The utilization of dextrose in the manufacture of fruit sauces and syrups.

THE UTILIZATION OF DEXTROSE IN THE MANUFACTURE OF FRUIT SAUCES AND SYRUPS

MORRISON - 1938

THE UTILIZATION OF DEXTROSE IN THE MANUFACTURE OF FRUIT SAUCES AND SYRUPS

Charles W. Morrison

Thesis submitted for
the degree of
Master of Science

MASSACHUSETTS STATE COLLEGE, AMHERST

May 31, 1938

Table of Contents

	Page
Introduction	1
Review of Literature	
History of Corn Sugar	2
Method of Manufacture	2
The Present Status of Corn Sugar	4
Correction Factor for Substituting Dextrose	5
Commercial Grades of Corn Sugar	5
Review of Previous Work	7
Chemical and Physical Properties of Dextrose	9
Short Discussion of the Crushed Fruits and Syrups Industry	13
Experimental Procedure	
Introduction to the Problem	15
Experimental Results on Commercial Formulas	16
Birch Beer Syrup	16
Cherry Syrup	17
Chocolate Fudge Sauce	18
Chocolate Syrup	19
Coffee Syrup	20
Ginger Syrup	21
Maple Syrup	22
Marshmallow Sauce	22
Pineapple Fruit Sauce	23

Pineapple Syrup 24

Raspberry Fruit Sauce 25

Sassafras Syrup 26

Strawberry Fruit Sauce 27

Strawberry Syrup 28

Vanilla Syrup 29

Microbiological Studies 30

Sodium Benzoate as a Preservative 30

Sugar as a Preservative 31

Experimental Work on the Preserving Action of Sucrose and Dextrose 33

Summary 37

Conclusion 39

Bibliography 40

Acknowledgment 42

Introduction

Corn sugar is a relatively new sweetening agent having first been produced commercially in 1922. Production on a commercial scale was made possible through the research efforts of NewKirk (1923), who patented various steps of the process. The commercial production in its first year (1922), totaled 50,000 pounds and has since risen to an annual production of over 240,000,000 pounds.

Many commercial users of sugar have become interested in this product due to the fact that corn sugar usually sells for about a dollar a hundredweight cheaper than cane sugar. The substitution of dextrose for sucrose in the manufacture of various food products has been investigated for a number of years. With the increased acceptance of dextrose, manufacturers and consumers are continually seeking new methods and products to extend the utilization of this domestically produced sugar.

The manufacturers of fruit sauces and syrups for the fountain and ice cream trades are large consumers of sugar; consequently, the work of this thesis should be of most value to them. Their formulas and procedures were used in the experimental work. Also, in view of the fact that fountain sauces and syrups are excessively sweetened, there should be a demand for a less sweet sugar as dextrose. By

replacing part of the sugar with dextrose the cost of raw materials would be considerably reduced.

History of Corn Sugar

Dextrose was first obtained in very small quantities from honey by Lowitz as early as 1792.* However, the manufacture of dextrose was not given much consideration until 1811 at which time Kirschoff* demonstrated the possibilty of making it commercially in the form of corn syrup by the hydrolysis of corn starch.

The first patent in this country was granted to F. W. Gossling in 1864.* At this time most of the corn sugar products were sold in the syrup form or as a crude dry dextrose. Further work was done by Behr* in 1882, who produced an anhydrous glucose from the hydrated corn sugar by controlled conditions of crystallization. Further developments of a commercial nature were rather sluggish until the World War. Due to war conditions much interest was aroused in domestic sugar production.

Method of Manufacture

All of the commercial forms of corn sugar are prepared from corn starch by hydrolysis.* The first step involves

---

* Treasury Dept. Document No. 535. Internal Revenue. Prepared by National Academy of Science. G. F. Barker, Chairman. Report of Glucose. p. 9. 1884.

the heating of a water suspension of the starch which has been acidulated with a small amount of hydrochloric acid. This is usually done in a steam-jacketed kettle known as a converter. The acid present is merely a catalyst which hastens the conversion of the starch to dextrose.

When the conversion is complete, the crude syrup is treated with soda to neutralize the acid. The resulting syrup is clarified and decolorized by filtering through bone black. Water is evaporated until the solution becomes saturated and then the sugar is crystallized on special plates. The dextrose is readily deposited with a thick heavy mass of non-sugars. This heavy syrup is removed from the crystals by the use of a hydraulic press. Further purification is sometimes effected by recrystallization. The final product is 99 percent dextrose.

Newkirk's (1923) patents deal mostly with the process of crystallization which is rather unique for commercial practice. The process involves the control of crystallization conditions and the formation of chunky hydrate crystals that may be purged and washed in a centrifuge. This is preceded by crystallizing while in motion and seeding with a relatively high proportion of mother crystals.

Rehwald (1926) states that the recovery of pure dextrose depends upon: (1) the use of material of the purest possible character, (2) the hydrolysis to be accomplished under pressure, (3) the careful recrystallization and purification, (4) the

separation of the crystals from the molasses and refining by recrystallization and (5) the adequate supervision in each stage of the process.

The Present Status of Corn Sugar

A general prejudice against corn sugar was aggravated in 1906 when corn sugar was described by the Food and Drug Administration of the United States Department of Agriculture as a "muddy brown product less than fifty percent sweet". As a result of this feeling, corn sugar was defined technically as an adulterant unless its presence was declared on the label. Many states insisted on outlawing the use of dextrose entirely in various foods, on the claim that it was an inferior product.

However, corn sugar was given full recognition by a ruling of the Secretary of Agriculture, Hyde (1930), of the Department of Agriculture. The ruling stated that corn sugar is suitable in the "packing, preparation, or processing of any article of food in which sugar is a recognized element" and therefore it did not need to be declared on the label. This move by the government has been accepted by most states. The majority of states not accepting this regulation have a competing sugar industry of their own, either beet or cane sugar. Their ban is not a reflection on the quality of dextrose.

Correction Factor for Substituting Dextrose

In using commercial corn sugar, it is necessary to make corrections for the moisture content or water of hydration. As a result, it is necessary to use 109.4 pounds of dextrose when substituting for one hundred pounds of sucrose.

Commercial Grades of Corn Sugar

Cerelose or Dextrose

Commercial corn sugar is sold mainly as cerelose. This nearly pure form of dextrose is produced in the greatest quantities. It is a fine, white, crystalline product, containing seven to nine percent water. Usually the crystals are in the form of thin plates, although an alternate form appears as fine needles. The product hereafter referred to as dextrose, unless otherwise mentioned, will be the above described cerelose.

Dyno

Dyno, a product obtained by additional recrystallization, is a purer product than cerelose. It is usually sold in small packages for general home and table use and is somewhat

more expensive than the commercial cerelose.

A chemical analysis of the two common forms of hydrate corn sugar, cerelose and Dyno, is as follows:*

	Regular hydrated dextrose (Cerelose) percent	Refined hydrated dextrose (Dyno) percent
Moisture	7.75	8.00
Dextrose	91.40	91.80
Purity	99.50	99.80
Ash	0.05	0.009
Fe	0.00001	0.0002
Cl	0.016	0.002
SO_4	0.008	0.008
SiO_2	0.0035	0.005
Ca	0.0022	0.002

Anhydrous Dextrose

The anhydrous form of corn sugar is produced by a more accurate control of the temperature of crystallization. The crystallization temperature for this product is 50° C. (122° F.) Like Dyno, anhydrous dextrose is also somewhat higher in price than cerelose, but finds a ready market for use in products in which the water of crystallization might be detrimental, for example, chocolate coated candies.

Corn Syrup

Corn syrup is the product of incomplete hydrolysis of corn starch and it contains dextrins, maltose and dextrose.

---

* Fellers, C. R., Miller, J. and Onsdorff, T., 1937. Dextrose in the manufacture of fruit and vegetable products. Ind. Eng. Chem. 29

The grades sold are intended to meet requirements of the consumer depending upon the purity, density and ash content. Some corn syrups contain added sucrose such as the well known commercial product, Karo.

Review of Literature

Van Arsdale and Eddy (1933) packed 302 different types of fruits and vegetables using various combinations of cane and corn sugar. They found that tomatoes, peas, beets, and carrots gave satisfactory packs with all forms of corn sugar in combination with cane sugar. Plum jam was satisfactory when made with a 60-40 ratio of corn to cane sugar, if the finishing temperature was raised 2° F. In the preparation of strawberry jam a ratio of corn to cane sugar greater than 40-60 gave an off-flavored product and with blackberry jam the acceptable limit was reached at a 50-50 ratio. With canned peaches and pears in 55, 40 and 30° Brix syrups, acceptable products were obtained with a 50-50 ratio. Raspberry, cherry and peach preserves were acceptable when made up using a 50-50 ratio. These authors concluded that corn-sucrose combinations tend to reduce the excessive sweetness, but at the same time give the syrup a desirable body.

Onsdorff (1935) found that many fruits and the delicately flavored jams and jellies are injured by the substitution of large percentages of corn sugar for cane sugar. Corn canned

with dextrose was definitely inferior while pickles seemed to be greatly improved. He suggested that cranberry sauce offers a good opportunity for the use of corn sugar.

J. Miller (1936) in his studies concluded that rhubarb sauce was greatly improved when 50 percent of the sugar added was dextrose; applesauce with the same ratio of corn sugar was equal to that of the all-sucrose pack. He also concluded that all fruit products containing 25 percent dextrose and 75 percent sucrose with the exception of canned blackberries and canned or preserved blueberries were comparable to the all-sucrose pack. Strawberry preserves, currant jelly, cherry preserves, and applesauce packed with a concentration of 25 percent dextrose and 75 percent sucrose were found to be superior to the all-sucrose packs. The addition of one to two percent of dextrose to a pickle brine was found to be of advantage in supplying a readily available source or bacterial food for fermentation and making conditions ideal for the growth of desirable lacto-bacilli. Their development inhibits the growth of putrefactive bacteria. Howard (1938) showed that most pickle products were improved in quality and texture by the use of from 10 to 50 percent of the total sugar as dextrose. He found dextrose gave higher yields of finished pickles than sucrose.

Newman (1937) reported that pineapple fruit sauce, bittersweet sauce, coffee syrup, ginger syrup, orangeade, lemon syrup, strawberry fruit sauce, butterscotch sauce,

pineapple syrup and chocolate syrup were improved by substituting 50 percent of the sugar with dextrose. Chocolate fudge sauce, bittersweet sauce, and vanilla syrup were found acceptable in a ratio of 25 cane to 75 of dextrose. Dextrose could be substituted entirely for sucrose in building up the juice drained from strawberries frozen with about 30 percent cane sugar. Dextrose could also be substituted entirely in the manufacture of marshmallow sauce.

W. Miller (1937) found that when dextrose was added to strawberries to be frozen, that a blue or purple coloration readily appeared in the undissolved sugar. This coloration he believed was due to a chemical reaction between the dextrose and the anthocyanin pigments of the berries. When the pH was lowered the discoloration did not form.

Ruffley (1938) concluded that a 50 degree syrup containing 20 percent dextrose was preferred with canned baked apples.

The Chemical and Physical Properties of Dextrose

Chemical Structure of Dextrose as Compared to Sucrose

The hydrated dextrose contains one molecule of water of crystallization. The formula for this type is $C_6H_{12}O_6 \cdot H_2O$. Dextrose is the monosaccharide often referred to as grape-sugar or glucose. Sucrose is a disaccharide with a molecular weight nearly twice that of anhydrous dextrose. The formula

is $C_{12}H_{22}O_{11}$. Sucrose on inversion will yield equal amounts of dextrose and levulose, this product being known as invert sugar.

Colligative Properties

Due to the difference in molecular structure the colligative properties of these sugars vary considerably. The osmotic pressure exerted by a solution of dextrose is approximately twice that of sucrose. The boiling and freezing points are also affected more by dextrose than sucrose, the boiling point being raised and the freezing point being lowered.

Solubility

Jackson and Silsbee (1923) found that the maximum solubility or saturation point of dextrose at 20° C. is 44 grams in 100 cubic centimeters of pure water. The solubility increases directly with the temperature, but as the solution cools to room temperature the excessive dextrose readily crystallizes out. The limited solubility of dextrose is a decided disadvantage of this sugar. The low solubility of dextrose prevents the substitution of dextrose for sucrose entirely when preparing jams, jellies, or other products

requiring a high percentage of sugar.

In the heat treatment of fruit products, especially those containing acid, inversion of sucrose takes place with an increase in dextrose. As a result the solubility of dextrose is materially decreased when the sucrose is inverted to any great extent. This is an important fact to take into consideration when using dextrose in the presence of sucrose, especially with heat treated products.

Viscosity

The viscosity of a sugar solution varies with the type sugar or sugars present. Dextrose solutions are less viscous than sucrose solutions of equal concentration. Onsdorff (1935) concluded that between 77° F. and 122° F. a 50 percent dextrose solution was 22 percent less viscous than a sucrose solution of the same density. This is of advantage when highly concentrated syrups are handled and when a low viscosity is desired. But this may be considered a disadvantage in some products where a more viscous syrup really aids the appearance and lends body to the product such as in canned peaches or pears.

Effect of Acids and Alkalies

A monosaccharide like dextrose is not affected to any great extent by the presences of weak acids. Strong alkalies

like strong acids decompose any type of sugar quite readily. Very weak alkalies merely cause a rearrangement of the molecule, according to Bodansky (1934).

Sweetness

Sweetness is an important quality in any preserving sugar. In fact, sugar is usually added to a product to improve the flavor or bring out the natural flavor to make it predominant. This fact is especially noticeable with frozen strawberries. The unsweetened product is usually judged much weaker in flavor than those packed with a certain amount of sugar. Whether this is really the case or whether we are more accustomed to eating this fruit with sugar is a matter of opinion. Naturally there is a limiting taste factor to the indiscriminate use of any sugar. When excessive dextrose is added to a product, a typical cloying effect becomes apparent.

There being no chemical or other accurate method of measuring the sweetness values for the common sugars, Biester, Wood and Walkin (1925) set up a table as follows by organoleptic tests which they conducted. Sucrose is arbitrarily the control with a value of a 100.

Levulose (fruit sugar, fructose)	175.3
Invert Sugar	127.4
Sucrose (cane sugar)	100.0

Dextrose (corn sugar, glucose or grape sugar)	74.3
Maltose (malt sugar)	32.5
Galactose	32.1
Lactose (milk sugar)	16.0

Short Discussion of the Crushed Fruits and Syrups Industry

There are about 12 or 15 large manufacturers of crushed fruits and syrups, and thousands of small ones in the United States. The present day competition in this field is very keen and the margin of profit so small that the manufacturer must manage his costs and expenses efficiently in order to succeed. Each company has a formula book often written in code kept carefully under lock and key and accessible only to the foreman and "coster". All of this secrecy is more or less absurd because the necessary ingredients of each product are primarily the same.

The standard price list of all manufacturers is essentially the same. However, each manufacturer usually produces one or more "specials" which he considers of exceptional quality. These are lead products through which he attempts to maintain the interest of his trade.

The type of fountain products made are as follows:

Pure flavored products:

According to law and general acceptance, "pure" products

are those made of pure fruits without extracts or fillers.

Pure flavored products:

According to law and general acceptance, "pure flavored products" are those made up in almost any fashion but which may derive their flavor from such materials as true fruit extracts or various essential oils such as those of the orange, lemon or lime. They might be described as "fortified" pure products.

Imitation products:

This classification refers to any products made up without the use of fruit or fruit juice, or which contains imitation flavors rather than true flavors.

All fountain products, may be divided into three classes and a general formula for each class will cover the entire list if enough variations are used:

1. Fruits, crushed fruits, or fruit sauces.
2. Fruit syrups.
3. Flavored syrups.

A general fruit formula is as follows:

100 pounds of fruit, or fruit mixture freed from excees juice.

100 to 125 pounds of sugar

3 to 5 gallons juice

Color to suit product and to give an attractive appearance

after cutting.

Flavor to stand cutting.

Added acid to mask excess sugar.

One-tenth of one percent of sodium benzoate.

A general fruit syrup formula is as follows:

Fruit juice is made up to 35 or 36 degree Beaume with sugar.

Sufficient flavor, color and acid are added to stand cutting.

Add one-tenth of one percent sodium benzoate.

Experimental Procedure

Introduction to the Problem

The experimental work of this thesis was devoted to determining the advisability of substituting dextrose for part of the sucrose in the manufacture of syrups and fruit sauces for the soda fountain and ice cream trades.

The method of study was primarily that of substituting dextrose in varying percentages for the amount of sucrose normally used in making up the sauces or syrups. The beneficial or detrimental effects of the added dextrose were determined by noting the color and flavor of the product and comparing it with the control sample which was made up using all sucrose. In this way, there was always a definite standard

sample under the same conditions with which to compare the new product. The dextrose was substituted directly in the commercial formula in which sugar was needed.

All of the fruit sauces and syrups used by the industry contain from 60 to 65 percent sugar. This amount of sugar aids in preventing spoilage by inhibiting the growth of yeast and bacteria. The high sugar content also gives body to the product. Dextrose should be of advantage when a syrup of lower viscosity is desired for some particular product.

In addition to sugar, these products usually contain added color and flavor in order that they may withstand "cutting" or diluting with simple syrup at the fountain by the soda fountain operator. Citric acid is often added to cut the excessive sweetness due to the large amount of sugar present. Sodium benzoate is usually added as a preservative.

In this experimental work observations were made also on the effect of dextrose on the viscosity and keeping qualities of the products.

Birch Beer Syrup

Birch beer syrups are primarily designed for use in carbonated beverages. One part syrup is usually diluted with six parts of carbonated water. Samples of the syrups made with varying amounts of dextrose were carbonated and judged for flavor. All of the birch beer sodas made from these

syrups were considered equally good in flavor.

The criticism in Table 1 was based on the flavoring qualities of the syrups without dilution. The syrup made up using the 50 to 50 ratio of dextrose to sucrose was considered inferior to all the other syrups. The all sucrose syrup was preferred by most of the judges.

Commercial formula - Birch Beer Imitation

12 ounces of birch beer extract

1/2 ounce of sugar color

Make up to one gallon with benzoated simple syrup.

Cherry Syrup

Cherry syrup is used in the manufacture of soft drinks. The term "soft drink" is applied in the United States to common beverages which contain no alcohol. No regulations are placed on these products by the government. The composition of soft drinks varies with each manufacturer. The carbonated beverages made from cherry syrups listed in Table 2 were all considered equal in flavor.

The cherry syrups containing dextrose were judged superior in flavor to the all-sucrose syrup. The all-sucrose syrup was considered poor in that the flavor was impaired by the excessive sweetness.

Crystallization of dextrose was observed when a simple

Table 1. Physical Properties of Birch Beer Syrup

Lot	Sucrose-dextrose ratio	Soluble solid by refractometer	Crystallization	Relative viscosity	Criticism
1	100 - 0	64	none	7.6	acceptable
2	50 - 50	66	"	3.6	not acceptable
3	65 - 35	61	"	3.8	acceptable
4	80 - 20	62	"	5.0	acceptable

Table 2. Physical Properties of Cherry Syrups

Lot	Sucrose-dextrose ratio	Soluble solid by refractometer	Crystallization	Relative viscosity	Criticism
1	100 - 0	67	none	20	acceptable
2	50 - 50	65	"	11	"
3	65 - 35	66	"	14	"
4	80 - 20	66	"	17	"

of Lot 2 was stored in the refrigerator for a period of two months. The crystals readily dissolved again when the container was placed in hot water (180° F.) for a few minutes.

Commercial formula - Cherry Syrup

20 gallons of strawberry syrup from cold pack fruit (28 degrees Beaume)
105 pounds of sugar
1/4 pound of sodium benzoate
8 ounces raspberry red
30 ounces guinea green
35 ounces strawberry red
1 pound citric acid dissolved in one quart of water
Heat until solution is complete, and not over 150° F.
Add -
52 ounces of true fruit cherry extract
80 cubic centimeters benzaldehyde in 4 ounces of alcohol.
Put together in order indicated.

Chocolate Fudge Sauce

Four chocolate fudge sauces were made using 0, 20, 35, and 50 percent dextrose. The chocolate flavor was so predominant that it was difficult to distinguish any difference among the sauces; they were judged to be equal in flavor. Due to the limited solubility of dextrose, it could not be

used as the only source of sugar in this product.

Commercial formula - Chocolate Fudge Sauce

32 pounds of corn syrup

40 pounds of sugar

1 3/4 gallons of water

1/8 ounce of salt

24 pounds of melted chocolate liquor

6 pounds of saltbutter

3 quarts of heavy cream

All the ingredients mixed together, heated to about 200° F. and homogenized.

Chocolate Syrup

Four chocolate syrups were made using 0, 20, 35 and 50 percent of dextrose. Again the chocolate flavor was so predominant that it was difficult to distinguish any difference among the syrups; they were all judged to be equal in flavor.

The apparent viscosity of the syrup made using 50 to50 ratio of sucrose to dextrose was much lower than that of the all-sucrose syrup. This change in viscosity should be of advantage when the syrup is dispensed at the fountain.

Commercial formula - Chocolate Syrup

198 pounds of cocoa

500 pounds of sugar

Mix to aid dispersion

376 pounds of sucrose
62 gallons of water
5 1/2 ounces of vanilla
50 cubic centimeters of coumarin solution*
2 3/4 pounds of salt
1 pound 10 1/2 ounces of sodium benzoate

Part of the sugar and cocoa are mixed together and thrown on top of the heated water. The other ingredients are added in rotation and brought to boiling.

Coffee Syrup

Coffee syrup is a flavored sugar solution containing corn syrup which gives a bland body. All coffee extracts and syrups contain glycerine.

The judges of this product preferred the syrup made with a 50 to 50 ratio of dextrose to sucrose. The coffee flavor was more pronounced or definite at this ratio. This is probably due to the fact that this syrup is less sweet than the all-sucrose one.

Commercial formula - Coffee Syrup

17 gallons of water
1 gallon of corn syrup
1 gallon of glycerine
300 pounds of sugar
1/2 pound of benzoate of soda

* 2 ounces of coumarin made up to a quart with 190 proof alcohol.

Table 3. The Physical Properties of Coffee Syrup

Lot	Sucrose-dextrose ratio	Soluble solid by refractometer	Crystallization	Relative viscosity	Criticism
1	100 - 0	67	none	19	acceptable
2	50 - 50	68	"	11	preferred
3	65 - 35	65	"	15	acceptable
4	80 - 20	66	"	19	"

1 quart of sugar color
168 ounces of coffee extract

Ginger Syrup

Ginger syrup is used generally in the manufacture of ginger ale. Samples of the syrups listed in Table 4 were carbonated and judged for flavor and color. All of the sample mixed with carbonated water produced a very good ale. The syrup made with a 50 to 50 ratio of sucrose to dextrose would be ideal for the manufacture of a "dry" ginger ale. A carbonated beverage prepared from this syrup met the qualifications of this type of ginger ale in that it was completely light in flavor and not too sweet.

The criticism listed in Table 4 is based on the flavor of the syrups without dilution or carbonation. The all-sucrose syrup was considered excessively sweet. Lots 3 and 4 were considered acceptable.

Commercial formula - Ginger Syrup

60 ounces of water
7 pounds of sugar
4 ounces of ginger extract
5 grams of benzoate of soda (dry)
6 cubic centimeters of sugar color

Table 4. Physical Properties of Ginger Syrup

Lot	Sucrose-dextrose ratio	Soluble solid by refractometer	Crystallization	Relative viscosity	Criticism
1	100 - 0	67	none	20	acceptable
2	50 - 50	64.5	"	11	preferred
3	65 - 35	65.5	"	14	acceptable
4	80 - 20	66	"	17	"

Maple Syrup

The maple syrup referred to here is a flavored simple syrup. This type of syrup is usually used to flavor ice cream or to make the product known as "nuts in syrup."

All of the syrups listed in Table 5 were considered equal in flavoring qualities. These samples were not diluted or carbonated because they are never used in that form by the trade.

Commercial formula - Maple Syrup

10 ounces of maple flavor extract

1/2 ounce of sugar color

Make up to one gallon with a benzoated simple syrup.

Marshmallow Sauce

There are different types of marshmallow sauces on the market and each one is designed to meet a particular requirement. The sauce made in this experiment was of the type used at the soda fountain for ice cream dishes, such as sundaes.

No noticeable difference was found in flavor or consistency of the four products made using 0, 20, 35, and 50 percent dextrose. Some judges did express a slight preference for the sauce containing sugar of the 65 to 35 ratio. of sucrose to dextrose. Due to the plasticity of marshmallow

Table 5. Physical Properties of Maple Syrup

Lot	Sucrose-dextrose ratio	Soluble solid by refractometer	Crystallization	Relative viscosity	Criticism
1	100 - 0	67	none	21	acceptable
2	50 - 50	64	"	12	"
3	65 - 35	65	"	15	"
4	80 - 20	66.5	"	20	"

sauce, it was impossible to measure viscosity. The apparent viscosity of all types were considered the same. No crystallization or color changes were observed.

Commercial formula - Marshmallow Sauce

20 pounds of corn syrup

20 pounds of sugar

Heat to 230° F. This heated mixture is commonly called a "bob" syrup.

Put into the beater 70 pounds of corn syrup and then add hot "bob" syrup.

Start the beater and add -

1 pound egg albumen soaked in 1 quart of water

8 ounces of vanilla extract

Beat until the product has a density of 5 pounds to the gallon.

Pineapple Fruit Sauce

Canned Hawaiian pineapple is considered best for sauce manufacture because of the color and outstanding flavoring qualities. Crushed pineapple packed in its own juice in the grade usually used. A secondary source is the West Indian pineapple which is of a dull greyish color and has a tendency to darken during processing or during storage.

Although color or flavor is seldom used, a small amount

Table 6. Physical Properties of Pineapple Fruit Sauce

Lot	Sucrose-dextrose ratio	Soluble solids by refractometer	Crystallization	Criticism
1	100 - 0	53	none	preferrable
2	50 - 50	53	"	acceptable
3	65 - 35	55	"	"
4	80 - 20	51	"	"

of citric acid is usually added to cut the excessive sweetness due to the high concentration of sugar.

The pineapple sauce made with sucrose was prefferred by the judges. The sauces containing dextrose were considered acceptable. There was no apparent difference in the viscosity of any of the sauces.

Commercial formula - Pineapple Fruit Sauce

60 No. 10 tins of crushed pineapple packed in its own juice. Hawaiian type is usually preferred because of its color.

Drain off 23 gallons of juice

To the drained fruit add 8 ounces of fruit acid (citric)

1/2 pound of benzoate of soda in two quarts of water

300 pounds of sugar

Heat with stirring to 180° F. to dissolve the sugar.

Pineapple Syrup

The pineapple juice used in making pineapple syrup is the waste product drained from the canned crushed fruit used in making pineapple sauce. Many companies have this juice in such excessive quantities that much of it is not used for other purposes.

Pineapple syrup is usually added at the soda fountain milkshakes. The syrup is usually fortified by adding the true fruit extract in order that it may stand cutting with a

simple syrup at the fountain.

Pineapple syrup, Lot 2, Table 7, was considered superior in flavor to the other syrups. This was due to the fact that it was sweet and had a smoother flavor. The added extract flavor was not as prominent in the syrups containing dextrose as in the all-sucrose syrup. Lots 3 and 4 were considered comparable to the syrup made with a 50 to 50 ratio of dextrose to sucrose.

Commercial formula - Pineapple Syrup

1380 pounds of sugar is dissolved in 100 gallons of pineapple juice

2 pounds of sodium benzoate dissolved in 2 quarts of water

Add 400 ounces of pineapple true fruit extract to the solution.

Raspberry Fruit Sauce.

The West Coast Cuthbert raspberries are recommended for sauce production. This variety has a bright red color and clear cut raspberry flavor found only in the berries produced in this locality. The Columbian is a purple raspberry with a tendency to develop an acid or loganberry flavor on aging. The black raspberries are generally added to improve the color and flavor-tone, which is better than the plain cooked Cuthbert flavor.

Table 7. Physical Properties of Pineapple Syrup

Lot	Sucrose-dextrose ratio	Soluble solids by refractometer	Crystallization	Relative viscosity	Criticism
1	100 - 0	68	none	34	acceptable
2	50 - 50	66	"	22	preferred
3	65 - 35	66	"	24	acceptable
4	80 - 20	67	"	26	"

Four raspberry fruit sauces were made using 0, 20, 35 and 50 percent of dextrose. The sauce made up using the 50 to 50 ratio of sucrose to dextrose was preferred to the other sauces. This particular sauce had a more pronouced raspberry flavor and was less sweet.

Commercial formula - Crushed Raspberry Fruit Sauce

Put 1 barrel of (two-plus-one) raspberries in a kettle and heat to 160° F.

Allow to stand 10 to 15 minutes and heat again with stirring to 200° F.

Let stand 1 hour and drain off juice from bottom of kettle.

Weigh the balance in kettle and add .7 pound of sugar to each pound of fruit.

Add 10 ounces of raspberry red color.

1/2 pound of sodium benzoate in 1 pint of water.

Heat to 180° F. and then cool.

Add 2 gallons of corn syrup

8 ounces of fruit acid

Sassafras Syrup

Sassafras syrup is a flavored simple syrup used by the carbonated beverage industry and soda fountains. The sassafras soda is defined by Wiley (1919) as the carbonated or

artificially carbonated beverage prepared with potable water, acidulated sugar syrup, and sassafras flavor. It may or may not be acidulated.

Sassafras syrups were made using 0, 20, 35 and 50 percent dextrose. The flavor of the syrup made with a 50 to 50 ratio of dextrose to sucrose was preferred by the judges. The all-sucrose syrup was considered to be too sweet.

Samples of the syrups were carbonated and judged for flavor. All of the sodas made using the syrups listed in Table 8 were considered equal in flavor.

Commercial formula - Sassafras Syrup

10 ounces of sassafras extract

1/2 ounce sugar color

Make up to one gallon with benzoated simple syrup.

Strawberry Fruit Sauce

The best variety of strawberries for sauce manufacture is the West Coast Marshall. Frozen strawberries from Virginia and Maryland (Blakemore variety) are sometimes used. These berries are packed with a ratio of one part of sugar to two parts of berries. The southern berries have a more pronounced seed and a duller color often turning brown after packed. The flavor of these berries is not as strong or as pleasant as the West Coast Marshall.

Table 8. Physical Properties of Sassafras Syrup

Lot	Sucrose-dextrose ratio	Soluble solids by refractometer	Crystallization	Relative viscosity	Criticism
1	100 - 0	67	none	26	acceptable
2	50 - 50	64	"	12	preferred
3	65 - 35	65.5	"	15	acceptable
4	80 - 20	66	"	17	"

Four strawberry sauces were made using 0, 20, 35 and 50 percent dextrose. The sauce made with the 50 to 50 ratio of sucrose to dextrose was considered superior in flavor to the other three sauces. The substitution of dextrose for 50 percent of the sugar avoided the excessive sweetness usually found in this type of product.

Commercial formula - Strawberry Fruit Sauce

Drained and weighed fruit from one barrel (two-plus-one) strawberries.

1 pound of sugar to each pound of fruit

8 ounces of strawberry red color liquid

Heat to 180° F. to insure complete solution of the sugar.

Add -

16 ounces of fruit acid

2 gallons of juice

1/2 pound of sodium benzoate in two quarts of water

16 ounces of true fruit extract

Mix thoroughly.

Strawberry Syrup

Strawberry syrup is a by-product of the fruit sauce made from cold packed strawberries. It is highly flavored and

colored by the addition of true fruit extract and artificial color. The added dextrose allows for a more complete penetration of flavor. This is important to the consumer as the syrup is usually diluted at the fountain with a simple syrup.

The strawberry syrup of Lot 2, Table 9, was preferred by the judges. The flavor was smooth and bland as compared to the other syrups which were considered acceptable.

Commercial formula - Strawberry Syrup

39 gallons of strawberry juice drained from (two-plus-one) pack of fruit at 23° Beaume

300 pounds of sugar

3 pints of ponceau color solution (4 ounces ponceau made up to one gallon with water)

1/2 pound of sodium benzoate in two quarts of water

1 gallon of strawberry true fruit extract

Vanilla Syrup

Vanilla syrup is another popular flavoring agent commonly used in milk shakes or other drinks at the fountain. The vanilla extract used in flavoring ice cream was used to flavor these syrups.

Vanilla syrup of Lot 1 was preferred by the judges. This syrup had fine delicate flavor commonly associated with the vanilla. As this syrup is usually diluted at the

Table 9. Physical Properties of Strawberry Syrup

Lot	Sucrose-dextrose ratio	Soluble solids by refractometer	Crystallization	Relative viscosity	Criticism
1	100 - 0	68	none	35	acceptable
2	50 - 50	64	"	23	preferred
3	65 - 35	66.8	"	31.5	acceptable
4	80 - 20	66.2	"	40	"

fountain, the variation in flavor was not sufficient to disqualify the dextrose-sucrose made in the proportions shown in Table 10.

Commercial formula - Vanilla Syrup

44 gallons of simple syrup

8 ounces of sugar color

3 gallons of 10X vanilla extract

Microbiological Studies

Sodium Benzoate as a Preservative

Sodium benzoate is the only chemical preservative which may be legally added to foodstuff sold in the United States. The harmfulness or harmlessness of sodium benzoate or benzoic acid in foods has been the subject of much controversy and one in which some of the most eminent chemists and physiologists of the country have been interested. Unfortunately no concrete evidence has been produced as to the effect of this chemical on human nutrition and health. The United States Department of Agriculture through the Food and Drug Administration issued Food Inspection Decision No. 104 in 1909 saying, "It having been determined that benzoate of soda mixed with food is not deleterious or poisonous, and is not injurious to health, no objection will be raised under the Food and Drug Act to the use in food of benzoate of soda,

Table 10. Physical Properties of Vanilla Syrup

Lot	Sucrose-dextrose ratio	Soluble solids by refractometer	Crystallization	Relative viscosity	Criticism
1	100 - 0	62	none	6.8	preferred
2	50 - 50	58	"	3.0	acceptable
3	65 - 35	59	"	3.5	"
4	80 - 20	61	"	5.3	"

provided that each container is plainly labelled to show the presence and amount of benzoate of soda added."

However, sodium benzoate is considered a necessary ingredient of syrups and sauces in the crushed fruit and fountain syrups. The producer must protect his product from spoilage not only in storage but also when it is exposed while in use by the consumer. The product may be used from the original container or removed to a more convenient receptacle at the fountain. Also these products are usually packed in No. 10 tins or gallon jugs and are not all used at one time. The temperature of the room is usually ideal for the growth of molds or yeast. Consequently, in this industry the customary one-tenth of one percent of sodium benzoate is used and declared on the label.

Sugar as a Preservative

It is a well established fact that solutions such as brines or syrups will inhibit the growth of bacteria, yeasts and molds. It is not practical to use a syrup of such density that all growth would be prevented because such a product would be too sweet. Consequently, commercially and domestically, the fruits are packed in a thinner syrup and are sterilized by heating.

Experimental evidence (Rahm, 1928) has shown that it

takes more heat to kill bacteria or yeast in a sweetened fruit juice than in the same juice without sugar. The more sugar present the less moisture there is in the cells of the microorganisms due to the osmotic action of the solution. These partially dehydrated organisms are more resistant to the application of heat than are the normal vegetative cells.

If sufficient sugar is present in a solution enough dehydration may occur to render the microorganisms inviable and the sugar itself acts as a preservative. The osmotic pressure is directly proportional to the molecular concentration of the solutions. The dextrose molecule is half the size of the sucrose molecule. Therefore, theoretically, one would expect a dextrose solution to have twice as many molecules and a stronger preserving action than a sucrose solution of the same concentration.

Actual tests have shown, however, that in concentrated solutions, sucrose exhibits almost as much osmotic pressure as dextrose. Berkley (1906) showed that in dilute solutions it took 1.6 pounds of sucrose to exert the same osmotic pressure as did one pound of dextrose. In more concentrated solutions it took only 1.2 pounds of sucrose to one pound of dextrose to establish the pressure.

The difference in the relative affinities of the two sugars for water accounts for the similarities in osmotic

pressure effects. Sucrose has an affinity for water about 2.5 times that of dextrose. This hydration of the sugars in solution increases the actual concentration of sugar in free water, thereby exerting a higher osmotic pressure than one would expect.

Bacteriological examinations of sugar solutions have shown that the preserving power cannot be explained entirely on the basis of osmotic pressure. In dilute solutions sucrose was found to be more efficient than dextrose as a preserving agent, while in concentrated solutions dextrose was the slightly more efficient sugar. The investigators of this subject believe such behavior is due to the relative availability of the two sugars for bacterial growth.

Experimental Work on the Preserving Action of Sucrose and Dextrose

On the basis of these facts, an attempt was made to demonstrate the relative preserving action of sucrose and dextrose. Syrups were made using concentrations of 10, 20 and 40 percent of the two sugars and were enriched with one-tenth of one percent of peptone and ammonium di-phosphate. These solutions were inoculated with a one cubic centimeter water suspension of cells made from 48 hour cultures of yeast, bacteria and molds. The solutions containing bacteria

and yeast were examined at different intervals by counting the number of cells present, on a blood counting cell. All the material was incubated at room temperature.

The growth of the molds was judged by observation. Similar solutions of the two sugars were also benzoated (0.1%) to determine the relative preserving action of sodium benzoate in the presence of dextrose or sucrose.

A similar experiment was also conducted with coffee and raspberry syrups. Concentrations of 10, 20 and 40 percent were used with yeast and molds. Samples of these syrups were also benzoated (0.1%).

When interpreting these Tables (11 to 15), the availability of the monosaccharide as compared with that of the disaccharide from the nutritional aspect of the microorganism must be considered as well as the physical action through osmotic pressure. Taking these factors into consideration, a study of the tables shows that dextrose has a slightly greater bactericidal effect than sucrose. In some instances, as shown in the tables, depending on the type of microorganism and the concentration of the solute, greater reductions in the number of organisms occurred in the dextrose syrups.

Table 11 shows that there was a 60 percent reduction in the number of organisms (Bacillus mesentericus) in the 10 percent dextrose solution as compared to the sucrose solution of the same concentration. With the 20 percent

Table 11. Growth of *Bacillus mesentericus* in Sucrose and in Dextrose Syrups With and Without Sodium Benzoate (0.1%)

Concentration	Incubation time, days		
	4	8	24
	number of bacteria per cubic centimeter		
10% sucrose	248,000,000	152,000,000	100,000,000
20% "	148,000,000	36,000,000	34,000,000
40% "	---	375,000	---
10% sucrose, benzoated	24,000,000	40,000,000	32,000,000
20% " "	250,000	20,000,000	16,000,000
40% " "	---	---	---
10% dextrose	60,000,000	40,000,000	48,000,000
20% "	8,000,000	12,000,000	17,000,000
40% "	2,250,000	---	---
10% dextrose, benzoated	375,000	36,000,000	22,000,000
20% " "	40,000	8,000,000	3,200,000
40% " "	---	---	---
10% dextrose-sucrose (1:1)	48,000,000	29,600,000	90,400,000
20% " " "	89,000,000	28,000,000	84,000,000
40% " " "	---	---	---

Table 12. Growth of Saccharomyces ellipsoideus (Ausmannhausen) in Sucrose and in Dextrose With and Without Sodium Benzoate (0.1%)

Concentration	Time of incubation, days 4	8	15	24
	number of organisms per cubic centimeter			
10% sucrose	11,100,000	9,500,000	11,250,000	15,000,000
20% "	4,400,000	3,250,000	7,500,000	10,750,000
40% "	2,650,000	13,000,000	10,750,000	8,250,000
10% sucrose, benzoated	10,600,000	5,000,000	12,000,000	12,000,000
20% sucrose, benzoated	1,250,000	4,750,000	6,000,000	6,750,000
40% sucrose, benzoated	2,500,000	13,750,000	4,000,000	4,500,000
10% dextrose	5,800,000	6,500,000	7,750,000	10,000,000
20% "	350,000	4,000,000	5,550,000	6,250,000
40% "	750,000	2,000,000	3,750,000	3,500,000
10% dextrose, benzoated	3,350,000	3,500,000	5,750,000	6,000,000
20% dextrose, benzoated	70,000	2,500,000	3,250,000	2,750,000
40% dextrose, benzoated	30,000	250,000	325,000	750,000
10% dextrose-sucrose (1.1)	5,150,000	8,750,000	9,500,000	9,000,000
20% dextrose-sucrose (1.1)	500,000	4,500,000	7,000,000	7,500,000
40% dextrose-sucrose (1.1)	2,500,000	6,000,000	7,150,000	8,000,000

Table 13. Growth of Saccharomyces ellipsoideus (Ausmannhausen) in Raspberry Syrup Made With Sucrose and With Dextrose. With and Without Sodium Benzoate (0.1%)

Concentration	Incubation time, days 5	10	16
	number of bacteria per cubic centimeter		
10% sucrose	3,000,000	5,500,000	5,000,000
20% "	4,500,000	3,500,000	4,000,000
40% "	3,500,000	5,000,000	3,000,000
10% sucrose, benzoated	2,000,000	500,000	---
20% " "	500,000	---	---
40% " "	2,500,000	7,500,000	---
10% dextrose	3,000,000	3,000,000	7,000,000
20% "	6,500,000	4,500,000	4,500,000
40% "	1,000,000	500,000	---
10% dextrose, benzoated	500,000	---	500,000
20% " "	1,000,000	---	500,000
40% " "	1,000,000	500,000	---

Table 14. Growth of Saccharomyces ellipsoideus (Ausmannhausen) in Coffee Syrup Made With Sucrose and With Dextrose With and Without Sodium Benzoate (0.1%)

Concentration	Incubation time, days 5	10	16
	number of bacteria per cubic centimeter		
10% sucrose	5,750,000	5,500,000	2,750,000
20% "	7,750,000	3,000,000	20,000
40% "	80,000	40,000	30,000
10% sucrose, benzoated	50,000	80,000	40,000
20% " "	50,000	60,000	35,000
40% " "	90,000	50,000	140,000
10% dextrose	6,250,000	1,650,000	2,500,000
20% "	3,000,000	4,250,000	2,000,000
40% "	120,000	100,000	80,000
10% dextrose, benzoated	100,000	40,000	70,000
20% " "	80,000	10,000	60,000
40% " "	60,000	---	---

Table 16. The Relative Growth of Aspergillus niger in Plain, Coffee and Raspberry Syrups Made With Sucrose and Dextrose. With and Without Added Sodium Benzoate

Type of syrup	Amount of growth					
	surface	sediment	surface	sediment	surface	sediment
Plain syrup						
Sucrose	1	1	1	1	1	1
Dextrose	4	0	1	1	0	1
Sucrose, BzONa	0	1	0	1	0	1
Dextrose, BzONa	0	1	1	0	0	1
Coffee syrup						
Sucrose	3	1	4	4	3	1
Dextrose	4	1	4	4	3	1
Sucrose, BzONa	0	0	3	1	0	0
Dextrose, BzONa	0	0	0	0	0	0
Raspberry syrup						
Sucrose	4	4	3	4	4	4
Dextrose	3	4	4	2	4	4
Sucrose, BzONa	0	0	0	0	0	0
Dextrose, BzOna	0	0	0	0	0	0

Note: The above ratings were based on an estimation of the amount of growth, as follows:

Surface	Sub-surface or sediment
0 - No growth	0 - No growth
1 - One-fourth covered	1 - Slight growth
2 - One-half covered	2 - Moderate growth
3 - Three-fourth covered	3 - Moderately heavy
4 - Completely covered	4 - Heavy growth

BzONa - refers to 0.1 percent sodium benzoate.

solution of the two sugars there was an estimated 50 percent reduction in the dextrose syrup. In general, little growth occurred in the 40 percent solution of either sugar, with or without sodium benzoate. In the benzoated dextrose sclution of 10 and 20 percent the number of organisms was about one half that of the benzoated sucrose solution of similar concentration.

The number of yeast cells in the 10 percent dextrose solution, Table 12, was about two-thirds that of the 10 percent sucrose solution. There was no noticeable difference in the amount of growth with this organism in the 20 percent solutions of the two sugars. The preserving action of the benzoated dextrose solutions (10, 20 and 40 percent) was approximately twice as efficient as the benzoated sucrose solutions.

There was apparently no difference in the amount of growth of yeasts in raspberry syrups, Table 13, of 10 and 20 percent concentration made with dextrose and sucrose. However, growth in the 40 percent syrup with sucrose was fairly constant during incubation while in a syrup of the same concentration with dextrose, the number of organisms progressively decreased. There was no distinct difference in the number of organisms in the benzoated sucrose syrup as compared with the benzoated dextrose raspberry syrup.

The relative growth of yeast in 10, 20 and 40 percent syrups of the two sugars flavored with coffee, Table 14, was about equal. The same was true of the benzoated dextrose

and sucrose coffee syrups. However, growth in the 40 percent benzoated dextrose syrup decreased to below 10,000 organisms per cubic centimeter, while growth in the benzoated sucrose syrup of similar concentration was fairly constant during incubation.

There was very little difference, Table 15, in the amount of mold growth (Aspergillus niger) in sucrose and dextrose solutions of 10, 20 and 40 percent. The same was true of raspberry and coffee syrups made with these sugars. The benzoated coffee syrups were slightly more efficient in inhibiting growth than the control coffee syrup.

Summary

1. A brief history of the corn sugar industry is presented with a general review of the literature, a short discussion of the physical and chemical properties of dextrose, and a review of previous experimental work pertaining to the utilization of dextrose in food products.
2. A general discussion of the method of manufacture, present status of corn sugar and commercial grades of corn sugar is included. Also a short discussion of the crushed fruits and syrups industry with a classification of the various products is presented.
3. It was found that strawberry and raspberry fruit sauces, and strawberry, coffee, ginger, cherry, pineapple, birch beer and sassafras syrups were improved when 50 percent of the added sugar was dextrose. Marshmallow sauce, maple syrup, vanilla syrup, chocolate syrup and chocolate fudge sauce were equal to the all-sucrose product when 50 percent of the added sugar was dextrose. Pineapple fruit sauce made with a 1 to 1 ratio of dextrose to sucrose was considered inferior to the all-sucrose sauce. The sauces made using 35 and 20 percent dextrose were judged equal to the all-sucrose sauce.

4. Solutions of dextrose and sucrose of various concentrations were inoculated with yeasts, bacteria and molds to determine the relative bactericidal action of the two sugars. No marked difference was observed between the dextrose and the sucrose.

Conclusion

Dextrose has a definite and important place in the food industries as a sweetening and preserving agent. Its use is often advantageous in reducing costs and improving the quality of certain candies, baked products, canned foods, preserved fruits, pickles, and fountain syrups or sauces. Dextrose is now obtained on the market comparable to sucrose in purity. Due to its lower solubility, final concentrations should be limited to approximately 50 percent, in order to prevent crystallization.

Dextrose may make up from 25 to 50 percent of the sugar used in the manufacture of sauces and syrups for the soda fountain trade. Here, the result is often a definite improvement as dextrose is less sweet than sucrose.

Bibliography

Berkeley, Earl of, and Hortley, E. J., 1906. Osmotic pressure of some concentrated aqueous solutions. Trans. Roy. Soc. London. 206, 481.

Biester, A., Wood, M. W. and Wahlin, C. S., 1926. The relative sweetness of pure sugars. Am. J. Physiol. 73, 387.

Howard, H., 1938. Use of dextrose in manufactured pickle products. Master's Thesis. Mass. State College, Amherst, Mass.

Hyde, H. M., 1930. Ruling by Secretary of Agriculture. Statement regarding new ruling. U. S. D. A.

Jackson, R. F. and Silsbee, C. G., 1922. The solubility of dextrose in water. Sci. Papers Bureau of Standards. 437, 720.

Miller, J., 1936. Master's Thesis. Mass. State College, Amherst, Mass.

Miller, W., 1937. Master's Thesis. Oregon State College, Corvallis, Oregon.

Newman, K., 1937. Master's Thesis. Mass. State College, Amherst, Mass.

Newkirk, W. B., U. S. Patent 1,471,347 (Oct. 23, 1923); U. S. Patent 1,508,569 (Sept. 16, 1924); U. S. Patent 1,521,830 (Jan. 6, 1925).

Onsdorff, T., 1935. Master's Thesis. Mass. State College, Amherst, Mass.

Rahn, O. Incomplete sterilization of food products due to heavy syrups. Canning Age. 705, 1928.

Rehwald, F., 1926. Starch Making. Scott, Greenwood and Sons, London.

Ruffley, J., 1938. Technical and nutritional investigations on canned baked apples. Master's Thesis . Mass State College, Amherst, Mass.

Van Arsdale, M. B., and Eddy, W. H., 1933. The value of types

of dextrose in the preservation of fruits and vegetables. Bur. Publ., Teachers College, Columbia University, New York.

Acknowledgment

The author wishes to express his sincere appreciation to Dr. C. R. Fellers and Dr. W. A. Maclinn for their guidance and thoughtful suggestions during the course of this research.

Also, the author wishes to express his gratitude to the Corn Products Refining Company, who has made this work financially possible and to the Horticultural Manufactures Department for supplying the facilities to carry out the work.

Approved by:

Carl R. Fellers

Merrill J. Maeb

Helen Knowlton

Graduate Committee

Date: May 31, 1938