large quantity of fruit like 800 grams, boiling for thirty minutes is optimum. Boiling for one hundred and twenty minutes obtains more solids but the increase is so slight it does hot pay.

5. The greatest percent of pectin is extracted in the first ten or fifteen minutes of boiling. This is true of the 100, 400, and 800 gram quantities. After this first ten or fiftenn minutes the amount of pectin extracted is very

slight, but during the last 40 or 120 minutes (according to the series used) there is a more decided gain in the amount extracted. This suggests the possibility of a greater disintegration of the fruit pulp or a more complete transformation of pectose into pectin through prolonged boiling.

6. There is an increase in the acid with increase in the time of boiling but the greatest percent of acid per unit of time is extracted in the first five minutes. The grams of acid extracted per minute decreases with the time of boiling.

7. The specific gravity of a juice increaases with the time of boiling due to the fact that solids are being continually cooked out of the pulp. The percent of increase becomes smaller with increase d time of boiling.

8. As the specific gravity increases, the weight of the pulp residue decreases. This shows that there is more disintegration of the cell wall and that a larger percent of the solids has been extracted.

9. The specific gravity of cranberry juice is a guide to its chemical composition and may be used to indicate its suitability for jelly making.

10. A low specific gravity means a low percentage of substances essential for jelly making.

   a. The weakest group of juices ranging in specific gravity from 1.0105 to 1.0124 contained from .15 to .20% pectin and from 0.54% to 0.87%

acid.

b. The strongest group ranged in specific gravity from1.0177 to 1.0297 and contained from 0.625% to 1.27% pectin and from 0.987% to 1.285% acid.

c. The middle group ranged in specific gravity from 1.0147 to 1.0158 and contained from o.25% to 0.46% pectin and from 0.65% to 0.84% acid.

11. Those juices containing less than 0.46% pectin would be regarded as having too little for satisfactory results for jelly making. Those containing more than 0.86 probably have more than is necessary. This is within the limits set by Singh and Poore.

12. In all cases titratable acid was larger than the optimum (0.5%) recommended by most authors and in the greatest number of samples it was very greatly in excess of the amount.

13. The hydrogen-ion concentration, in all of the juices was too ~~low~~ high. It ranged from a pH of 3.0 to 2.6. Most authorities believe it should range from a pH of 3.1 to 3.56.

14. The two constants, pectin and acid, are probably the two most important substances in jelly making.

15. When a second extraction is made from a pulp it is found that the amount of solids present have decreased about fifty percent. There is a similar decrease in the third

extraction.

16. The amount of total solids, pectin and acid obtained in a juice is about 50% greater when extracted by the successive method rather than by the continuous method.

17. There is a very close correlation between the specific gravity of a juice and the total solids it contains. The percent of total solids increases as the specific gravity increases.

18. The percent of pectin and acid in a juice also increases with increased specific gravity but there is not as close a correlation as between the total solids and the specific gravity.

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