POTATO SUGAR AS A SWEETENER FOR SOME FOOD PRODUCTS

by

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INTRODUCTION

White potatoes (Solanum tuberosum) is one of the major crops in many countries of the world including the United States of America. Potatoes are either used for food as such or are transformed into processed products and by-products. (Whatever quality grade of the potatoes, they always contain one basic constituent, namely starch.) Three products are usually derived from this starch: syrup, dextrose, and dextrin. The starch and its three products are utilized either for food or for industrial products. Of the total amount of syrup distributed in any one year in the United States of America, 95 per cent or more is used for food, while the rest is utilized for non-food and industrial applications (7, p.27).

Starch conversion into glucose and syrup has been practices for more than a century. Kirchhoff (2) in 1811 was the first to produce glucose using potato starch as the raw material. It was afterwards produced from other starches and starch containing materials (2, p.318). Under ideal conditions, pure starch will be completely converted into glucose by acid hydrolysis. This indicates that glucose constitutes the sole building block for the starch molecule (12, p.632).

Starch conversion into syrup is a large industry today. A total of 2,580 million pounds of corn starch were converted into syrup and sugar in 1949 (7, p.15). The syrup is made by heating a mixture of starch and acid in closed tanks, called "convertors". The acid used in this process is usually hydrochloric acid; the same as found in the human stomach but in a different concentration. Two enzymes, alpha- and beta-amylase, have been used for the conversion process.

The author is a native of Lebanon, where sometimes there exists a surplus of agricultural products such as potatoes. Nothing has been done to utilize this surplus of potatoes. Lebanon also imports all the sugar needed for consumption by its people.

This investigation was undertaken as an attempt to produce a partially refined syrup from the starch of cull and surplus potatoes for the possible use as a partial substitute for sucrose in food industries existing in Lebanon.

REVIEW OF LITERATURE

Starch and starch syrups have been studied very extensively and a great volume of literature about them has been accumulated.

Starch Manufacture

Starch is commercially obtained from tubers such as potatoes; from cereals such as corn, wheat, and rice; from roots such as sweet potatoes; and from the pith of certain plants such as sago palm (2, p.1).

In general, roots and tubers with high contents of starch are crushed or broken up in order to open the cell walls and thus allow the starch granules to be liberated. The crushed material is then sieved and refined to remove impurities. The general steps in starch manufacture are summarized by Brautlecht (2, pp.50-122) and include: washing, grating, extraction of starch, refining, deaerating, drying, and milling. Dimler and coworkers (9) used centrifugation and tabling methods for starch separation. They found that the tabling process yields a prime quality starch fraction equivalent to 70-80 per cent of the starch in the wheat and a lower quality fraction, with 0.4 - 0.7 per cent protein, suitable for certain conversions for fermentation uses. The centrifuging process permits isolation of all the starch of the wheat flour in a single fraction with a protein content of 0.4 - 0.6 per cent.

Hydrolysis of Starch

A great number of methods have been used to hydrolyze starch. All the methods involve the breaking down of starch molecules into simple sugars. The choice of methods depends upon the practicalities in the different regions where hydrolysis is to be carried out. The methods most commonly used at the present time are those using high temperatures and acids as catalysts (5, 7), or those using enzymes (2). Infra red radiation (20) and supersonic waves (13) have also been used to produce satisfactory conversion.

The kind of acid used, its concentration, the temperature at which hydrolysis is carried out and the time of hydrolysis determine the rate of hydrolysis and the percentage conversion obtained. In a series of experiments x conducted at 100° C, using 0.1 N sulphuric or hydrochloric acid, Kryachlov (16) found that the catalytic activity of sulfuric acid is 56.5 per cent that of hydrochloric acid. Leman and Didry (17) using rice starch, found that when the starch was reacted with a determined volume of hydrochloric acid in different concentrations for one hour, the degree of hydrolysis of the starch reached a maximum of 97 per cent with one normal hydrochloric acid. They also found that the rate of hydrolysis decreased regularly in the presence of increased glucose concentration, and that the total hydrolysis required fifteen minutes with normal hydrochloric acid, 2.5 hours with 0.5 N hydrochloric acid, and 4 hours with 0.4 N hydrochloric acid.

Starch hydrolysis by enzymes such as amylase has been used very extensively. Starch is composed of amyloses and amylopectins (12, p.634) the first being considered as the linear components of the starch while the second are the highly branched and ramified components. It has been suggested (2) that the amyloses are broken down by the alpha-amylase and the amylopectins by beta-amylase. However, complete conversion is not obtained because of the presence of dextrins containing considerable amounts of phosphorous. Taylor and coworkers (21) reported that the temperature at which the starch substrate was prepared had a definite effect on the rate of amylase action.

Hydrolysis of starch has been accomplished by polarized infrared radiation. Semmens (20) found that polarized radiation passing through well washed potato starch hydrolyzed it to sugar.

Supersonic waves have been used to help in the hydrolysis of starch to sugar. Haissinsky and Prudhomme (13) reporting on the mechanism of chemical reactions produced by ultrasonic waves concluded that the predominance of oxidation reactions as a result of ultrasonics suggested that the mechanism was similar to that found with alpha rays, involving the formation of H, and OH radicals.

In acid hydrolysis the problem of discoloration of the solution becomes very important. Clendenning and Wright (5) reported that the intensification of color was at pH 4.5 - 5.0, and Englis and Hanahan (10) reported that, in the absence of sulfites, the degree of discoloration was mainly a pH effect. Deschreiber (8, pp.111-116) found that in syrups at pH 5.2 the color was most pronounced with glutamic acid, while double action occurred due to other amino acids in that they catalyzed the pyrolysis of glucose and formed more or less important nitrogen glycosides upon heating. Clendenning and Wright (5), in their work on starch syrups and their resistance to discoloration, reported that discoloration depended upon the storage temperature and the period of exposure to higher temperatures and that the proteins and amino acids promoted discoloration.

The presence of certain minerals influence the discoloration to a large degree. Deschreiber (8, pp.25-36) reported that a yellowish coloration in the absence of sulfur dioxide and copper was due to pyrolysis with the formation of (hydroxy methyl) furfural, and that browning occurred if glycine was present; any increase in copper up to 10 ppm augmented the color due to the furfural. At pH 4.0 - 5.0, in the presence of ammonia nitrogen, there was some browning with a reddish tint.

Decolorization of sugar solutions has been accomplished by using different reagents; carbon, diatomaceous earth, and synthetic resins (18, pp.278-310). Clendenning (4) found that the activity of carbon depended upon the method of manufacture. Acid-tempered bone char removed 99 per cent of the color while activated carbon removed only 20 per cent. Jacobs and Rawlings (15) used synthetic resins to remove the coloring materials from syrups. Freed and Hilbert (11) found that the amount of color removal, when using carbon as decolorizing agent, was a linear function of the amount of carbon added at all pH values they investigated.

For the neutralization of the acid used in hydrolysis, many compounds have been used. Sodium carbonate is the most extensively used compound (4); however resins are being used at the present time (18).

Contamination of the hydrolyzates with 1.6 per cent protein promoted foaming, turbidity and bitterness. The off-flavor was due mainly to ammonium chloride (5).

Sweeteners for Food Products

The U. S. Pure Food and Drug law requires that the amount of starch converted syrup cannot exceed 25 per cent of the total weight of sweeteners used in food products based on the dry weight of the sweeteners (22).

Since the manufacture of the two sugars, sucrose and dextrose, are in competition, there is some controversy as to the relative merits of each. Dextrose is advertised as the quick energy sugar, implies that dextrose, the sugar in blood, need not be digested before being absorbed in the blood stream.

According to Wiegand (23) the use of dextrose in the food industry is quite adaptable for canning because of the improvement it produces in the appearance and quality of the finished products, its physical and chemical structure, and its food value. The fruit becomes firmer when combined with dextrose than with sucrose. The lack of excessive sweetness in dextrose accounts for the improved flavor. Wiegand found that as the sweetness increased the true flavor of the fruit was decreased. Due to the structure of dextrose, with its low molecular weight, it was readily absorbed by the fruit tissue, thus preventing shrinkage which occurred when absorption was very low. The plumpness due to ready absorption of dextrose was increased and as a result the appearance was improved. Wiegand recommends the use of 1/3 of the sweetener as dextrose, though in some products the fraction could be raised up to 1/2 of the total sweetener added.

Sather and Wiegand (19) found that all samples that rated first in flavor, texture, and character were those containing 40 to 50 per cent corn syrup solids. The flavor was outstanding when used on raspberries, red sour pitted cherries, and loganberries. When used with apples, apricots, pears, and peaches the corn syrup imparted its characteristic brown color. Heyl (14), reporting about the suitability of different syrups according to their conversion percentages, found that the low conversion syrups (28-33 per cent) were not suitable for fruit canning because they lacked sweetness and had high viscosity. The medium conversion syrups (40-42 per cent) were satisfactory. The high conversion syrups (52-57 per cent) would have been extremely satisfactory were they not subject to the development of a bitter flavor, and possibilities of crystallization of dextrose when the acid conversion was carried too far.

According to Bruce (3) the manufacturers of jams and jellies were limited to the use of only 20 per cent dextrose because of excessive inversion, and the possibilities of having an overbalance of dextrose resulting in crystallization if the finished jam or jelly was stored too long before consumption. According to the same author the flavor-carrying power and flavor preserving and enhancing value of a syrup depended largely on the density or concentration of sugar in solution. In dealing with certain delicate flavors, such as is encountered in preserved fruits, a syrup of sufficient density to properly carry and preserve these flavoring substances sometimes carries a seasoning or sweetening value sufficient to mask the delicate fruit flavors. Theoretically, a sugar syrup that would produce the same density but have a low sweetness value would permit preservation of texture and provide sufficient solids in solution to carry flavors, and not mask but materially enhance the delicate flavors.

Many other sweeteners are used in the food industry but on a much smaller scale than those previously mentioned. These sweeteners include: lactose, maltose, honey, d-fructose, and corn syrup solids.

METHODS AND MATERIALS

A thorough review of literature revealed that many ways exist for converting starch into syrup. Acid hydrolysis with hydrochloric acid as a catalyst was selected for this work because hydrochloric acid is inexpensive, hydrolysis is rapid, and the method of conversion is relatively simple.

The potatoes used in this study were low grade surplus potatoes obtained through the Food Technology Department at Oregon State College. It was believed that these potatoes represent the surplus and low grade potatoes generally available.

Preparation of Starch

Initially, attempts were made to prepare syrup directly from raw potatoes, but it was found that the hydrolyzates were very difficult to purify because of the presence of fairly large amounts of proteins and minerals. In addition, it was found to be practically impossible to decolorize the hydrolyzates by removing the colored compounds which were formed from the proteins and other non-starch materials during the hydrolysis.

Further attempts were made to prepare syrup from cooked potatoes but similar difficulties were encountered. As a result, it was believed necessary to separate the starch from the potato and then prepare syrup from the relatively pure starch. In this manner, it was believed that the syrup would be relatively pure and free of the undesirable materials obtained by direct hydrolysis of potatoes.

Most tubers, especially those of low grade or quality, are usually contaminated with adhering soil. Therefore, it was found necessary to wash the potatoes. Drying was unnecessary since water was to be added during the disintegrating process and during the settling operation.

Approximately 250 pounds of potatoes were washed and disintegrated in a Fitzpatrick Mill. The mill was operated with the blunt edge of the blades as the leading edges.

Starch, being heavier than water, had a tendency to settle while the pulp (a mixture of cellulose, starch, protein, pectins, hemicellulose, etc.), being lighter than water tended to float over it.

A settling table was constructed for this study (Fig. 1). The starch was settled down over a long channel while the pulp was carried away with the running water. The settling table was 30 feet long. Two planks (3 inches by 4 inches) were placed 10 inches apart on top of the table to form a channel or trough from one end to the other.

To prevent the liquid from running out of the channel, it was necessary to line this channel with waxed paper. The table was inclined slightly making one end three inches higher than the other, thus forcing the starch slurry to flow in one direction. The slurry was allowed to flow from a 25 gallon tank placed at the high end of the table.

To prevent the starch from settling down and plugging the faucet of the tank, it was necessary to keep the contents of the tank agitated. This was conveniently accomplished by introducing, at the bottom of the tank, a stream of water strong enough to keep the contents of the tank agitated, yet not exceeding the amount of water coming out from the tank. This water was also needed to dilute the starch slurry in the tank and facilitate its passage through the faucet and eventually its settling on the table. A gradual build up of the starch at the start of the flume was observed, and gradually decreased till practically no starch could be found at the lower end.

After all the potato slurry was run through the faucet, and the starch settled on the table, the upper surface of the layer of starch was sprinkled with water to remove some of the impurities that settled on top of the starch. The waxed paper lining the channel, with the starch on it, was then placed in a tank and flushed with a stream of water to remove the starch. The starch so prepared contained some impurities such as grit, sand, and pulp. These

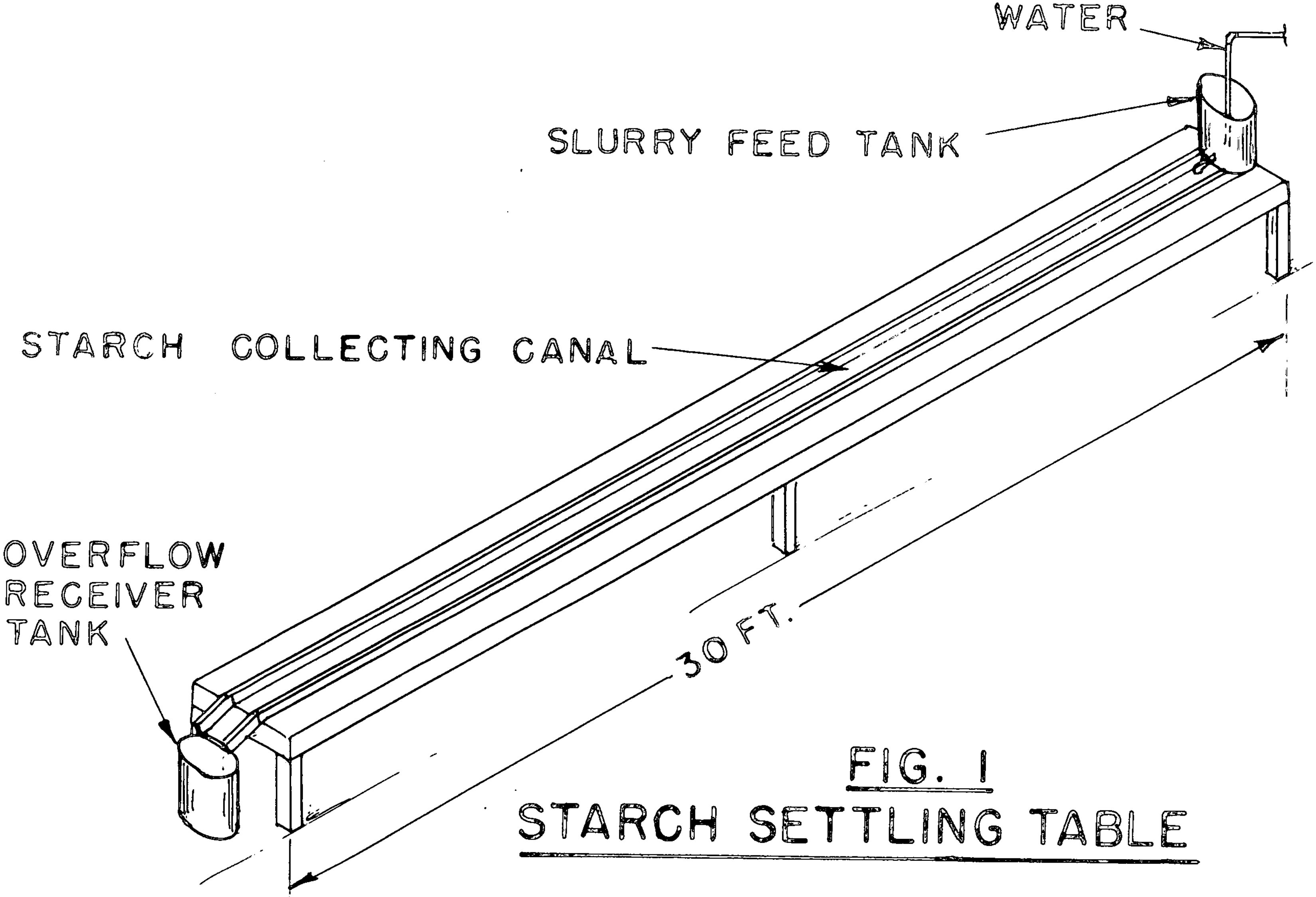

FIG. 1
STARCH SETTLING TABLE

impurities precipitated with the starch during the settling operation. To remove these impurities, the starch was run through a 200 mesh screen. Continuous shaking of the sieve and washing with running water was necessary to prevent the starch from settling down and plugging the screen. Washing the starch with more water after screening was found necessary to rid the starch from colored water that was produced by the action of the enzymes on the proteinaceous materials of the potatoes. Usually three washings were necessary.

After the third washing, the water was decanted and the starch was spread on 24 x 24 inch trays in 1-inch thick layers. To dry the starch, the trays were placed in a tunnel-type dehydrator at a temperature of 120°F. Air movement was regulated to prevent the starch from blowing off the trays after drying. Approximately 36 hours were necessary to dry the starch. After dehydration the starch was removed from the trays and stored in 10 pound cans with friction lids at room temperature.

Protein and moisture contents of the dry starch were determined using the Association of Official Agricultural Chemists methods (1, pp.12 and 493).

Acid Hydrolysis

Conversion of potato starch was carried out at 267 F. which was the maximum temperature obtainable with the available equipment. In each of several 400 ml beakers, 250 grams of 20° Baume' (100 grams of starch in 150 ml of water) starch solution were placed, 5 ml of 1 N hydrochloric acid (0.20 per cent on the dry weight basis of the starch) were added, thoroughly mixed to have the acid well distributed in the starch slurry, and the beakers placed in the convertor. The convertor was a small retort commonly used for canning. The beakers were covered with pyrex petri dishes to prevent contamination of the starch solution with foreign materials. The convertor was swept with steam and the pressure raised to 25 pounds per square inch, which corresponded to 267° F. The time of conversion was very critical in obtaining the correct dextrose equivalent (total amount of reducing sugars contained in the product, calculated as percentage of dextrose on dry basis) for the syrup made. At the end of the conversion period the beakers were removed very quickly and their contents transferred to a large vessel. The pH was adjusted to 5.0 - 5.1 with one normal sodium hydroxide because the literature reported that the isoelectric point of these protein impurities is at this pH (5) thus allowing easier removal of these impurities.

The hydrolyzates were then poured into 250 ml centrifuge bottles and centrifuged for 10 minutes at 1000 revolutions per minute to separate as much as possible the insoluble materials. The liquid was then decanted from the bottles, fresh 50 ml portions of distilled water were placed in the bottles and the contents shaken vigorously. Centrifugation was repeated to remove the syrup that had been adhering to the settled solids, the liquid was decanted and the solids were discarded. The centrifuged hydrolyzates were placed in a large container and 0.2 per cent decolorizing carbon based on the dry basis of the starch was added and stirred well to allow the syrup to come in contact with the carbon. The hydrolyzates were heated to 140° F. and kept at that temperature for two hours, after which they were filtered through Whatman No. 1 Filter Paper, and then through Whatman No. 30 Filter Paper. The second filtration was found necessary to remove some impurities which escaped the first filtration. The filter papers were washed with distilled water before filtration in order to wash away any off-flavor-imparting materials. The filtrates from the second filtration were white and ranged in concentration between 30-35° Brix as determined by a Zeiss refractometer.

The syrup was then concentrated under a vacuum of approximately 27 inches to a concentration of 77° Brix. The vacuum operation was used to prevent caramelization and flavor reversion that may have occurred at high temperatures. This high concentration of syrup prevented spoilage by microorganisms.

The syrup was analyzed for ash, sodium chloride, moisture content, and protein using the Association of Official Agricultural Chemists methods (1, pp.493, 532, 493, and 11).

Preparation of Jams, Preserves, and Fruit Juices Using the Syrup as a Partial Substitute for Sucrose.

Preliminary tests to determine the correct proportions of sucrose and potato syrup were determined. Strawberries, frozen with 4+1 fruit to sucrose were used to prepare the strawberry preserves. The proportions of sucrose and syrup on sugar solids basis used in the preliminary tests are shown in Table 1.

Table 1: Proportion of Sucrose and Syrup Used in Making Strawberry Preserves of Different Treatments in the Preliminary Tests.

Treatment No.	Parts of Sucrose (dry basis)	Parts of Syrup (dry basis)
1	4	1
2	3	2
3	2	3
4	1	4

These preserves were tasted by a panel of twelve judges to evaluate their flavor, using the form appearing on page 34. Treatments three and four were found undesirable while treatments one and two produced satisfactory products. Hence it was decided to prepare the different products using the concentration of sucrose and syrup as shown in Table 2.

Table 2: Proportions of Sucrose and Syrup Used in Preserves, Jams, and Orange Juice.

Treatment No.	Parts of Sucrose (dry basis)	Parts of Syrup (dry basis)
1	5	0
2	4	1
3	2	.1

Strawberry preserves, peach preserves, orange marmalade, orange juice, and blackberry jam were then prepared using the three treatments in each case.

Immediately after preparation the products were evaluated organoleptically for flavor by a panel of twelve tasters, and graded by an Agricultural Marketing Service inspector as well as by a panel of six judges from the Food Technology Department.

RESULTS AND DISCUSSION

Potatoes should be free of all impurities such as sand, grit, and soil, if pure starch is to be obtained. Thorough washing would not remove some of those adhering impurities. If it is economically possible, it is suggested that potatoes be peeled before grating.

It is important to have all cell walls of the potatoes ruptured in order to liberate all the starch granules, otherwise some of the starch would be lost in the pulp.

Proper adjustment of the settling table and regulation of the flow of the starch slurry in the trough is important in order to get a good yield of starch.

It was necessary to dry the starch to prevent spoilage in storage and the starch so prepared was found to contain 11 per cent moisture. As commercial starch contains 12-20 per cent of water, the theoretical yield is about 1.1 to 1.2 times that of the starch in the potatoes.

A yield of 27½ pounds of starch was obtained from 250 pounds of potatoes, amounting to 11 per cent of the total weight of the potatoes. Commercially, similar low yields of starch are obtained from cooking potatoes, although yields as high as 20% of starch are obtained from varieties especially cultivated for starch production (2, p.31).

There are several possible reasons which may account for the low percentage of starch obtained in this work:

1. The potatoes used were of a low grade some of which were spoiled. Soil impurities such as sand were attached to the skin of the potatoes and this lowered the percentage yield of the starch.

2. The potatoes may not have been crushed fine enough to allow ready separation of the starch from the tissue and pulp.

3. Different varieties of potatoes contain different percentages of starches (2, p.31). The potatoes used in this experiment may have been of a lower starch content variety.

The starch was compared with the commercial potato starch as reported in literature (2, p.154) and the comparison is shown in Table 3 below:

Table 3: Comparison of Commercial Potato Starch, as Reported in Literature, and the Potato Starch Prepared in this Laboratory.

	Moisture %	Protein %
Commercial Potato Starch	12-20	0.100 - 0.175
Potato Starch as prepared in this Laboratory	11	0.102

Hydrolysis of Potatoes

Attempts were made to prepare potato syrup from ground potatoes, both in the raw and cooked state. The syrups prepared by these methods were unsatisfactory because the color of the hydrolyzates was excessively dark and the coloring could not be completely removed with decolorizing materials. Moreover, undesirable off-flavors were produced which could not be removed completely. When starch was separated from the potatoes and then hydrolyzed, satisfactory syrups were obtained. It is believed that separation of the starch from the other ingredients of the potatoes before hydrolysis eliminates the problem of color and off-flavor development.

Conditions for Potato Starch Hydrolysis

As previously mentioned under acid hydrolysis (page 15) the temperature used for hydrolysis was 267° F. and the hydrochloric acid concentration was 0.2 per cent on dry starch weight basis. Hydrolysis was carried out at these conditions.

Results obtained from the preliminary work for the determination of the minimum time for the hydrolysis of potato starch at the conditions stated, and yet obtaining a dextrose equivalent of 40 is reported in Table 4.

Table 4: Relation of Operation Time to Hydrolysis of Potato Starch

Time in Minutes	Temperature° F	Dextrose Equivalent
75	267	43.1
73	"	41.4
72	"	37.5
70	"	34.4

The degree of conversion is expressed by the "dextrose equivalent" (D.E.) which is the total amount of reducing sugars contained in the product calculated as a percentage of dextrose on a dry weight basis. Determination of the dextrose equivalent was performed according to the Shaffer-Hartman methods as modified by Zerban and Sattler (24).

It was necessary to determine the correct time of conversion because any increase in dextrose equivalent due to an increase in operating time of the convertor would result in a syrup characterized by bitterness and off-flavors which are difficult to remove. Also if the operating time of the retort was reduced, the syrup would be of a low dextrose equivalent, not sweet enough for use in preserves, jams, and jellies. A medium conversion syrup of 40-42 dextrose equivalent is quite satisfactory as a sweetener for making jams, jellies, preserves, and other food products.

From the data presented in Table 4, it is seen that the shortest time to obtain a dextrose equivalent of 40 under the experimental conditions used was between 72 and 73 minutes. The time of operating the convertor was set at 72½ minutes and was believed to be the correct time of hydrolysis necessary to obtain the required dextrose equivalent. It was not believed that the time would be the same if another system was adopted, though the temperature and the amount of acid used remained the same. The time could be different and most probably would be lower if a stirring device was used to stir the hydrolyzates. It was believed that the hydrolyzates did not have a uniform dextrose equivalent when they were unagitated in the convertor. The outer portions of the hydrolyzates in the beakers may have attained a higher dextrose equivalent than those in the center of the beakers. The uneven conversion of the starch in the center of the beakers and the outer portions may have led to some of the undesirable properties of the syrup.

The syrup was analyzed for ash, sodium chloride, moisture content, and protein and found to compare favorably with potato syrups as reported by Clendenning and Wright (5).

Table 5: Analysis of Potato Syrup

	Ash %	Moisture %	Protein %	NaCl	D.E.
Commercial Potato Syrup	0.28	18.5	0.07	0.23	39.4
Potato Syrup as Prepared in this Laboratory	0.39	23	0.103	0.28	40

Grading of the Preserves, Jams, and Orange Marmalade.

Data in Tables 7, 8, 9, and 10 represent the average grade points given the different products when graded by Agricultural Marketing Service graders and six staff members and graduate students from the Food Technology Department at Oregon State College, using the Agricultural Marketing Service Grading System.

The three treatments of each product were of the same lot of fruit, contained the same Brix reading and were made under the same conditions.

Table 6: AMS Grading System

Factors			Score Points	
I.	Consistency	20	(A) (B) (SStd)	17-20 14-16* 0-13*
II.	Color	20	(A) (B) (SStd)	17-20 14-16* 0-13*
III.	Absence of Defects	20	(A) (B) (SStd)	17-20 14-16* 0-13*
IV.	Flavor	40	(A) (B) (SStd)	34-40 28-33* 0-27*
	Total Score	100		

(*) Indicates limiting rule.

Table 7: AMS Grading of Strawberry Preserves

Treatment No.	Sucrose : Syrup Proportion (dry basis)	Consistency	Color	Absence of Defects	Flavor	Total
1	5 : 0	17	18	18	35	88
2	4 : 1	17	18	19	35	89
3	2 : 1	18	19	19	33	89
Maximum Score		20	20	20	40	100

Table 8: AMS Grading of Blackberry Jam

Treatment No.	Sucrose : Potato Syrup Proportion (dry basis)	Consistency	Color	Absence of Defects	Flavor	Total
1	5 : 0	18	18	19	36	91
2	4 : 1	17	18	19	36	90
3	2 : 1	18	18	18	35	89
Maximum Score		20	20	20	40	100

Table 9: AMS Grading of Peach Preserves

Treatment No.	Sucrose : Potato Syrup Proportion (dry basis)	Consistency	Color	Absence of Defects	Flavor	Total
1	5 : 0	18	17	18	35	88
2	4 : 1	17	16	19	35	87
3	2 : 1	18	17	19	33	87
Maximum Score		20	20	20	40	100

Table 10: AMS Grading of Orange Marmalade

Treatment No.	Sucrose : Potato Syrup Proportion (dry basis)	Consistency	Color	Absence of Defects	Flavor	Total
1	5 : 0	17	16	18	36	87
2	4 : 1	16	17	18	34	85
3	2 : 1	17	16	18	34	85
Maximum Score		20	20	20	40	100

From the data presented the following points could be observed:

Consistency: If the consistency of the products where pure sucrose was used was considered as a standard, then it was noticed that the consistency of treatments 2 and 3, where syrup in its various concentrations was used, did not deviate much from the standard. In the case of strawberry preserves where 4:1 sucrose to syrup were used, the product was given the same value as the standard, but every other product with the same proportion of sucrose to syrup was given one point lower. This seems to indicate that on the average, the consistency score may be lowered some by using 4:1 sucrose to syrup on the dry basis.

In the case where 2:1 sucrose to syrup were used, treatment 3 of the strawberry preserves was given one point higher than treatment one, but treatments three of the blackberry jam, orange marmalade and peach preserves were given the same grade as that where sucrose was the sole sweetener. This seems to indicate that the use of 2:1 sucrose to syrup may result in an improvement of the consistency or may give the same consistency as that where sucrose is the sole sweetening agent.

Color: If, again, the color of the product where sucrose was used as the sole sweetening agent, was considered as standard, then it was noticed that potato syrup, as a partial substitute for sucrose as a sweetener did not have much effect on color.

Strawberry preserves were given the same points for treatments 1 and 2, but a grade of 1 point higher for treatment 3. Blackberry jam was given the same points for treatments 1, 2, and 3, but peach preserves was given one point lower for treatment 2 than for treatments 1 and 3. In the case of orange marmalade, the color was graded higher in treatment 2 than treatments 1 and 3 which received the same grade. As far as it is noticeable, no general relationship was found between the color of the product and the sweetening agent.

Absence of Defects: Defects that might occur in the jams or preserves are due to defects in the fruit itself or in the manufacture of the jams and preserves, and not due to the sweetening agents. Any differences in grades are therefore due to the previous two factors.

Flavor: In this study flavor is the most important factor to consider. In strawberry preserves, peach preserves, and blackberry jam treatment No. 2 received the same grade as treatment No. 1 while in orange marmalade treatments 2 and 3 received 2 points lower than treatment 1. This seems to indicate that potato syrup could be used in a proportion of 4:1 sucrose to syrup without imparting any effect on the flavor of the strawberry and peach preserves and blackberry jam, but impairs the flavor of orange marmalade. Treatments 3 of strawberry preserves, peach preserves and orange marmalade were 2 points lower than treatments 1 but treatment 3 of blackberry jam was 1 point lower than treatment 1. This indicates that whenever 2:1 sucrose to syrup were used, the score of the product was reduced one or two points.

Table 11: Average grade point of Peach Preserves, Strawberry Preserves, Blackberry Jam, and Orange Marmalade prepared with 5:0, 4:1, and 2:1 Sucrose to Syrup on dry weight basis. No stopper is considered in this table.

	Peach			Blackberry			Orange Marmalade			Strawberry		
Judge	5:0	4:1	2:1	5:0	4:1	2:1	5:0	4:1	2:1	5:0	4:1	2:1
1	84	82	87	89	90	87	87	82	83	92	95	94
2	85	86	86	83	88	86	84	80	79	82	89	88
3	89	85	82	91	92	91	88	84	84	90	78	85
4	82	82	83	85	81	83	82	81	78	80	85	81
5	94	92	92	92	92	89	91	93	92	90	89	89
6	91	89	88	94	94	96	90	92	96	92	91	91
7	93	94	94	95	94	93	did not grade			93	94	92
Total	616	611	612	639	631	625	522	512	512	619	621	620
Average	88	87	87	91	90	89	87	85	85	88	89	89

Table 11 is an overall picture of the grade of the four products as tested by Agricultural Marketing Service graders and by six judges from the Food Technology Department. No stopper was considered in this work.

Where 4:1 of the sweetener used was replaced by syrup on dry basis the following results were observed:

Peaches: treatment 2 was 1 point lower than treatment 1, but the overall grade was an A.

Blackberry Jam: a score of 90 was given to treatment 2 and the grade was an A.

Orange Marmalade: the grade was 2 points lower than that of treatment 1 and the grade was an A.

Strawberry Preserves: the score of treatment 2 was 1 point higher than that of treatment 1 and the grade was an A.

Where 2:1 sucrose:syrup were used, these results were obtained:

Peaches: the grade was 1 point lower than treatment 1, but still was an A grade.

Blackberry Jam: the grade was 2 points lower than treatment 1, but was an A in grade.

Orange Marmalade: the grade was 2 points lower than treatment 1, and was given a very low A grade.

Strawberry Preserves: the grade was 1 point higher than treatment 1 and was A in grade.

The four products mentioned previously and orange juice were tested organoleptically for flavor by 12 judges in duplicates or a total of 24 tests using the form below. It was found that there is some preference for treatments 1 and 2 over that of 3, as shown in Table 12. Very few disliked samples in treatments 1 and 2, but more in treatments 3.

Oregon Agricultural Experiment Station
Taste Test Ballot

Test No.________

Date________________________________Taster__________________________

SAMPLE	Flavor	Comments
1		
2		
3		
4		
5		

Score: 10--ideal
9--excellent
8--very good
7--good
6--fairly good
5--acceptable
4--fair
3--poorly fair
2--poor
1--very poor
0--repulsive

(Use numbers from 0 to 10 to indicate quality. If a score lower than 4 is given please make comments.)

Table 12: Flavor Preference of 24 Tests

Scores		0	1	2	3	4	5	6	7	8	9	10
	Sugar:Syrup	No. of Tasters										
Blackberry Jam	5:0			1		3	3	9	3	4	1	
	4:1				3	3	5	3	5	4	1	
	2:1	2	1	1	2	3	8	1	4		2	
Peach Jam	5:0			1				2	7	7	6	1
	4:1			1		5		4	9	5		
	2:1		1	3		7		3	6	3	1	
Strawberry Jam	5:0				1	3	2	9	3	6		
	4:1				1	6	4	5	2	5	1	
	2:1											
Orange Marmalade	5:0			1	3	1	4	4	4	6	1	
	4:1		1	1	1	2	4	5	7	1	2	
	2:1			5	1	2	4	2	6	2	2	
Orange Juice	5:0					1	2	3	6	10	2	
	4:1						4		10	8	2	
	2:1					1	1	2	5	10	5	

Scores: 10--Ideal, 9--Excellent, 8--Very Good, 7--Good, 6--Fairly Good, 5--Acceptable, 4--Fair, 3--Poorly Fair, 2--Poor, 1--Very Poor, 0--Repulsive

Chapter V

SUMMARY AND CONCLUSIONS

The use of potato syrup as a partial substitute for sucrose as a sweetener was investigated. Preparation of starch from cull potatoes was necessary before making the syrup, and a rapid method for starch preparation from cull potatoes was developed. Acid hydrolysis was used to prepare the syrup and the minimum time of conversion of the starch was found to be $72\frac{1}{2}$ minutes at 267° F. and 0.2 per cent hydrochloric acid on the dry weight basis. The syrup was considered to be of good quality and could be used as a partial substitute for sugar in preserves and jams.

The second phase of the work comprised the preparation of strawberry preserves, peach preserves, blackberry jam and orange marmalade using three treatments of each product. Treatments No. 1 contained sucrose as the sole sweetener; treatments No. 2 contained 1 part of potato syrup to 4 parts of sucrose as sweetener on dry basis; treatments No. 3 contained 1 part of potato syrup to 2 parts of sucrose on dry basis. The products were graded by Agricultural Marketing Service graders and by staff and graduate students. Also the products were graded organoleptically by a panel of 12 judges.

The results indicate the following conclusions:

1. 1/5 by weight on dry basis of the sucrose used in strawberry and peach preserves, blackberry jams and orange marmalade could be replaced by potato syrup of 40 dextrose equivalent without affecting the grade of the product.
2. Increasing the sucrose replacement by syrup to 1/3 on dry basis reduced the score of the products slightly, though it did not reduce the grade.
3. When 2:1 sucrose to syrup on dry basis were used the most important change was in the flavor of the product, while consistency, color, and absence of defects remained unaffected.

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