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

Kenneth Raycraft Newman
University of Massachusetts Amherst

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

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

Kenneth R. Newman

Thesis submitted for the degree of
Master of Science
MASSACHUSETTS STATE COLLEGE
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Introduction and Purpose

The history of the commercial production of corn sugar is a short one. The manufacture of dextrose was made commercially possible in 1922 by Newkirk's patented process (16, 17). Commercial production in its first year, 1922, totalled 50,000 pounds and has risen since to the phenomenal annual production of 240,000,000 pounds in 1936 (10).

With the increased acceptance of hydrated dextrose, manufacturers and consumers are seeking new methods and products to extend the utilization of this domestic, manufactured product.

Recognition was thus accorded to the manufacture of fruit sauces and syrups for the soda fountain trade. This field has remained obscured to a great extent by its unwillingness to accept scientific aid and to make changes that are deemed unnecessary in view of the fact that they have successfully manufactured their products over a long period of time.

Fruit sauces and syrups, as they are now manufactured, contain a high percentage of sugar which, in itself, makes the product excessively sweet. This thesis was initiated to study the possibilities of substituting a major proportion
of dextrose for sucrose and thus avoid the excessive sweetness obtained with the sole use of sucrose. At the same time the substitution would lessen the cost of the product by the utilization of dextrose which may be obtained in large quantities at a substantial reduction over the cost of sucrose.

The method of study is mainly an investigation of changes in appearance, color, flavor, consistency and crystallization. The substitution of dextrose hydrate for sucrose will necessitate the development of new commercial formulae.
Review of Literature

History of Corn Sugar

Corn sugar is really a product of recent development, having had its start in 1922 when Newkirk made possible the commercial production by his crystallization process. However, it was possible to obtain dextrose in small quantities as early as 1792 when Lowitz (24) prepared it from honey.

The manufacture of corn sugar by the action of hydrolysis has been known since 1811 at which time Kirschoff (24) was able to demonstrate the possibility of its commercial manufacture in the form of corn syrup. With subsequent improvements in methods of manufacture and its various uses, a plant was erected at Sackett Harbor by S. Guthrie and Captain Potter in 1831 for the manufacture of corn sugar syrup.

The first American patent was granted to F. W. Gossling in 1864 (24). In 1882, Behr (24) demonstrated the production of anhydrous dextrose from the hydrated corn sugar by a rigid control of crystallization conditions.

Subsequent developments were slow as far as improvements in production of corn sugar are concerned until 1922 at
which time Newkirk (16, 17) was granted a patent on the basis of a new technique in the method of crystallization. The patent thus granted has been questioned by other manufacturers who would like to enter the field of corn sugar manufacture. At the present date infringement of previous patents has not been proven and decisions are still in favor of the Newkirk patents (2).

Method of Manufacture

In brief the commercial corn sugar, hydrated dextrose, is produced by the acid hydrolysis of corn starch (1). A suspension of starch in water is heated in a steam-jacketed kettle by steam under pressure and acid is added to increase the hydrolysis reaction, or the conversion of the starch. In the manufacture of corn sugar the starch is completely converted to dextrose. The acid in the process plays no part other than that of a catalyst.

Possible intermediate products of this process are dextrin and corn syrup. The latter is a mixture of dextrin, maltose, and dextrose which is neutralized and filtered to remove salts formed by neutralization and later concentrated in a partial vacuum to the correct proportion of sugar solids.

The final product is corn sugar which is nearly pure hydrated dextrose. The color is removed by passing through a boneblack, filtration process and the sugar syrup is evaporated to the crystallization point. The syrup is
allowed to crystallize and the thick liquid containing products other than sugar is removed by hydraulic presses. A process of recrystallization is carried out to purify the product.

The process used in crystallization is unique in commercial practice, and the uniqueness of the method is the reason that Newkirk's patents have withstood legal investigation. 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 crystals (2).

The Present Status of Dextrose

The development of corn sugar production was greatly stimulated by the recognition accorded it by the Department of Agriculture in 1930 (13). The Department of Agriculture ruled that corn sugar is suitable in the "packing, preparation, or processing of any article of food in which sugar is a recognized element" (13) and therefore, need not be declared on the label. Previous to this ruling, corn sugar was technically an adulterant unless its presence was declared. Since the removal of this stigma to its use, production and consumption have increased phenomenally. Acceptance of the ruling by the states has not been unanimous and
possibly will never be as long as those states that outlaw its use have a sugar industry of their own.

Commercial Trades of Corn Sugar

Corn sugar is presented to the market in many forms and grades. The commercial corn sugar is sold as cerelose and, of the crystalline products, is produced in the greatest quantity. It is nearly pure dextrose, a fine, white, crystalline product, containing one molecule of water of crystallization, and a small amount of ash. In this paper dextrose refers to the hydrated form of dextrose.

Another product of further refinement is one commercially called Dyno. This product has the advantage of greater purity obtained by an additional recrystallization. Its use is somewhat limited to household and dietary needs because its cost is prohibitive to commercial utilization.

By a more rigid control of the temperature of crystallization, it is possible to produce anhydrous dextrose. The crystallization temperature for this product is 50°C. (122°F.) Commercial use is limited to such products where the slightest amount of water is detrimental, for example in dipping chocolate.

Corn syrup has found a place in food preparation and is manufactured in many grades to meet the necessities of
its consumers. The grades vary greatly with total sugars, reducing sugars, ash, and other constituents. Some products contain added sucrose as does the well known commercial product Karo.

Prices of corn syrup vary as to the standards they meet, their purity, and their density. Prices on commercial dextrose are approximately a cent a pound less than sucrose in carload lots.

Chemical and Physical Properties of Corn Sugar

Chemically, dextrose is a monosaccharide frequently referred to as grape sugar or dextro-glucose. The term glucose has been used extensively in texts but is misleading, and, therefore, should be avoided to eliminate all possible association with the so-called glucose syrup, which is a mixture of dextrin, maltose, sucrose, and dextrose. Sucrose, on the other hand, is a disaccharide with a molecular weight nearly twice as great as anhydrous dextrose and does not have any molecule of water of crystallization as does dextrose. The formula for sucrose is $C_{12}H_{22}O_{11}$; the formula for the hydrate form of dextrose is $C_6H_{12}O_6 \cdot H_2O$. Sucrose will on inversion yield equal amounts of dextrose and levulose, the mixture being called invert sugar.
Since there exists a difference in molecular weights of sucrose and dextrose, it is but natural that other properties vary. Physical chemistry explains the variations that occur in boiling points, freezing points, and osmotic pressure of two solutions of the sugars in equal concentrations.

Dextrose solutions have a tendency to raise the boiling point much more than do solutions of sucrose. This fact makes it necessary to determine a new finishing point for products manufactured by temperature control. The refractometer and hydrometer read within a negligible error the correct soluble solids and therefore have replaced the thermometer in many instances.

The freezing point is affected likewise by dextrose. Dextrose will lower the freezing point more than sucrose. It is because of this fact that some objections are voiced in the use of dextrose in making products that are ultimately to be used in the manufacture of ice cream.

Variations in osmotic pressure are in direct relation to the number of molecules of the soluble solid in solution. Since sucrose has nearly twice the molecular weight of dextrose it should theoretically exert less osmotic pressure than a solution of equal concentration of dextrose. The relative, theoretical values may be determined from the molecular weights. Since the molecular weights are 198
for dextrose \( \text{C}_6\text{H}_{12}\text{O}_6 \cdot \text{H}_2\text{O} \) and \( \frac{5}{2} \) for sucrose
\( \text{C}_{12}\text{H}_{22}\text{O}_{11} \), the resulting ratio is \( 1 \) to \( 1.73 \), or
dextrose exerts an osmotic pressure \( \frac{3}{4} \) times as great
as does sucrose. On this basis it is to be expected that
dextrose would be \( \frac{3}{4} \) times as effective in preserving
power. The preserving action of any sugar solution is due
primarily to the osmotic pressure it exerts on the cell
membrane of a microorganism and the subsequent plasmolysis
of the cell, or its dehydration.

Experimentally the above theoretical relationship
between sugar solutions has not been proven. Berkeley
and Hortley (5) have shown that as the concentration of
the solutions are increased the osmotic pressure of a
sucrose solution will approach that of a dextrose solution.
Hunziker (12) concluded in his work that dextrose in the
concentration used in the manufacture of sweetened con-
densed milk was \( 1.25 \) to \( 1.33 \) times as effective as sucrose.
This possible greater preservative power of dextrose has
not been too thoroughly studied and is a factor worthy of
consideration in many products now manufactured.

The limited solubility of dextrose is a decided dis-
advantage in the manufacture of many products such as jam,
jellies, preserves, etc. A dextrose sugar solution of
high concentration may be produced by heating to dissolve
the sugar. When cooled the sugar is partially in a super-
saturated condition which may exist for a considerable
period of time but, as is true of other super-saturated
solutions, crystallization will take place in the presence
of a number of factors such as evaporation, agitation,
seeding, and fluctuations in temperature.

Dextrose shows a more rapid increase in solubility as
the temperature increases than does sucrose. This is more
adequately shown in data which have been compiled by the
Bureau of Standards (14) and show the maximum solubility
of dextrose at various temperatures. Thus, at a temperature
of 22.38°C. (73.3°F.), the solubility in water is 49.37
percent and at 90.80°C. (195.7°F.), the solubility rises
to 84.9 percent.

Since the products with which this thesis is concerned
are of high sugar concentration, it is quite evident that
in the substitution with dextrose it is not to be expected
that one may substitute dextrose for all the sucrose.

Over-concentrated sucrose products (67-69%) will
crystallize at normal or lower temperatures of storage.
Although it has been pointed out that fluctuations in
temperatures do not increase or decrease the solubility of
sucrose nearly as much as they do the solubility of dextrose,
a mixture of sucrose and dextrose make possible a higher
concentration of total sugars without crystallization than
may be obtained with either one alone. The fact that dextrose can be added to a sucrose solution without crystallization and without changing the solubilities of either sugar noticeably has found extensive application in the manufacture of those products where concentration by heating is avoided and errors of a few percent would cause crystallization.

Many sugars are available to the commercial manufacturer but few are within the price range that he wishes to pay. The sugars most frequently used are sucrose, dextrose, and invert sugar.

Sugar is used in food for its preserving action and its improvement in the flavor of the product. For the maximum preserving action in preventing the growth of bacteria and yeast, a saturated solution of sucrose is necessary and from available data it would seem that the same concentration is necessary with dextrose.

In the attempt to obtain the maximum preserving action, the manufacturer must often sacrifice flavor by the incorporation of large amounts of sucrose which lead to excessive sweetness. This is somewhat eliminated by the use of dextrose because it is less sweet. From the following table it can be seen that dextrose is about 75 percent as sweet as sucrose.
Comparative Sweetness of the Common Sugars

<table>
<thead>
<tr>
<th>Sugar</th>
<th>Comparative Sweetness</th>
</tr>
</thead>
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<tr>
<td>Levulose</td>
<td>173.3</td>
</tr>
<tr>
<td>Invert sugar</td>
<td>107.4</td>
</tr>
<tr>
<td>Sucrose</td>
<td>100.0</td>
</tr>
<tr>
<td>Dextrose</td>
<td>74.3</td>
</tr>
<tr>
<td>Maltose</td>
<td>32.5</td>
</tr>
<tr>
<td>Galactose</td>
<td>32.1</td>
</tr>
<tr>
<td>Lactose</td>
<td>16.0</td>
</tr>
</tbody>
</table>

This table of comparative sweetness of sugars has been worked out by organoleptic tests conducted by Blester, Wood, and Wahlin (5).

Since sugar has the power to contribute or detract from the flavor of a product, it is only natural that it should be considered of prime importance in the manufacture of foods prepared with sugar. Some sugars contain impurities that may be removed by further purification. Therefore, it is customary for the manufacturer who utilizes sugars to inspect them for off-flavors that are strong enough to be noticeable in his finished product. At one time off-flavors were quite common in corn sugar, but improvement of dextrose manufacture has largely eliminated this justifiable objection.

At present the chemical analysis of the two forms of hydrate corn sugar is as follows (10):
Woodman (26) accredits ordinary granulated sugar with 99.85 percent sucrose giving it a purity of nearly 100 percent.

Off-flavors in dextrose might be attributed to its impurities, but it is inconceivable in view of the relatively small amounts that are present.

In using corn sugar, it is obvious that one must make allowances for the moisture content. In other words, it is necessary to use 109.4 pounds of dextrose when substituting for one hundred pounds of sucrose (10).

Color in food products is important and the manufacturer is constantly trying to improve his processes so as to retain the natural color of the food. It is conceded that dextrose is quite often deleterious to the color of the product. Explanations of this fault are not much more than in the experimental stage and before any definite conclusions may be drawn, it would be advisable to carry
out further experimentation. According to Onsdorff (18),
dextrose solutions of high density have color which is
intensified by the action of heat, especially, that of
sterilization at 240°F. Ramsey, Tracy, and Ruehe (19) do
not substantiate the work of Onsdorff as they found no
discoloration after processing for 30 minutes at 250°F.
sugar and water solutions of sucrose, dextrose, and lactose.

The work of these three investigators has been carried
out in relation to sweetened condensed skim milk. They
heated water emulsions of casein and albumin and found no
discoloration, but when milk albumin or casein was heated
with dextrose or lactose, discoloration took place. This
was not found to occur with sucrose. These investigators
point out the similarity of dextrose and lactose; both are
reducing sugars with aldehyde groups.

It appears that the sugar combines with the amino
group of the protein, NH₂, which is alkaline and sets free
the acid group. When treated with alkalis, sugars turn
brown. On the other hand, no condensation product would be
formed with sucrose as the linkage of the ketone group and
aldehyde group is more stable. The only possibility of
a condensation product occurring with sucrose would be in
the case of the inversion of the sugar. Haradine (11) in
his study found this possible when invert sugar was present
in solutions of 35 percent or more.

Englis and Dykins (9) concluded that the sugar-protein reaction was intensified by decreasing the hydrogen ion concentration. This work is in accordance with that of the laboratories of the Corn Products Refining Company who state that the minimum change is at pH 4.5 (10).

When dextrose is used in the manufacture of products, the water should not be hard, and if it is, it should be neutralized with acid. Whenever possible, such as in the manufacture of sweetened condensed milk, the sugar solution should not be subjected to the lengthy heat treatment of the milk. Hunziker (12) advises drawing the sugar solution into the vacuum pan at the end of the process.

The viscosity of a sugar solution, or its resistance to flow, varies with the sugar or sugars present. Dextrose solutions are more fluid than cane sugar solutions of equal density. Ondorff (18) concluded that 50 percent dextrose was 22 percent less viscous than a sucrose solution of equal concentration between the temperature of 77° and 122°F.

This factor is of advantage in many instances, but the disadvantages are as numerous. It makes the handling of highly concentrated solutions much easier, and, when syrups of low viscosity are desired it is beneficial. But viscosity is necessary in many products either for appearance or other properties. In the experimental work to
follow, the author will attempt to point out these instances.

Nutritional Values of Dextrose

Since all sugars and starches are ultimately converted within the body to dextrose, the substitution of dextrose for sucrose is not injurious to health. It is true that the end products of hydrolysis of starches and sugars are not dextrose alone but also levulose and galactose. The liver functions in the conversion of the levulose and galactose to dextrose.

Therapeutic uses of dextrose have received much attention in recent years and no doubt, dextrose has a medicinal value in many ailments. The subject of remedial uses of dextrose is well summarized in a booklet published and distributed by the Corn Products Refining Company (3).

Review of Previous Work

Van Arsdale and Eddy (25) conducted a series of experiments on the preservation of fruits and vegetables using different combinations of corn sugar and cane sugar. These workers concluded that dextrose has a place in the field of fruit and vegetable preservation. They have worked out acceptable and non-acceptable combinations of the sugars for each product. Of 302 combinations studied and
judged, 192 have been judged as acceptable.

These same investigators have stated that in some products improvements have been accomplished by the use of corn sugar. The major improvement is the possibility of retaining the same concentration of sugar without the disadvantage of excessive sweetness. The use of dextrose was found acceptable in canned tomatoes, peas, beets, carrots, peaches, pears, marmalade, cranberry and currant jellies, and various other preserves.

Onsdorff (18) substantiated the work of Van Arsdale and Eddy (25) relative to corn packs and concluded that the presence of any dextrose was injurious to the qualities of the pack. This investigator studied cane-dextrose combinations in the canning of prunes and plums and reported favorably for these products. The use of dextrose was not found to be desirable with apple and pear products. Miller (15) in his studies concluded that cane-dextrose combinations gave favorable results with rhubarb sauce and applesauce in the ratio of 50 percent cane to 50 percent dextrose, with strawberry preserves, currant jelly and cherry preserves in the ratio 75/25; and with raspberry preserves and blackberry preserves in the ratio of 80/20. This worker also concluded that the use of dextrose with canned blackberries, canned blueberries and blueberry preserves was not desirable.

Onsdorff (18) and Miller (15) have concluded that dextrose has a definite place in pickle manufacture when
used in combination with sucrose. Dextrose improves the quality of the pickles and aids in preventing any undesirable fermentation.

Buchanan (6) in his studies on the use of dextrose in beverage manufacture has pointed out the advantage of its use. He states that dextrose, being less sweet, may be used to increase the solids without any deleterious effect to flavor; an increase in solids content will result in an improved body. Also, since the primary source of spoilage in this industry is fermentation by yeast, the use of dextrose decreases the possibility of yeast contamination because dextrose is manufactured free of this organism. Many samples of sucrose studied by this investigator have shown the presence of yeast.

The use of dextrose in milk products has been studied by many investigators. Rogers (22), Runziker (12), and Ramsey, Tracy, and Ruehe (19) have studied its use in the production of sweetened condensed milk. Runziker (12) concluded that it may be used to an advantage if properly incorporated. Ruehe (23) and Coombs and Bele (8) have found that dextrose has a possible place in the ice cream industry. The extent to which it may be used depends largely upon the general composition of the ice cream mix. It has found favor in building up the solids content of low fat ice cream. Its uses in sherbets and ices has been advised to prevent surface crusting of sucrose crystals.
Experimental Procedure

Introduction to the Problem

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

The method of study is mainly that of substituting dextrose in varying percentages of the normal amount of sucrose present and determining the beneficial or detrimental effects of its presence. If dextrose were found not to be detrimental at an definite percentage, the commercial formula was altered to incorporate this approximate percentage of dextrose.

All the fruit sauces and syrups, as a rule, contain approximately 65 percent sugar, an amount that will prevent the growth of yeast and bacteria. This extreme amount renders the product excessively sweet where sucrose is used entirely. Since dextrose is but three quarters as sweet as sucrose, its use in these products should be beneficial.

In addition to a sugar, fruit sauces and syrups contain added color and flavor to withstand "cutting" or diluting at the soda fountain, citric acid to prevent the masking of the flavor by the sugar, and sodium benzoate as a preservative.
The desired concentration is obtained by the addition of the correct amount of sugar rather than by a process of evaporation. Since dextrose contains a molecule of water of crystallization, it is necessary to make allowances in weight calculations.

Other experimental work consists of observations on the effect of dextrose on viscosity and keeping quality of the products.

**Sodium Benzoate as a Preservative**

The use of sodium benzoate is commonly practiced in the sauce and syrup industry. The producer must make certain that his product will not spoil under the most adverse conditions that it might meet in its normal commercial life. The product is expected to withstand mold growth after the container has been opened and allowed to remain in a warm room. In the industry the customary one tenth of one percent of sodium benzoate is used and stated on the label.

There seems to be no truth in the general belief that sodium benzoate is harmful, at least, not in the limited amounts commonly used. Chittenden, Long, and Herter (7) in 1909 concluded that sodium benzoate is harmful, but later investigation has not substantiated this.
Solubility of Dextrose in the Presence of Invert Sugar

In the heat treatment of fruit products, especially those containing large amounts of acid, inversion of added sucrose is to be expected. In Table 1 the author shows that the solubility of dextrose is materially decreased when sucrose is inverted to any great extent.

In advising the use of dextrose, it is well to allow a margin of safety because the extent of inversion will vary with the method of handling, the amount of acid present, and the heat treatment.

Experimental Results on Commercial Formulae

Strawberry Fruit Sauce

This product was prepared on an experimental scale. The commercial formula was reduced to a proportion easily handled in the laboratory. The products were observed for defects that might result from the use of corn sugar.

The addition of a dextrose-sucrose combination in the ratio of one to one was found to be acceptable for strawberry fruit sauce as shown in Table 2. With this combination excessive sweetness was avoided.
Table 1. Solubility of Dextrose in the Presence of Invert Sugar

<table>
<thead>
<tr>
<th>Sample no.</th>
<th>Sucrose percent</th>
<th>Dextrose percent</th>
<th>Viscosity (seconds)</th>
<th>Soluble solids by refract.</th>
<th>Dextrose added + dextrose formed by inversion</th>
<th>Remarks</th>
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<td>16*</td>
<td>8.5</td>
<td>53.5</td>
<td>4.8</td>
<td>61.0</td>
<td>63.0</td>
<td>&quot;</td>
</tr>
<tr>
<td>17*</td>
<td>--</td>
<td>67.0</td>
<td>5.0</td>
<td>62.0</td>
<td>67.0</td>
<td>&quot;</td>
</tr>
</tbody>
</table>

* Phosphoric acid used to invert the sucrose present. Heat treatment was 30 min. at 212°F.
Table 2. Physical Properties of Strawberry Fruit Sauce Prepared with Dextrose

<table>
<thead>
<tr>
<th>Lot</th>
<th>Sucrose-dextrose ratio</th>
<th>Soluble solids by refractometer</th>
<th>Crystallization</th>
<th>Criticism</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100 - 0</td>
<td>67.2</td>
<td>none</td>
<td>acceptable</td>
</tr>
<tr>
<td>2</td>
<td>75 - 25</td>
<td>66.5</td>
<td>none</td>
<td>acceptable</td>
</tr>
<tr>
<td>3</td>
<td>50 - 50</td>
<td>65.3</td>
<td>none</td>
<td>acceptable</td>
</tr>
<tr>
<td>4</td>
<td>25 - 75</td>
<td>66.1</td>
<td>slight</td>
<td>not acceptable</td>
</tr>
<tr>
<td>5</td>
<td>0 - 100</td>
<td>64.7</td>
<td>complete</td>
<td>not acceptable</td>
</tr>
</tbody>
</table>
Commercial strawberry fruit sauce formula:

To the drained and weighed fruit from one barrel of two-plus-one frozen strawberries add one pound of sugar to each pound of fruit. Add 8 ounces of strawberry red color liquid and heat to 180°F. to insure complete solution of the sugar. Add 16 ounces of fruit juice and 1/2 pound of sodium benzoate dissolved in two quarts of water. Add 16 ounces of true fruit extract and mix thoroughly.

The alterations necessary when dextrose is used in a 50/50 ratio are:

9 ounces of dextrose and 8 ounces of sucrose are used in place of one pound of sucrose to each pound of fruit.

14 ounces of fruit acid are used instead of 16 ounces.
Less flavor can be used if desired.

Pineapple Fruit Sauce

Pineapple fruit sauce is one of the few products that contains no added flavoring and coloring. Fruit acid has been added to cover the excessive sweetness that results from the incorporation of the high percentage of sugar. Possibly less sugar should be added, but this factor is one of individual taste.

* The originals of this and the following formulae may be found in Robertson's thesis (21)
In the judging of this product it was shown that the addition of dextrose in a 50/50 ratio improved the flavor. The all-dextrose product was acceptable except for the crystallization which is sufficient justification for disqualification. In all the ratios studied, no off-flavor or discoloration were found. The 50/50 ratio has been chosen as the ideal, primarily because of its excellent flavor and freedom from crystallization at normal storage temperatures.

If pineapple fruit sauce were made expressly for the ice cream trade, it would be possible and advisable to decrease the sugar content and pack in containers sufficient for only a single batch of ice cream.

In Table 3 the physical properties of pineapple fruit sauce, prepared with varying proportions of dextrose, are given.

**Commercial pineapple fruit sauce formula:**

From 60 large cans of crushed pineapple packed in its own juice (each can has a net weight of 6 pounds and 10 ounces) 24 gallons of juice are drained off. To this drained fruit 8 ounces of fruit acid, 1/2 pound sodium benzoate dissolved in 2 quarts of water, and 300 pounds of sugar are added. With stirring, it is heated to 180°F. to dissolve the sugar.

The alteration necessary when dextrose is used to yield a 50 cane to 50 dextrose ratio is 160 pounds of dextrose
Table 3. Physical Properties of Pineapple Fruit Sauce
Prepared with Dextrose

<table>
<thead>
<tr>
<th>Lot</th>
<th>Sucrose-dextrose ratio</th>
<th>Soluble solids by refractometer</th>
<th>Crystallization</th>
<th>Criticism</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100 - 0 Dyno</td>
<td>65.2</td>
<td>none</td>
<td>acceptable</td>
</tr>
<tr>
<td>2</td>
<td>75 - 25 &quot;</td>
<td>62.5</td>
<td>none</td>
<td>acceptable</td>
</tr>
<tr>
<td>3</td>
<td>50 - 50 &quot;</td>
<td>62.2</td>
<td>none</td>
<td>preferred</td>
</tr>
<tr>
<td>4</td>
<td>25 - 75 &quot;</td>
<td>60.0</td>
<td>slight</td>
<td>not acceptable</td>
</tr>
<tr>
<td>5</td>
<td>0 - 100 &quot;</td>
<td>57.1</td>
<td>complete</td>
<td>not acceptable</td>
</tr>
<tr>
<td>6</td>
<td>75 - 25 cerelose</td>
<td>60.0</td>
<td>none</td>
<td>acceptable</td>
</tr>
<tr>
<td>7</td>
<td>50 - 50 &quot;</td>
<td>61.3</td>
<td>none</td>
<td>acceptable</td>
</tr>
<tr>
<td>8</td>
<td>25 - 75 &quot;</td>
<td>59.4</td>
<td>none</td>
<td>acceptable</td>
</tr>
</tbody>
</table>
and 150 pounds of sucrose in place of 300 pounds of sugar.

Chocolate Fudge Sauce

Chocolate fudge is a sauce that is not very easy to manufacture in the laboratory. Small batches require a very fine control in order to obtain comparable results in using different combinations of dextrose and cane.

This product obtains its viscosity from the dextrins in corn syrup rather than the sugar added, therefore, the tendency to thicken, as do other chocolate products, is greatly eliminated.

Sweetness is not a problem in this product. The experimental work was to determine the possibility of substituting dextrose for the sucrose present. A ratio of 25 cane to 75 dextrose of the added sugar was found acceptable.

Commercial chocolate fudge formula:

A mixture of 32 pounds of corn syrup, 40 pounds of sugar, 1 3/4 gallons of water, and 1/8 ounce of salt is made and heated to 210°F. The heated mixture is placed in the beater and to it is added slowly 24 pounds of melted chocolate liquor. The above is cooled by beating slowly. After cooling, 6 pounds of salted butter and 3 quarts of heavy cream are beaten into the above ingredients.
The alteration necessary to obtain a 25 cane to 75 dextrose ratio is the addition of 33 pounds of dextrose and 10 pounds of sucrose instead of 40 pounds of sugar.

**Bittersweet Sauce**

Bittersweet sauce is like chocolate syrup in general composition, except for its higher content of cocoa. This sauce is subject to the same defects as chocolate syrup, that is, it will thicken abnormally; this thickening is not prevented by the presence of dextrose.

A 50/50 ratio is considered the most preferable of all ratios studied. A 25 cane to 75 dextrose is acceptable.

**Commercial bittersweet sauce formula:**

75 pounds of Dutch process cocoa are thoroughly mixed with 75 pounds of sugar and are added to a heated sugar solution (10 gallons of water and 75 pounds of sugar). 8 ounces of sodium benzoate, 24 grains of salt, and 8 pints of glycerol are added to the above mixture.

The alteration necessary when dextrose is used in the ratio of 50 cane to 50 dextrose is 80 pounds of dextrose dissolved in 10 gallons of water rather than 75 pounds of sugar.
Butterscotch Sauce

The butterscotch sauce made up as directed in the formula that is to follow is not an ideal one for experimental purposes. Laboratory batches were not made in quantities large enough for use in a homogenizer that could develop the high pressure desired to distribute thoroughly the fat globules.

Partial substitution of dextrose did not impair the quality of the product although no improvement was evident. The use of dextrose in this product is limited by crystallization. The recommended formula is one using a ratio of 50 cane to 50 dextrose of the added sugar.

Commercial butterscotch sauce formula:

10 pounds of corn starch is mixed thoroughly with 6 gallons of water. 20 gallons of corn syrup and 200 pounds of sugar are added to the starch and water mixture. After heating the above to boiling, 10 pounds of butter, 3 quarts of vinegar, and 2 ounces of sugar color are added. The sauce is homogenized at 3000 pounds pressure.

The alteration necessary when dextrose is used in the ratio of 50 cane to 50 dextrose is 100 pounds of sucrose and 110 pounds of dextrose instead of 200 pounds of sugar.
There are many marshmallow sauces on the market and each and everyone is to meet a specific need. The one studied here is a common product used in the soda fountain trade.

The author was unable to find any noticeable differences existing when the product was made by substituting dextrose for the total amount of sucrose present. Therefore, it is deemed acceptable to use dextrose entirely.

Commercial marshmallow sauce:

20 pounds of corn syrup and 20 pounds of sugar are heated to 230°F. This mixture is added to 70 pounds of corn syrup that has been placed in the beater. The beater is started, and one pound of egg albumin which has been soaked in one quart of water, and 8 ounces of vanilla extract are added.

The alteration necessary with the use of dextrose as the entire amount of added sugar is 22 pounds of dextrose rather than 20 pounds of sugar in the above formula.

Strawberry Syrup

Strawberry fruit syrup is a by-product of the strawberry fruit sauce made from cold packed fruit. The strawberry syrup derived from this fruit will contain approximately
46 percent sugar. The general method in use is to increase the sugar to 65-67 percent by the refractometer.

Since cold packed fruit contains sucrose, the work on this product had to deal with the added sugar. When fresh fruit is used it is best not to exceed the ratio of 50 cane to 50 dextrose of the entire amount of the sugar present as shown in Table 1.

Since this product is highly flavored and colored by the addition of true fruit extract and artificial color, the problem is mainly one of crystallization and sweetness.

Dextrose, being less sweet, allows a more complete penetration of flavor, therefore, it is possible to extend the syrup further. When cold packed fruit is used, dextrose may be substituted entirely as the added sugar in the formula.

Commercial strawberry syrup formula:

300 pounds of sugar is added to 39 gallons of strawberry fruit juice from two-plus-one fruit. To this is added 3 pints of ponceau color solution (4 ounces of ponceau made up to a gallon with water) and 1/2 pound of sodium benzoate dissolved in 2 quarts of water. The flavor is fortified with one gallon of true fruit extract.

The alteration necessary when dextrose is used is 330 pounds of dextrose instead of 300 pounds of sugar. If the flavor is too strong, the amount of extract should be decreased.
Table 4. Physical Properties of Strawberry Syrup Prepared with Dextrose

<table>
<thead>
<tr>
<th>Lot</th>
<th>Fruit</th>
<th>Sucrose- dextrose ratio</th>
<th>Soluble solids by refract.</th>
<th>Crystallization</th>
<th>Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>fresh</td>
<td>100 - 0</td>
<td>65.2</td>
<td>none</td>
<td>acceptable</td>
</tr>
<tr>
<td>2</td>
<td>fresh</td>
<td>75 - 25</td>
<td>66.0</td>
<td>none</td>
<td>acceptable</td>
</tr>
<tr>
<td>3</td>
<td>fresh</td>
<td>50 - 50</td>
<td>64.5</td>
<td>none</td>
<td>acceptable</td>
</tr>
<tr>
<td>4</td>
<td>fresh</td>
<td>25 - 75</td>
<td>64.7</td>
<td>slight</td>
<td>not judged</td>
</tr>
<tr>
<td>5</td>
<td>fresh</td>
<td>0 - 100</td>
<td>65.3</td>
<td>complete</td>
<td>not judged</td>
</tr>
<tr>
<td>6</td>
<td>cold packed</td>
<td>100 - 0</td>
<td>66.3</td>
<td>none</td>
<td>acceptable</td>
</tr>
<tr>
<td>7</td>
<td>cold packed</td>
<td>75 - 25</td>
<td>67.1</td>
<td>none</td>
<td>acceptable</td>
</tr>
<tr>
<td>8</td>
<td>cold packed</td>
<td>50 - 50</td>
<td>65.8</td>
<td>none</td>
<td>acceptable</td>
</tr>
<tr>
<td>9</td>
<td>cold packed</td>
<td>25 - 75</td>
<td>61.7</td>
<td>none</td>
<td>acceptable</td>
</tr>
<tr>
<td>10</td>
<td>cold packed</td>
<td>0 - 100</td>
<td>62.9</td>
<td>none</td>
<td>acceptable</td>
</tr>
</tbody>
</table>
Pineapple Syrup

The manufacture of pineapple fruit syrup is an attempt to make an economical use of an otherwise waste product. Sales of pineapple syrup are limited.

In this product it was found that dextrose and cane combinations were acceptable. The most ideal ratio was one of 50/50 as this withstood exposure better than the other combinations including the all sucrose preparation. Surface crystallization was absent from this combination whereas all sucrose and 75 sucrose to 25 dextrose formed a crust of sucrose crystals.

Discoloration of this product by dextrose was not found to occur. Flavor and palatability of the product is influenced more by the extract added than by the sugar present.

Pineapple syrup having a 50 cane to 50 dextrose ratio of added sugars has been found acceptable as shown in Table 5.

Commercial pineapple syrup formula:

1380 pounds of sugar is dissolved in 100 gallons of pineapple juice. 2 pounds of sodium benzoate dissolved in 2 quarts of water and 400 ounces of pineapple true fruit extract are added to the solution.
Table 5. Physical Properties of Pineapple Syrup
Prepared with Dextrose

<table>
<thead>
<tr>
<th>Lot</th>
<th>Lot Sucrose ratio</th>
<th>Changes in viscosity* percent</th>
<th>Soluble solids by refractometer</th>
<th>Crystallization criticism</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100 - 0</td>
<td>69</td>
<td>63.2</td>
<td>none</td>
</tr>
<tr>
<td>2</td>
<td>75 - 25</td>
<td>69</td>
<td>63.4</td>
<td>none</td>
</tr>
<tr>
<td>3</td>
<td>50 - 50</td>
<td>32</td>
<td>63.5</td>
<td>none</td>
</tr>
<tr>
<td>4</td>
<td>25 - 25</td>
<td>41</td>
<td>62.5</td>
<td>slight</td>
</tr>
<tr>
<td>5</td>
<td>0 - 100</td>
<td>67</td>
<td>60.2</td>
<td>complete</td>
</tr>
</tbody>
</table>

* +% increase in viscosity in relation to that of sucrose.
- -% decrease in viscosity in relation to that of sucrose.
The alteration necessary when dextrose is used in a 50 cane to 50 dextrose ratio is 750 pounds of dextrose and 700 pounds of sucrose rather than 1380 pounds of sugar.

Chocolate Syrup

Chocolate syrup is the most popular syrup manufactured. The method of manufacturing varies greatly with the individual producer. In this work the use of dextrose in chocolate syrup is studied in relation to but one formula which results in a good product and seems to be representative of the industry.

In summarizing the results of the experimental work on chocolate syrup, the following has been found: crystallization took place at the ratio of 25 cane to 75 dextrose; all combinations, including the all dextrose product, were judged equal; surface crusting was absent in the ratios of 50/50 and others containing a greater proportion of dextrose; initial viscosity was lower when dextrose was used; all combinations thickened on storing; and mold growth was prevalent in all combinations.

The product made from the formula to follow is not used in the manufacture of ice cream primarily because of its high sugar content. In the production of a chocolate syrup for ice cream use, the sugar content is approximately
that of the ice cream mix in which it is to be used. This is accomplished by mixing proper proportions of cocoa or chocolate liquor, sugar, and water. Another method is to mix thoroughly cocoa and a small amount of sugar and incorporate this in an ice cream mix. In general practice the ice cream manufacturer makes up his own chocolate syrup.

**Commercial chocolate syrup formula:**

198 pounds of cocoa and 500 pounds of sugar are mixed thoroughly to aid dispersion. 376 pounds of sugar are dissolved in 62 gallons of heated water and the cocoa and sugar mixture is added and stirred while heating until smooth. Pure vanilla, or 5 1/2 ounces of vanillin and 10 1/2 ounces of sodium benzoate are then added.

The alterations necessary in the presence of dextrose in the ratio of 50 cane to 50 dextrose are 275 pounds of dextrose and 250 pounds of sucrose rather than 500 pounds of sugar to be mixed with the cocoa and 200 pounds of dextrose and 190 pounds of sucrose rather than 376 pounds of sugar to be dissolved in the water.
### Table 1. Physical Properties of Chocolate Syrup Prepared with Dextrose

<table>
<thead>
<tr>
<th>Lot</th>
<th>Sucrose-Dextrose Ratio</th>
<th>Surface Crystallization</th>
<th>Crystallization</th>
<th>Thickening</th>
<th>Criticism</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100 - 0</td>
<td>yes</td>
<td>none</td>
<td>yes</td>
<td>acceptable</td>
</tr>
<tr>
<td>2</td>
<td>75 - 25</td>
<td>yes</td>
<td>none</td>
<td>yes</td>
<td>acceptable</td>
</tr>
<tr>
<td>3</td>
<td>50 - 50</td>
<td>none</td>
<td>none</td>
<td>yes</td>
<td>acceptable</td>
</tr>
<tr>
<td>4</td>
<td>25 - 75</td>
<td>none</td>
<td>slight</td>
<td>yes</td>
<td>not acceptable</td>
</tr>
<tr>
<td>5</td>
<td>0 - 100</td>
<td>none</td>
<td>complete</td>
<td>yes</td>
<td>not acceptable</td>
</tr>
</tbody>
</table>
Chocolate Syrup for Ice Cream

A single formula for a chocolate syrup to be used in ice cream is as follows: one pound of sugar is mixed thoroughly with 1 1/4 pounds of cocoa and stirred rapidly into 2 quarts of heated water.

Since the sugar content is low, there is no danger of dextrose crystallization when used as the entire source of sugar. Yeast fermentation occurs in this product.

When each combination was used in the manufacture of a chocolate ice cream, judges stated that there was no recognizable difference between combinations of dextrose and sucrose.

Coffee Syrup

Coffee syrup is merely a flavored simple syrup with a sugar content ranging from 60-65 percent. Corn syrup and glycerol are added to produce a better body. In addition there exists a belief that glycerol aids in the prevention of mold growth (20) and is a better carrier of extract than alcohol.

The substitution of dextrose for sucrose in this product improves the flavor and renders milk shakes less sweet.
In judging coffee syrup it seemed advisable to use it in milk shakes as this is its most common use. Consensus of opinion among the judges granted that coffee syrup is improved by the addition of dextrose; the majority preferring an all dextrose product. But, since crystallization is dangerous at a 25 cane to 75 dextrose ratio, the ratio should not exceed 35 cane to 65 dextrose.

This product should be stored in a refrigerator away from light and heat to aid in the prevention of mold growth, which is prevalent in this product as is shown in Table 7.

Commercial coffee syrup formula:

17 gallons of water, one gallon of corn syrup, one gallon of glycerol, and 300 pounds of sugar are heated together to obtain a complete solution of all ingredients. To the above 1/2 pound of sodium benzoate, one quart of sugar color, and 168 ounces of coffee extract are added.

The alteration necessary when dextrose is used is 210 pounds of dextrose and 110 pounds of sucrose instead of 300 pounds of sugar in the above formula.

Ginger Syrup

Ginger syrup is a flavored simple syrup which is very similar to many other syrups on the market.

Dextrose may be substituted for sucrose up to the point of crystallization without any noticeable defects and
Table 7. Physical Properties of Coffee Syrup
Prepared with Dextrose

<table>
<thead>
<tr>
<th>Lot</th>
<th>Sucrose-dextrose ratio</th>
<th>Changes in viscosity%</th>
<th>Mold growth</th>
<th>Soluble solids by refract.</th>
<th>Crystallization</th>
<th>Criticism</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100 - 0</td>
<td>yes</td>
<td>63.1</td>
<td>none</td>
<td>acceptable</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>75 - 25</td>
<td>yes</td>
<td>59.4</td>
<td>none</td>
<td>acceptable</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>50 - 50</td>
<td>yes</td>
<td>61.5</td>
<td>none</td>
<td>preferred</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>25 - 75</td>
<td>yes</td>
<td>59.9</td>
<td>slight</td>
<td>not acceptable</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0 - 100</td>
<td>yes</td>
<td>58.7</td>
<td>complete</td>
<td>not acceptable</td>
<td></td>
</tr>
</tbody>
</table>

\* - % decrease in viscosity in relation to that of sucrose.
some decided improvements as is shown in Table 8. Dextrose improves the penetrating qualities of the flavoring extract, thereby permitting the use of more sugar per unit volume of extract which results in an improved body of the beverage without excessive sweetness.

A ratio of 50 cane to 50 dextrose is recommended. This ratio will yield a product not too sweet or too dry.

Commercial ginger syrup formula:

7 pounds of sugar are dissolved in 60 ounces of water by heating. To this sugar solution 4 ounces of ginger extract, 5 grams of sodium benzoate, and 6 cc. of sugar color are added.

The alteration necessary when dextrose is used to obtain a 50 cane to 50 dextrose ratio is 3.75 pounds of dextrose and 3.5 pounds of sucrose rather than 7 pounds of sugar.

**Vanilla Syrup**

Vanilla syrup is another flavored simple syrup representative of those made by diluting extracts with sugar syrups so that they may be used at the fountain. The partial substitution of dextrose does not detract from the product as long as it is not added in an amount that will cause crystallization. This is shown in Table 9. The syrup is not generally used in ice cream manufacture.
Table 8. Physical Properties of Ginger Syrup
Prepared with Dextrose

<table>
<thead>
<tr>
<th>Lot</th>
<th>Sucrose-dextrose ratio</th>
<th>Change in viscosity* percent</th>
<th>Soluble solids by refract.</th>
<th>Crystallization</th>
<th>Criticism</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100 - 0</td>
<td>0</td>
<td>65.4</td>
<td>none</td>
<td>acceptable</td>
</tr>
<tr>
<td>2</td>
<td>75 - 25</td>
<td>- 15.0</td>
<td>65.2</td>
<td>none</td>
<td>acceptable</td>
</tr>
<tr>
<td>3</td>
<td>50 - 50</td>
<td>- 19.5</td>
<td>64.1</td>
<td>none</td>
<td>preferred</td>
</tr>
<tr>
<td>4</td>
<td>25 - 75</td>
<td>- 22.4</td>
<td>63.3</td>
<td>partial</td>
<td>not acceptable</td>
</tr>
<tr>
<td>5</td>
<td>100 - 100</td>
<td>- 26.9</td>
<td>64.7</td>
<td>complete</td>
<td>not acceptable</td>
</tr>
</tbody>
</table>

* % decrease in viscosity in relation to that of sucrose.
Table 9. Physical Properties of Vanilla Syrup
Prepared with Dextrose

<table>
<thead>
<tr>
<th>Lot</th>
<th>Sucrose-dextrose ratio</th>
<th>Changes in viscosity* percent</th>
<th>Soluble solids by refract.</th>
<th>Crystallization</th>
<th>Criticism</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100 - 0</td>
<td>-</td>
<td>54.0</td>
<td>none</td>
<td>acceptable</td>
</tr>
<tr>
<td>2</td>
<td>75 - 25</td>
<td>-3.0</td>
<td>54.0</td>
<td>none</td>
<td>acceptable</td>
</tr>
<tr>
<td>3</td>
<td>50 - 50</td>
<td>-3.0</td>
<td>53.5</td>
<td>none</td>
<td>acceptable</td>
</tr>
<tr>
<td>4</td>
<td>25 - 75</td>
<td>0</td>
<td>54.0</td>
<td>none</td>
<td>acceptable</td>
</tr>
<tr>
<td>5</td>
<td>0 - 100</td>
<td>-6.0</td>
<td>54.0</td>
<td>complete</td>
<td>not acceptable</td>
</tr>
</tbody>
</table>

* - decrease in viscosity relative to that of sucrose.
but the amount of dextrose, if substituted, would not be deleterious to the ice cream.

A vanilla syrup of a 25 cane to 75 dextrose ratio is recommended and is acceptable.

Commercial vanilla syrup formula:

4 1/2 gallons of simple syrup (60-65°) are mixed thoroughly with 8 ounces of sugar color, and 3 gallons of 10 X vanilla extract.

The alteration necessary to obtain the recommended cane-dextrose ratio 25/75 is a simple syrup made up of 25 cane to 75 dextrose (15 pounds of sucrose, 49 pounds of dextrose, and 36 pounds of water will yield a 60° syrup).

Orange Syrup

The use of dextrose in an orange syrup did not yield as good results as were obtained in other products. The dextrose allowed a complete penetration of a rind taste which is very disagreeable. Possibly this taste is caused by the instability of the terpenes in the oil of orange. It was found to be more disagreeable as the percentage of dextrose increased.

The use of dextrose should be avoided where the dextrose content will exceed that of a ratio of 75 cane
to 25 dextrose as shown in Table 10.

Commercial orange syrup formula:

11 gallons of concentrated orange juice (6 to 1) are diluted with 90 gallons of water. 2 pounds of sodium benzoate, 1650 pounds of sugar, and 2 gallons of sunset yellow liquid (4 ounces of dry sunset yellow made up to one gallon with water) are dissolved in the orange juice prepared above with the aid of heat. An emulsion of 8 pints of oil of orange and 8 pounds of gum arabic is added to the orange syrup.

Orangeade

The difference between orangeade and orange syrup is the higher acid content of the former.

With orange syrup it was found that dextrose did not improve the flavor. In the case of orangeade it is possible to add some dextrose without encountering any defects. The acid probably masks these defects.

Table 11 shows that no crystallization occurs at a ratio of 50 sucrose to 50 dextrose. This ratio has been judged as preferable in relation to others prepared. The acid should be modified to taste.

Commercial orangeade formula:

15 gallons of concentrated orange juice (6 to 1) is diluted with 90 gallons of water. To the orange juice prepared 17 pounds of citric acid dissolved in 5 gallons
Table 10. Physical Properties of Orange Syrup Prepared with Dextrose

<table>
<thead>
<tr>
<th>Lot</th>
<th>Sucrose-dextrose ratio</th>
<th>Soluble solids by refractometer</th>
<th>Crystallization</th>
<th>Criticism</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100 - 0</td>
<td>67.5</td>
<td>none</td>
<td>preferred</td>
</tr>
<tr>
<td>2</td>
<td>75 - 25</td>
<td>66.5</td>
<td>none</td>
<td>acceptable</td>
</tr>
<tr>
<td>3</td>
<td>50 - 50</td>
<td>66.0</td>
<td>none</td>
<td>not acceptable</td>
</tr>
<tr>
<td>4</td>
<td>25 - 75</td>
<td>65.0</td>
<td>partial</td>
<td>not acceptable</td>
</tr>
<tr>
<td>5</td>
<td>0 - 100</td>
<td>64.5</td>
<td>complete</td>
<td>not acceptable</td>
</tr>
</tbody>
</table>
Table II. Physical Properties of Orangeade Prepared with Dextrose

<table>
<thead>
<tr>
<th>Lot</th>
<th>Sucrose-dextrose ratio</th>
<th>Soluble solids by refractometer</th>
<th>Crystallization</th>
<th>Criticism</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100 - 0</td>
<td>66.3</td>
<td>none</td>
<td>acceptable</td>
</tr>
<tr>
<td>2</td>
<td>75 - 25</td>
<td>65.2</td>
<td>none</td>
<td>acceptable</td>
</tr>
<tr>
<td>3</td>
<td>50 - 50</td>
<td>67.1</td>
<td>none</td>
<td>preferred</td>
</tr>
<tr>
<td>4</td>
<td>25 - 75</td>
<td>64.3</td>
<td>partial</td>
<td>not acceptable</td>
</tr>
<tr>
<td>5</td>
<td>0 - 100</td>
<td>64.5</td>
<td>complete</td>
<td>not acceptable</td>
</tr>
</tbody>
</table>
of water, 2 1/2 pounds of sodium benzoate dissolved in one
gallon of water, 1650 pounds of sugar, and one gallon of
sunset yellow liquid are added. An emulsion of 4 pints of
oil of orange, 4 pounds of gum arabic, and 8 pints of water
is added to the above solution.

The alteration necessary when dextrose is used is
900 pounds of dextrose and 825 pounds of sucrose.

Lemon Syrup

A lemon syrup is not much different from other syrups.
The sugar content is built up to 55 percent; the flavoring
depends upon the addition of oil of lemon; and the coloring
depends upon the addition of color characteristic to that
of the fresh fruit juice.

Improvements are quite evident with the substitution
of dextrose. The excessive sweetness is reduced and the
natural flavor is enhanced. Table 12 shows that a 50
cane to 50 dextrose ratio is best. Crystallization takes
place at a ratio of 75 dextrose to 25 cane. Extensive
inversion of the cane sugar is likely to occur in this
acid product. Such an inversion will cause crystallization
at lower concentration of added dextrose.

Commercial lemon syrup formula:

2 crates of lemons (300 count) are peeled. The
juice is extracted from 4 crates, including the two peeled
Table 12. Physical Properties of Lemon Syrup
Prepared with Dextrose

<table>
<thead>
<tr>
<th>Lot</th>
<th>Sucrese-Dextrose Ratio</th>
<th>Soluble solids by refractometer</th>
<th>Crystallization</th>
<th>Criticism</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100 - 0</td>
<td>65.0</td>
<td>none</td>
<td>acceptable</td>
</tr>
<tr>
<td>2</td>
<td>75 - 25</td>
<td>65.0</td>
<td>none</td>
<td>acceptable</td>
</tr>
<tr>
<td>3</td>
<td>50 - 50</td>
<td>65.0</td>
<td>none</td>
<td>preferred</td>
</tr>
<tr>
<td>4</td>
<td>25 - 75</td>
<td>65.0</td>
<td>slight</td>
<td>not acceptable</td>
</tr>
<tr>
<td>5</td>
<td>0 - 100</td>
<td>65.0</td>
<td>complete</td>
<td>not acceptable</td>
</tr>
</tbody>
</table>
20 gallons of water are added to the fruit pulp and a second extraction is made. Sugar is then added to a concentration of 65 percent by the refractometer. The peels previously removed are ground and 3 gallons of alcohol are added. The alcohol and ground peels are to stand overnight. The oil of lemon is extracted by pressure and added to the lemon syrup above. The syrup is colored with tartrazine and made up to 65 percent with additional sugar.

The alteration necessary when dextrose is used is merely the addition of a mixture of sugars, 54 percent dextrose and 46 percent sucrose rather than the addition of all sucrose.

Studies on Thickening of Chocolate Products

It is well known that the most common defect in chocolate products used as sauces or syrups is the abnormal thickening that frequently occurs on standing. As a rule these products are returned to the manufacturer and are incorporated into the next batch of chocolate. This undesirable thickening may be avoided by producing a syrup of less initial viscosity, that is, one containing more water. It seems that dextrose will reduce the viscosity for a longer period of time than sucrose but even in the presence of dextrose the product will thicken to the extent
that it is impossible to use at the soda fountain.

The theory has been ventured that the thickening may be due to the starch content of the cocoa or chocolate. In an attempt to prove this theory, the amylolytic enzymes, diastase, were used in trying to break down the starch content of the syrup. All attempts to reduce viscosity by this method proved futile, primarily, because cocoa starch is inherently resistant to the diastatic reaction.

The author realizes that it is possible to break down the starch with the enzyme diastase by the creation of conditions suitable for the optimum reaction. However, an attempt to produce such conditions in this work would be losing sight of the ultimate goal - the production of a chocolate syrup.

Viscosity Studies

Dextrose solutions are of lower viscosity than sucrose solutions. This fact has been shown in various tables included in this work.

This factor has been judged as objectionable in many products prepared with sugar. But in the preparation of sauces and syrups, it should not be considered as
objectionable since it allows a freer running syrup which is a practicable factor at the soda fountain. In instances where corn syrup is used to increase the viscosity, it might be argued, that the slight decrease that occurs due to dextrose, is undesirable, but it is doubtful that the difference is significant.

As was previously pointed out, dextrose, although it will lower the initial viscosity of chocolate products, it will not prevent them from thickening.

Dextrose as a Preservative

As explained previously, there is some argument that dextrose should act in a greater capacity as a preservative than does sucrose. Buchanan (6) found this theory to hold true in the lower dilutions, but it has been shown that as the concentration is increased the osmotic pressure of dextrose solutions approach that of sucrose.

Since the products studied here have a high sugar content, the spoilage, if properly handled, is limited to mold growth. It was thought that a casual observation of spoilage in the products would be sufficient to determine the beneficial or detrimental qualities of dextrose as a preservative in relation to these products. In all cases where products developed mold growth easily, those containing varying proportions of dextrose were not protected by
the presence of the dextrose.

The Utilization of Fruit Sauces and Syrups
Prepared with Dextrose in Ice Cream

There is no reason to believe that dextrose will injure the quality of ice cream if used in reasonable amounts. The amount that would be added through the utilization of dextrose in the preparation of fruit and syrups is not equal to the amount that may be added as a sweetening agent in the original mix.

In this investigation, the work was done with an ice cream mix of 1% percent fat and sweetened solely by the use of sucrose. All ice cream made from prepared sauces and syrups did not show any material difference between varying ratios of cane and dextrose.

Summary of Acceptability of Sauces and Syrups
Prepared with Dextrose

Chart I is presented to summarize the results obtained in this investigation. The chart shows the ratio containing the highest proportion of dextrose that may be used in preparation of products that will be acceptable in comparison
Chart I. Summary of Preferred and Acceptable Dextrose-Sucrose Combinations of Added Sugar in Sauces and Syrups

<table>
<thead>
<tr>
<th>Product</th>
<th>Preferred* sucreose-dextrose ratio</th>
<th>Acceptable* sucreose-dextrose ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strawberry fruit sauce</td>
<td></td>
<td>50-50</td>
</tr>
<tr>
<td>Pineapple fruit sauce</td>
<td>50-50</td>
<td></td>
</tr>
<tr>
<td>Chocolate fudge sauce</td>
<td></td>
<td>25-75</td>
</tr>
<tr>
<td>Bittersweet sauce</td>
<td>50-50</td>
<td>25-75</td>
</tr>
<tr>
<td>Butterscotch sauce</td>
<td></td>
<td>50-50</td>
</tr>
<tr>
<td>Marshmallow</td>
<td></td>
<td>0-100</td>
</tr>
<tr>
<td>Strawberry syrup</td>
<td>0-100</td>
<td></td>
</tr>
<tr>
<td>Pineapple syrup</td>
<td>50-50</td>
<td></td>
</tr>
<tr>
<td>Chocolate syrup</td>
<td>50-50</td>
<td></td>
</tr>
<tr>
<td>Coffee syrup</td>
<td>50-50</td>
<td>35-65</td>
</tr>
<tr>
<td>Ginger syrup</td>
<td>50-50</td>
<td></td>
</tr>
<tr>
<td>Vanilla syrup</td>
<td></td>
<td>25-75</td>
</tr>
<tr>
<td>Orange syrup</td>
<td></td>
<td>75-25</td>
</tr>
<tr>
<td>Orangeade</td>
<td>50-50</td>
<td></td>
</tr>
<tr>
<td>Lemon syrup</td>
<td>50-50</td>
<td></td>
</tr>
</tbody>
</table>

* Preferred - a product better than that prepared with sucrose.

Acceptable - a product equal to that prepared with sucrose.
to all sucrose products. In instances where dextrose improved the product the preferred ratio is given.

**Summary**

1. A brief history of the corn sugar industry is presented with a general review of the literature, a discussion of the physical and chemical properties of dextrose, and a review of previous experimental work relative to its utilization in food products.

2. A general discussion of the composition of sauces and syrups is presented with an explanation of the purpose of each constituent.

3. Dextrose solubility is decreased in the presence of invert sugar.

4. Pineapple fruit sauce, bittersweet sauce, coffee syrup, ginger syrup, orangeade, and lemon syrup were found improved by the ratio of 50 sucrose to 50 dextrose. The improvement was that of a less intense sweetness resulting in a better flavor. Strawberry fruit sauce, butterscotch sauce, pineapple syrup, and chocolate syrup were found acceptable at a ratio of 50 sucrose to 50 dextrose. Chocolate fudge sauce, bittersweet sauce, and vanilla syrup were found acceptable at a ratio of 25 cane
to 75 dextrose. Marshmallow and strawberry syrup were found acceptable when the entire amount of added sugar is dextrose. The ratios mentioned deal entirely with added sugar.

5. The presence of dextrose in quantity in an orange syrup definitely injures the flavor. A ratio of 75 cane to 25 dextrose was judged acceptable.

6. Diastase does not prevent thickening of chocolate products.

7. Dextrose will lower the viscosity of sugar solutions but not enough to be detrimental or to prevent thickening of chocolate products.

8. Dextrose does not exert any greater preserving power against mold growth than does sucrose.

9. Ice cream, flavored with these products, was not injured by the dextrose content.

Conclusion

Dextrose has proven its worthiness in food manufacture from an economical and quality product basis. The use of dextrose is greatly limited by its solubility point. Wherever dextrose may be used in part of the total sugar or as all the sugar, it makes the product less expensive to produce and may improve quality.

Dextrose has a place in the manufacture of sauces and
syrups for soda fountain use. Invariably the product is improved slightly by having a less intense sweetness. The formulae recommended are those that the writer feels will give a satisfactory product prepared with dextrose.
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    Dextrose in the Manufacture of Fruit and Vegetable Products.


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Approved by:

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Marvin E. Friedman

Merrill J. Mack

Graduate Committee

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