This is to certify that the

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The Effect of Different Sweeteners
on the Quality of Maraschino Cherries

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TOURAN CHERAGHI-SEIFABAD

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THE EFFECT OF DIFFERENT SWEETENERS ON THE QUALITY OF MARASCHINO CHERRIES

By

Touran Cheraghi-Seifabad

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ABSTRACT

THE EFFECT OF DIFFERENT SWEETENERS ON THE QUALITY OF MARASCHINO CHERRIES

By

Touran Cheraghi-Seifabad

Studies were initiated to determine the effect of eleven corn syrups and corn syrup-sucrose mixtures on the quality of maraschino cherries. Maraschino cherries were produced using commercially brined Napoleon cherries and commercial finishing procedures but substituting the various corn sweetener or corn sweetener-sucrose mixture (50/50) for sucrose. Granulated cane sugar was used as a control. Sweetener composition was determined by HPLC at the beginning of the study. Replicated samples of all treatments were stored at 44^{o}F (6.6^{o}C), 72^{o}F (22.6^{o}C), 84^{o}C (31.7^{o}C); samples were removed at one month intervals to determine product shelf life indicating variations in weight, firmness, falvor and acceptability. Results indicate that during the finishing process the control (sucrose) and High Fructose corn syrups had the highest weight gains. During the storage period products stored at 44^{o}F (6.6^{o}C) had significantly higher weight gain than at the other temperatures. No significant difference was found between firmness of any of the products except the samples made with nusweet, corn syrup, which had a very soft texture.

To my parents and sister and brothers

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INTRODUCTION

For many years, sucrose has been the major sweetener used by the food industry. However, recent economic and availability factors affecting sucrose have placed the spotlight on corn derived sweeteners. These sweeteners are gaining wide acceptance in the food processing industry but before corn syrups can be substituted for sucrose in any product, studies must be done to determine the syrups functionality in the particular system. Although corn syrups have been used to some extent in maraschino cherry production, detailed studies have not been done to determine the effects these sweeteners may have on the final quality of the product.

The purpose of this study was to determine the effects of different sweeteners, alone and in combinations, on the final quality and shelf-life of maraschino cherries.

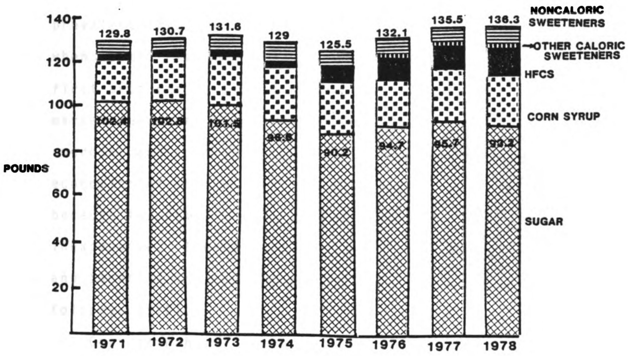
LITERATURE REVIEW

Michigan ranks among the top four states in the United States in production of sweet cherries and 85% to 90% of the crop is processed, mainly as brined fruit for maraschino and glace production (Michigan Agricultural Statistics, 1980). The annual raw product value for 1980 was approximately $10,000,000 and after processing the value would be increased 5 fold, so brining and finishing sweet cherries is economically important to the state of Michigan.

During the finishing operation brined cherries are leached in boiling water to remove SO_2 then placed in a solution containing a sweetener, colorant, flavoring material and perhaps an acid. The concentration of the sweetening agent is increased gradually over a period of time so that the cherry can equilibrate and absorb the finishing solution without shriveling, which would occur if a high osmotic gradient were set up by too high a sweetener concentration. When properly finished, the processed cherry will gain 8 to 10% in weight but this is dependant on many factors, one of the most important of which is the type of sweetener used.

As indicated in Figure 1, the major sweeteners in the U.S. are sucrose and corn syrups (G.A.O. 1980). Sucrose, which is the oldest sweetener known to man is a disaccharide

SUGAR AND OTHER SWEETENERS :U.S. PER CAPITA CONSUMPTION, 1971-1978



SOURCE: OBTAINED FORM GAO

Figure 1. Sugar and other sweeteners: U.S. per capita consumption, 1971-1978.

(α-D-Glucopyransoyl β-D-Fructofranoside) sugar. The primary functions of sucrose are to sweeten and contribute to flavor but sucrose has other properties too. Because sucrose is a disaccharide, it can give a product body, viscosity, surface tension, mouth feel, and under many circumstances it can act as an antioxidant.

One of the major problems with using sucrose as a primary sweetener is the price fluctuation, which has been very prevalent throughout the world. In times of major crisis, when normal channels are interrupted, sugar is one of the first products to be rationed. For this reason, the world market needs new sweeteners which can be used in place of sucrose, and corn products appear to fill this need. The economics of corn wet-milling are generally favorable, because in normal times, corn is plentiful and relatively inexpensive. The industry is highly mechanized, nonseasonal, and benefits the economy (AN FE research report, 1975; Kolodny, 1976).

Corn starch is, therefore, a relatively inexpensive source of carbohydrate and corn syrup derived from starch is a relatively inexpensive sweetener. The corn sweetener systems are particularly interesting at the present time because they are undergoing a revolution. The new system allows corn syrup to be produced by acid conversion, enzyme conversion or both acid and enzyme changes, whereas early syrups were made by strictly acid conversion techniques.

Acid converted syrups are less acceptable because they are limited to about 50% dextrose equivalent (D.E.). Further conversion with acid causes development of highly colored products and off-flavors, which has caused these products to have a low price in the market place. Since starch hydrolyzates were first introduced in 1912, producers of starch syrups have been attempting to increase the sweetness of their syrups without causing color and flavor problems, and thus obtain increased usage of the syrup as sweeteners (Memelstein, 1975; Lloyd et al., 1972).

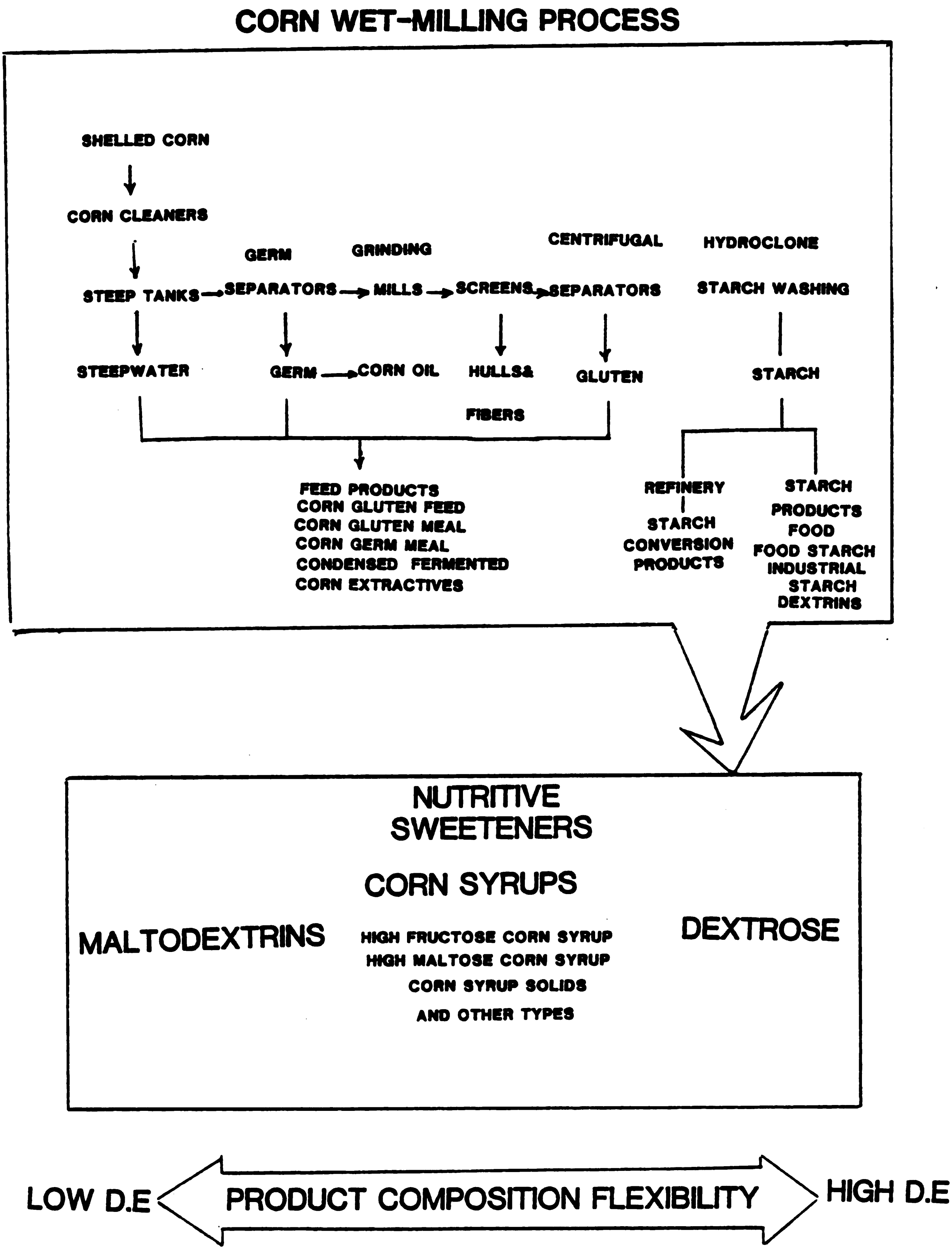
The development of enzyme technology, both from the standpoint of enzyme production and the unique processing involving their use, is a definite technical success story. The number of possible products resulting from these processes is tremendous. In the late 1930's, saccharifying was used in order to produce corn syrup. But before that, liquifying enzyme (alpha amylase) had been used for partial hydrolysis of starch to achieve viscosity reduction for industrial purposes.

In the new enzymatic process, starch was partially hydrolyzed with acid to about 52 D.E. and then hydrolysis was continued to a D.E. of 61-65 with saccharifying enzyme. The resulting syrup did not crystallize as readily as acid-converted syrup but it was still not as sweet as desired. A variety of enzyme systems were eventually introduced and used to create a spectrum of corn syrups having a wide range of sweetness and functional properties (Figure 2 and 3).

Dextrose, which is 100% dextrose monhydrate, is a product made essentially by hydrolysis of starch (Schanefelt, 1977). At first, dextrose, like corn syrup, was produced by acid conversion and had different by-products. The liquid dextrose, known as dydrol, was very difficult to crystalize and was a dark colored, unpalatable liquid. In 1958, dextrose was produced commercially using acid-conversion, followed by enzyme (glucoamylase) hydrolysis (Longlosis, 1942). In this process, starch was partially acid hydrolyzed and then treated with fungal saccharfying enzyme until a D.E. level of 80-95 was attained. This product was more than 80% dextrose and found to be very acceptable on the market. Today a combination of liquifying enzyme (alpha-amylase) and a starch saccharfying enzyme (glucoamylase) is being used.

High fructose corn syrup (HFCS), a new sweetener which may substitute for sugar, first appeared commercially in 1964 and its use has grown rapidly. The product is essentially a 50-50 liquid mixture of D-glucose and D-fructose, with a composition very similar to liquid sugar (Andres, 1974). HFCS sells for less than sugar, which provides an incentive to sugar users to substitute the new sweetener.

In the early 1960's, Japanese scientists developed a production process known as glucose isomerization by which dextrose (glucose) could be enzymatically converted into



SOURCE:CORN REFINERS ASSOCIATION,INC

Figure 2. Corn wet-milling process.

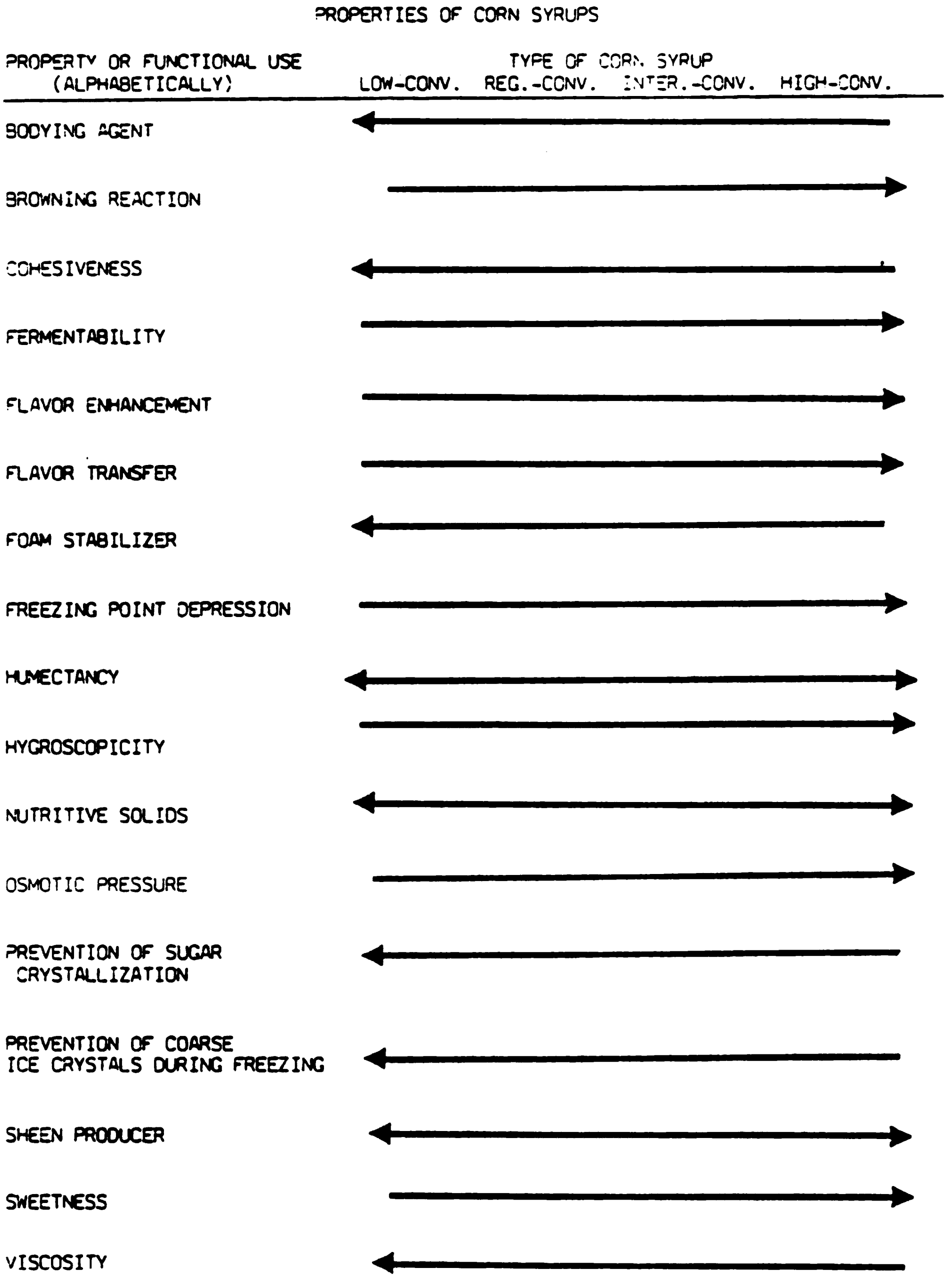


Figure 3. Properties and functional uses of corn syrups

fructose. The general name for these enzymes is Ketol isomerase and they catalyze the rearrangement of sugar molecules in an equilibrium reaction.

Aldose form Ketose form

The transformation involves an intramolecular transfer of H between adjacent carbon atoms in a sugar molecule. In 1957, Marshall and Kooi published their discovery in science under the title "Enzymatic conversion of D-glucose to D-fructose" showing that the enzyme preparation from Pseudomonas hydrophilia, which they described as a specific "xylose isomerase" would, in fact, function also as a "glucose isomerase". Based on the fact that the glucose isomerase enzyme, unlike most other enzymes, is usually retained within the bacterial cell rather than being extracted into medium, one practical technique was to use the whole bacterial cells containing the immobilized enzyme as the isomerizing agent (Natake and Yoshimura, 1963). The glucose isomerase organism grows on xylose in a fermentation medium which is very expensive. Therefore, in 1966, Takasaki proposed that the cost could be reduced by growing special strains of Streptomyces on crude xylan, such as cereal bran or straw, in place of xylose. The results were very satisfactory. Takasaki produced a commercial enzyme in which enzyme containing cells of Streptomyces albuse could be added directly to the dextrose substrate. This enzyme could be reserved either in batch systems or continuously as an immobilized form in columns. The term "immobilized D-glucose isomerase" refers to an enzyme that is insoluble in a water solution of D-glucose and/or D-fructose in low ionic strength, at pH, s between 4 and 9 but can catalyze the reversible isomerization of D-glucose to D-fructose when placed in contact with a solution of D-glucose.

Using these enzyme systems, the production of HFCS is not complicated and involves just a few steps. A suspension of starch in water is heated under pressure, either with a small amount of acid or in the presence of alpha-amylase, at 180^{o}F and a pH around 6.0 for 10 to 20 minutes. After the conversion of starch to about 15-25 D.E. the pH is adjusted to 4.3 and temperature is adjusted to 140^{o}F. This temperature will be held until 95% of the starch is converted. Usually it takes about 72 hours for conversion to be complete unless glucoamylase is added, which reduces the amount of time (McAllister, 1977). This step is called saccharification. A series of filterations and ion-exchanges are then carried on in order to reduce all noncarbohydrate material, such as mineral compounds, which could cause off odor and flavor. At this point, the pH is adjusted to 7.5 and temperature is increased to 150^{o}F. This solution continuously passes through a vessel where it makes contact with immobilized glucose isomerase and conversion is complete in 20 to 30 minutes. The most common compound resulting from this system is a high fructose corn syrup with a composition of about 42% fructose, 52% glucose and 6% other saccharides (on a dry weight basis). A syrup with a higher level of fructose (70% dry basis) can be made from this high fructose corn syrup. One way this is done is to concentrate the liquor under low pressure to a relatively high dry substance level, then separate a crystalized glucose with carefully controlled seeding, gradual cooling and agitation. This new syrup is called fructose-enriched product (Figure 4). Enriched-fructose product also can be made by chromatography but this is a very expensive process and is not commercially feasible. In order to effectively utilize any of these corn products in a processing situation it is necessary to relate the product to a specific operation because we know that the relative sweetness of these compounds is influenced by concentration and the temperature at which the sweetener is used. With sucrost taken as a sweetness level of 100, dextrose solutions up to 15% concentration have been reported to have a relative sweetness of 53 to 87 (Brooks et al., 1973). At concentrations of 40% to 50%, the relative sweetness of dextrose has been reported as high as 100 (Dehlberg and Penczek, 1941; Eickelberg, 1940) (Figure 5). Values in the range of 79 to 180 have been given as the relative sweetness of levulose (fructose) in comparison to sucrose (Redfern and Hichen Bottom, 1972). Invert sugar

Starch Water

Addition of Acid

Liquification Process

Addition of Enzyme

(Alpha-Amylase)

72 hrs

Heat Treatment
$180^{o}F$

Corn Syrup with
Dextrose Equivalent
15-25

pH Adjustment (4.3)
Addition of Gluco-amylase

Heat Treatment
$140^{o}F$

Saccharification Process

Dextrose (95% glucose)

Series of Filtrations

pH Adjustment (7.5)
With Magnesium and Bisulfate

Figure 4. Production of HFCS using immobilized enzyme.

Heat Treatment
$150^{o}F$

Addition of Glucose-isomerase

20 mins High - Fructose - Corn Syrup
(42 Fructose, 52 glucose, 6 higher polysaccharides)

Concentration
at Low Pressure

Crystallization of
Glucose

Removal of Crystallized
Glucose

Enriched - Fructose
(70% dry basis)

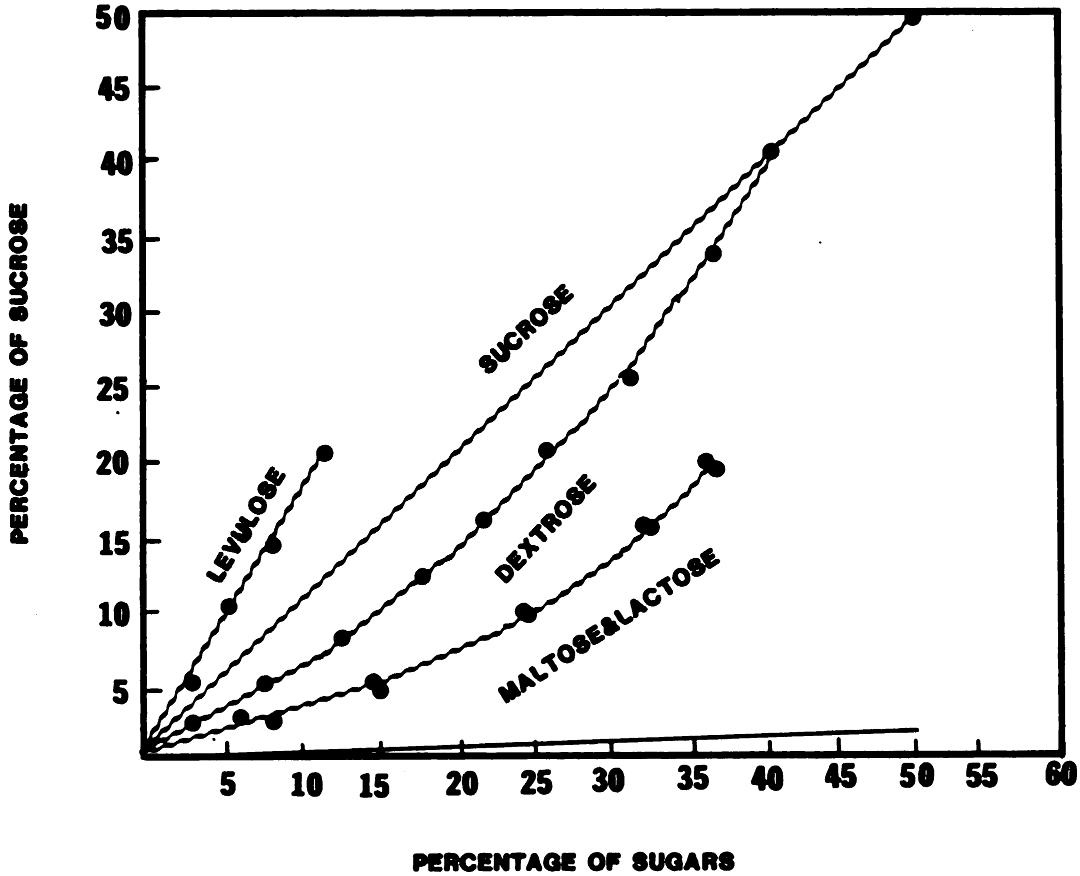


Figure 5. Percentage of different sugars (g/100 ml soln) needed to give the same sweetness as sucrose solutions of various concentrations. From Dehlberg and Penzek (1941).

which is simply the name for the mixture of dextrose (glucose) and levulose (fructose) when these two sugars are chemically split from sucrose, has a relative sweetness of 135, whereas levulose alone has been rated up to 166-175% sweetness, depending on grade and type of application (Walter, 1974). The temperature does not have any noticable effect on the sweetness of some sweeteners, but the relative sweetness of fructose decreases dramatically with increases in temperature as shown in Figure 6 (Tsuzuki and Yamazaki, 1953; Junk and Pancost, 1973; Shallenberger and Birch, 1975).

The relative sweetness of these sweeteners had always been examined in solutions of distilled water, until Harris et al. (1978) and Pangborn (1963) examined relative sweetness using flavored beverage media. The results of similar works by Armand et al. (1979) are shown in Figure 7. When fructose and sucrose are compared in different media it can be seen that fructose is sweeter than sucrose by a factor of approximately 1.6 when these two sugars are mixed with distilled water at low concentration. At higher concentrations the relative sweetness of fructose decreased to 1.0. At low concentrations of citric acid containing media fructose had a relatively large sweetening advantage (1.8-1.9) over sucrose at low concentrations. This work shows, quite graphically, that the relative sweetness of each sugar has to be considered within the context of its specific application.

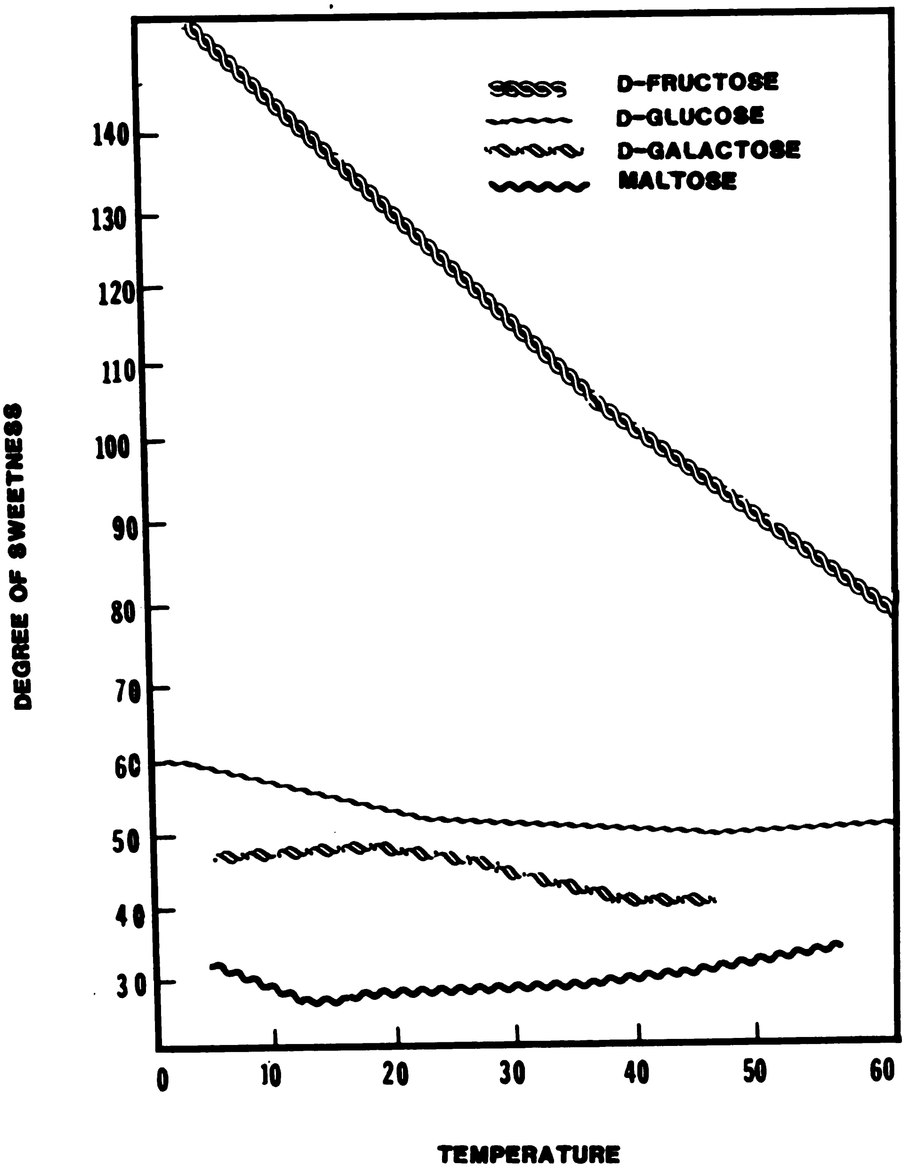


Figure 6. Effect of temperature on the relative sweetness of sugars at 10% concentration. From Tsuzuki and Yamazaki, 1953.

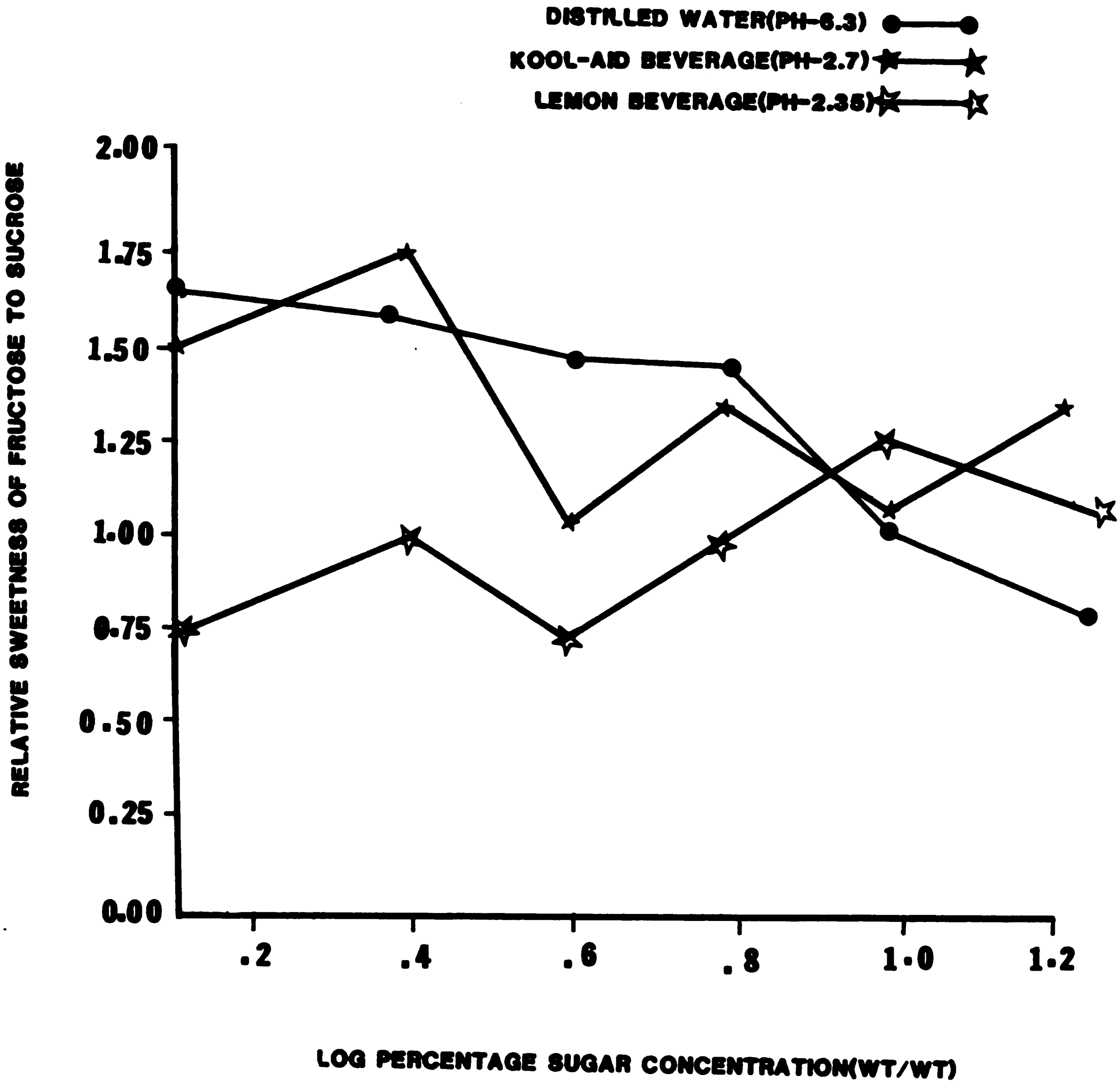


Figure 7. Relative sweetness of fructose to sucrose as a function of sugar concentration for the different media. From: Armand et al., 1979.

Invert sugars (glucose-fructose) have different applications in the food industry, mostly being used for soft drinks, because they are sweeter than sucrose and cost less. Invert sugar can be used for other products because it provides some sheen and mouthfeel, gives a higher osmotic pressure than sucrose and consequently, permeates fruit or vegetable membranes faster than sucrose. Invert sugars are not used in jellies, jams and preserves because they add water to the product, and it is difficult to evaporate.

Dextrose is used extensively in all types of fruit and vegetable canning operations where standards permit sweeteners. For citrus fruit, dextrose can constitute up to one third of the total sweetener allowed; in vegetables, it can be used in a mixture with sucrose and in meat products it may replace up to 25% of the sucrose. Dextrose is used in the meat industry as a coloring agent, since dextrose can react with protein to provide red color. The functionality of dextrose lies particularly in its being a simple sugar with greater penetration because of its ability to create higher osmotic pressure than sucrose or other syrups. The greatest disadvantage of using dextrose is that it readily crystalizes at high concentrations.

The term corn syrup denotes a heterogeneous mixture of sugar derived from corn starch and may range from a D.E. of 20% up to 99%. The degree of sweetness in corn syrup is increased as the D.E. increases while viscosity decreases at higher D.E. Depending on the level of conversion, corn syrups have different uses in the food industry. Low conversion, low-cost corn syrup, which is highly concentrated and does not require heat to prevent crystalization may be used in bakery products (Jackel, 1975). Some bakers have tried to meet 10% to 25% of their fermentable carbohydrate need by internal treatment of the dough with alpha-amylase enzymes on pergelatinized starch. Corn syrups with higher D.E. level are used in the candy, beverage and canning industry. The type of corn syrup used and its D.E. level are dependent upon the initial requirements and the desired outcome for the products being processed (Henry, 1976).

HFCS, which has been a revolution in the sugar industry, can be used in almost any kind of food. Since it is only available in liquid form, it can only be used in the industrial market where it is capable of replacing sugar, either totally or partially, in many applications. This syrup is low in viscosity and easy to ship, store and blend. It has the ability to retain moisture or to prevent drying-out in such items as icing and fondants, although in some foods, there may be a problem of excessive moisture pickup in humid air. HFCS is clear in color, bland in taste and has a high osmotic pressure so it can easily penetrate through cell walls.

Beverages are the largest potential market for HFCS. It has been estimated that it could replace up to 50% of the 2.5 million tons of sugar the industry uses annually and HFCS can be substituted, in part or completely, for sucrose, or invert sugar with few modifications in formula or procedures (G.A.O.). Carbonated beverages made with HFCS, have shown good storage stability (Fruin and Barrett, 1975). Non-carbonated fruit drinks have utilized combinations of sucrose or invert and HFCS ranging from 50/50 to 25/75 and they have been found to be acceptable sweeteners which import good body and mouthfeel to the drinks (Godizicki, 1975) (Table 1).

Many bakeries have already begun replacing sucrose with HFCS in yeast-raised items such as bread, and it has been estimated that HFCS can replace up to 25% of sugar in cakes and other non-yeast-raised goods. In pie filling, 50/50 combination of HFCS and higher D.E. corn syrup have been used to replace sucrose-corn syrup blends. Due to its molecular structure, HFCS lowers the freezing point of ice cream, making storage and handling more difficult but corn syrup with low or medium conversion could be used instead of HFCS. In many canned foods such as jams and preserves, sugars are being replaced with corn syrup and HFCS and it is estimated that anywhere from 50 to 100 per cent of the sugar may be replaced in this application (LeMaire, 1978). In the preparation of

Table 1. Application of HFCS with invert sugar and sucrose in carbonated beverages.

Combination	Ratio	Application
I. *Sucrose/H.F.C.S.	75/25	Carbona
II. Sucrose/H.F.C.S.	50/50	Carbonated
III. *Invert/H.F.C.S.	75/25	Beverages
IV. Invert/H.F.C.S.	50/50	

* Corn products INVERTOSE high fructose corn syrup.

Sucrose/high fructose corn syrup*, invert/high fructose corn syrup* pickles, relish, maraschino cherries and other similarly preserved items, the low molecular weight of sugar in HFCS increases the osmotic pressure (Anonymous, 1971) which favors a more rapid penetration of tissue by HFCS than would be the case with sucrose, medium invert or ordinary corn syrup alone. This pressure speeds equilibrium of the cherries and syrup and, by permitting faster penetration of membranes, minimizes cell damage (Newton and Wardrip, 1974).

In the preparation of maraschino cherries, it is very feasible that sucrose or medium invert sugar can be replaced with HFCS on an equal dry weight basis, making proper allowance for moisture content, as is necessary. Clarity, clean taste, low viscosity, high osmotic pressure, uniformity and economy are factors favoring the use of HFCS in this application.

MATERIALS AND METHODS

Raw Product

The Napoleon variety of sweet cherry (*Prunus avium* L.) was used in this study. The brined cherries were obtained from Kroupas Inc. and R.C. Warren Company Inc., both of Traverse City, Michigan. The brined cherries consisted of a combination grade 1-2-3, size 16 to 22 cm and greater.

These cherries were harvested, brined and stored in 1979. After pitting by the briner, they were brought to the Food Science Department and held in a cooler at a temperature of 44^{o}C until they were used.

Sweeteners were obtained from Corn Products Company (International Plaza, Englewood Cliffs, New Jersey), Clinton Corn Processing Company (Clinton, Iowa), and Staley Industrial Products (A.E. Staley Manufacturing Co., Decatur, IL).

Brined Cherry Preparation

Fifteen pounds of commercially brined cherries were soaked for twenty-four hours in a moderately hard water solution. The cherries were then brought to a boil twice, in two changes of water, to bring the concentration of sulfur dioxide down to the range of 150 to 200 PPM.

Treatments

Maraschino cherries were prepared, using the various sweeteners, alone and in combination with sucrose. These treatments are shown in Table 2.

Processing of Maraschino Cherries

The fourteen treatment combinations were all approximately 7-8^{o} Brix at initiation of the finishing procedure. On the first day the Brix levels were brought to 10^{o} with syrup prepared from a stock solution. For the next six days, each treatment combination was heated for 10 minutes at 140 to facilitate sugar uptake. Sweetener additions were made over the six days to give a final syrup concentration of 40^{o} Brix. The cherries were drained off the syrup and packed in sample jars to give a fill weight of 35-40 grams of fruit. A fresh 40^{o} Brix syrup was brought to a boil and sample jars were filled, sealed immediately, then held for 3 minutes before cooling.

Storage Conditions

Triplicate samples from each of fourteen treatment combinations were stored at 44^{o}F (6.6^{o}C), 72^{o}F (22.2^{o}C), and 89^{o}F (31.7^{o}C).

Weight Change (Yield)

Weight changes were calculated for each treatment combination every day during the finishing procedure and

Table 2. Syrups used in the preparation of maraschino cherries.

Treatment	% Replacement of Syrup	Sucrose
Low conversion corn syrup (cpc)	100	0
Regular conversion corn syrup (c)	100	0
High conversion corn syrup	a: cpc 100	0
	b: s 100	0
	c: s 100	0
	d: nusweet 100	0
High fructose corn syrup	a: invertose (cpc)	100
	b: isosweet (s)	100
	c: isosweet (s)	100
	d: isomerose (c)	100
Blends	a: HFCS (cpc) + sucrose 50	50
	b: corn syrup (cpc) + sucrose 50	50
Control	sucrose 50	100

cpc = corn products company

c = clinton

s = staley

at monthly intervals during the storage phase of the study. Weights were determined by draining the cherries and holding at 72°F (22°C) until the fruit had equilibrated to temperature.

Texture

Texture of the cherries was evaluated using the Chatillon spring push gauge, (0-1000 grams), with a stainless steel tip, 1.6 mm in diameter (John Chatillon and Son, New Carden, New York). Samples were also tested by using the Allo-Kramer Shear press with the standard shear compression cell model TR-3 Texturecorder. Although the shear press may give more accurate measurements, the single punch, manual type instrument has gained wide acceptance for texture measurement of many food products (Bourne, 1975) and within the cherry industry. The Chatillon spring punch gauge is the most prevalent of the manual type punches. Brekke and Sandomire (1961) and Vibbert and Bedford (1978) have used the Chatillon type instrument to detect difference in firmness of brined cherries with fairly good results.

To determine shear values, the Allo-Kramer shear press, (using a 300 pound full load) with standard shear press compression cell was used. Duplicate 100 g cherry samples were subjected to a downward travel speed of 60 cm/min. Maximum force corresponding to maximum peak height was reported as pounds per 100 g of samples.

Viscosity

Syrup viscosities were determined prior to the initial processing. A Nametre model 7.006 Direct Readout Viscometer was used in conjunction with an Exacal 100 controlled temperature circulating water bath at $32^{o}C + .01^{o}C$. Approximately 40 ml of syrup obtained from each product were placed in glass beakers (3.5 cm x 7.7 cm) and the beakers were then lowered into the circulating water bath. Samples were allowed to equilibrate for 15 minutes before lowering the viscometer head into the sample. Once the head was immersed in the syrup the sample was allowed to equilibrate an additional 15 minutes before a reading was taken.

Taste Panel Procedure

A rating method was used to compare each sample with a reference. For each evaluation, judges were presented with 4 or 5 coded samples in labeled cups. The judges were asked to rank all the samples according to their personal preference. Each judge was asked to taste the reference, then separately taste each sample and compare it with the reference. The cherries were rated for sweetness, flavor, texture and acceptability.

Application of HPLC to Characterization of Individual Carbohydrates in Syrups

The HPLC used in this study was a Waters Associates Model P/N 84038 S/N. This unit contained a model R401 differential refractometer, and a M6000A solvent delivery system. The injection system was the Waters model U6K, the recorder was a variable speed model P/N. Carbohydrate separations were accomplished on a "U Bondapak carbohydrate" column (3.9 i.d. 30 cm long) from Waters Associates.

For corn syrup samples, the HPLC mobil phase consisted of a mixture of Acetonitrile and water (72.5:27.5 V/v) at pH 4.0 and the flow rate was 2.5 ml/min. For high fructose corn syrup samples a mixture of Acetonitrile and water (85:15 V/V) at pH 4.0 with a flow rate of 4.5 ml/min was used. The concentrations of sugars in the samples were obtained by comparison of peak area of samples with peak areas of standard sugar solutions of known concentration.

Sulfur Dioxide Determination

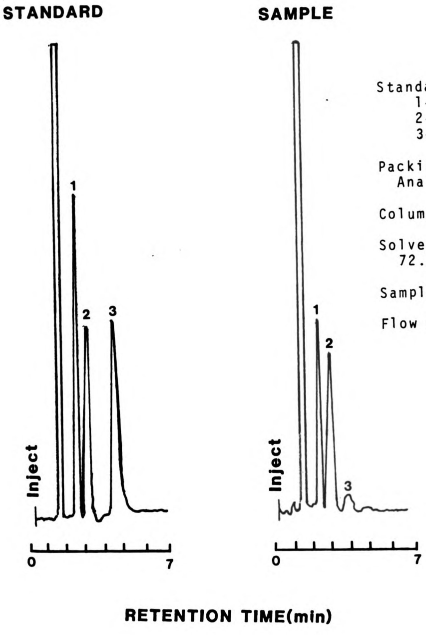
Sulfur dioxide content of the cherry brines was determined using the method of analysis of the Association of Official Analytical Chemists, 12th edition (1975).

RESULTS AND DISCUSSION

A number of factors may affect the final quality of a maraschino cherry but during the finishing process the most important item is the sweetener and the manner in which it is applied. A properly finished maraschino cherry should have good texture, firmness and acceptable weight gain, all of which can be partially attributed to the sweetening agent being used. In order to understand the effects of the eleven different sweeteners used in this study on the finished cherries, chemical and physical analysis were carried out, in conjunction with actual processing of cherry samples.

High pressure liquid chromatography (HPLC) analysis was used to compare the carbohydrate composition of all the sweeteners in the study.

The HPLC operating conditions and typical chromatograms for corn syrups and HFCS are shown in Figures 8 and 9. Comparison of the sample and standard chromatograms shows good agreement between the positions of the peaks in both instances, which allows for identification and quantitation of the components. The results of these analyses are shown in Table 3. These samples can be divided into four groups,



Standard: 1 mg/ml
1-Dextrose
2-Maltose
3-Maltotriose

Packing: Carbohydrate Analysis

Column: 3.9 mm x 30 cm

Solvent: H_2O/CH_3CH (27.5: 72.5)

Sample: Corn Syrup

Flow Rate: 2.0 ml/min

Figure 8. Typical HPLC analysis of corn syrup.

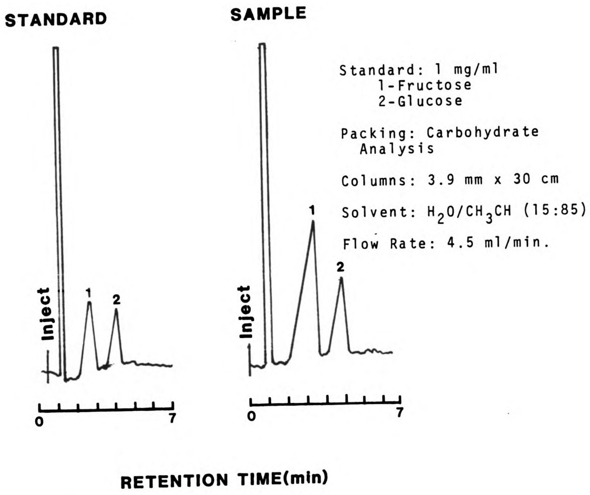


Figure 9. HPLC analysis of High Fructose - corn syrup.

Table 3. Characteristics of Various Syrups (HPLC) used in This Study.

Syrups	Carbohydrate Composition - % Solids			
	Glucose	Fructose	Maltose	Maltotriose
Hi Con CS	42.00	0	30.50	16.00
Hi Con CS	42.00	0	33.60	16.00
Low Con CS	24.84	0	19.88	12.03
Liquid Dextrose	93.00	0	5.00	0
Regular CS	20.70	0	19.30	0
HFCS	63.00	44.00	0	0
HFCS	55.00	43.00	0	0
NuSweet	41.00	0	30.05	12.05
Isomerose	55.50	43.00	0	0
Isosweet	45.93	54.07	0	0
Hi Con Cs	35.98	0	40.04	11.02

Standard = 1 mg/ml

according to their degree of conversion. Low conversion syrups are between 20 and 23% glucose on a dry weight basis. These syrups are only slightly sweet and have a high viscosity. Regular conversion syrups have a glucose range between 24 and 35%, are moderately sweet and also have a high viscosity. High conversion syrups have a glucose content in the 40 to 45% range are sweeter than either of the previously mentioned samples and have a fairly low viscosity. The last group, the high fructose corn syrups (HFCS), have a glucose content in the range of 45 to 55% and also contain 42 to 55% fructose. A more detailed description of the sweeteners used in this study can be found in Appendix A (Tables A1-A10).

The most critical aspect of finishing is getting acceptable weight gains in the final product and this is highly dependent upon the sweetener being used. During the finishing operation, the sweetener concentration is gradually increased over a period of several days to allow the cherries to absorb syrup and gain weight, without shriveling or "sugar shock" which would be caused by a high osmotic gradient from concentrated syrups. During this equilibration period of 4 to 7 days, commercial samples normally gain 8 to 10% in weight because of syrup uptake and this is considered to be a very acceptable gain. Under ideal conditions and with different kinds of sweeteners, however, the weight gain may go higher (Figure 10).

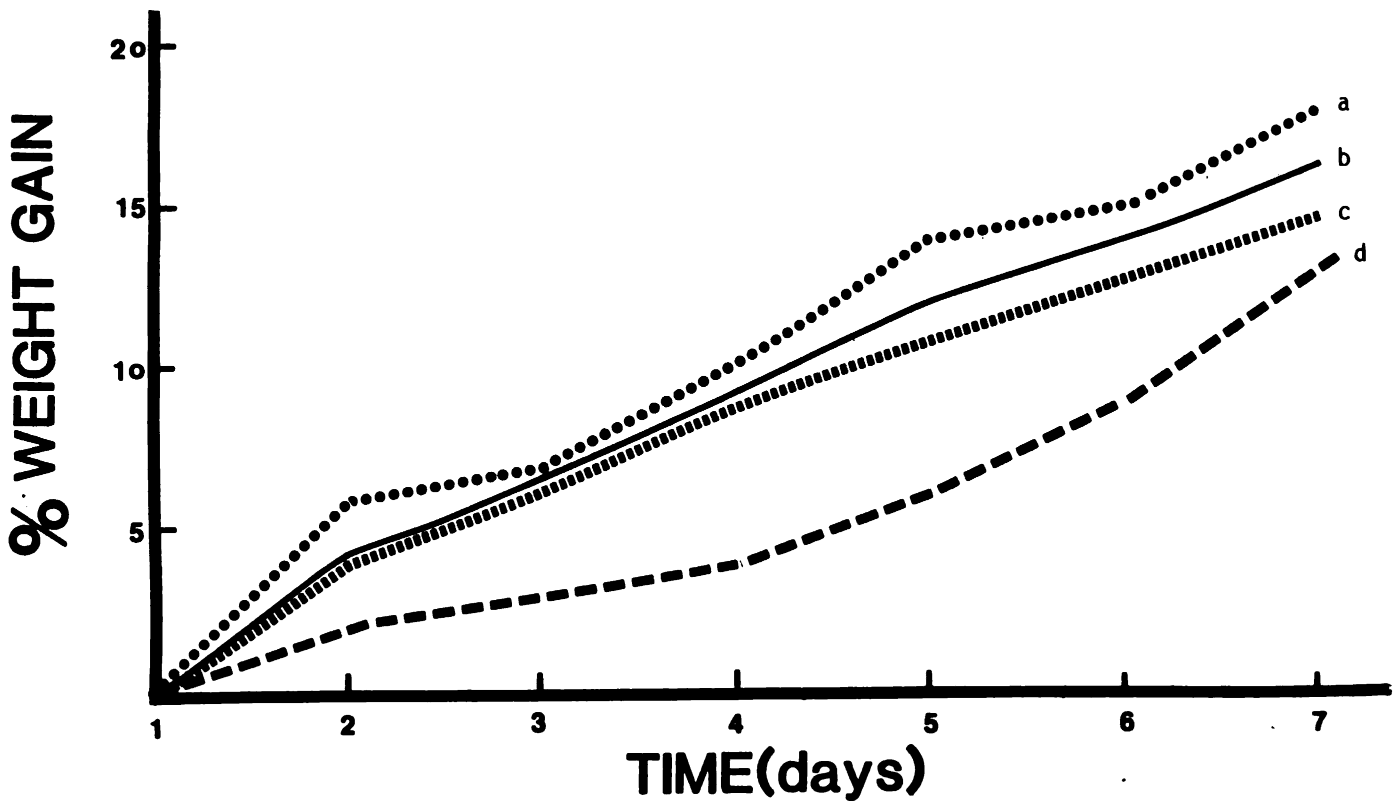


Figure 10. Percent weight gain after seven days finishing operation for flour group of treatments (corn syrup, HFCS/ control, blends). a: control (sucrose); b: high fructose corn syrup; c: corn syrups; d: blends.

A two way analysis of variance was determined for all treatments. Time in this experiment was seven days, with the first day recorded as zero and seventh day as six. The results of this analysis are shown in Table 4. It can be seen that the main effects of treatment and time have significant effects on weight gain but the interaction between these two does not exert a significant influence. The effect of individual treatments on weight gain during the finishing operation are shown in Figure 11. Percent weight gain for each treatment is presented as the mean of three replicates.

Treatment 5 (50/50 corn syrup/sucrose) had the lowest weight gains and proved to be significantly different (= 0.05 level) from all other treatments. Weight gains for treatment 12 (sucrose which was used as the control) were significantly higher than treatments 5 (50/50 corn syrup/sucrose) and 13 (50/50 HFCS/sucrose). None of the other treatments caused statistically significant differences in weight gain. Individual weight changes for each day of finishing are shown in Appendix B.

The percent weight changes for samples which were stored for three months at 44°F (66°C), 72°F (22.2°C) and 89°F (31.7°C) are shown in Table 5. Weight changes are calculated as the mean of three replicates after three month storage. These sweeteners do not react in the same manner at the different storage temperatures, as indicated

Table 4. 2-way analysis of variance, square mean and F-value for finishing process of maraschino cherries.

Source of Variation	Sum of square	DF	Mean squares	F	Signif of F
Main Effects	.440	17	.026	18.333	.001*
Syrup	.069	12	.006	4.053	.001*
Time	.371	5	.074	52.605	.001*
2-way Interactions	.010	60	.000	.122	.999
Syrup Time	.010	60	.000	.122	.999

s.e. = 0.0088

* = 0.05

min. sign. diff. = 0.042

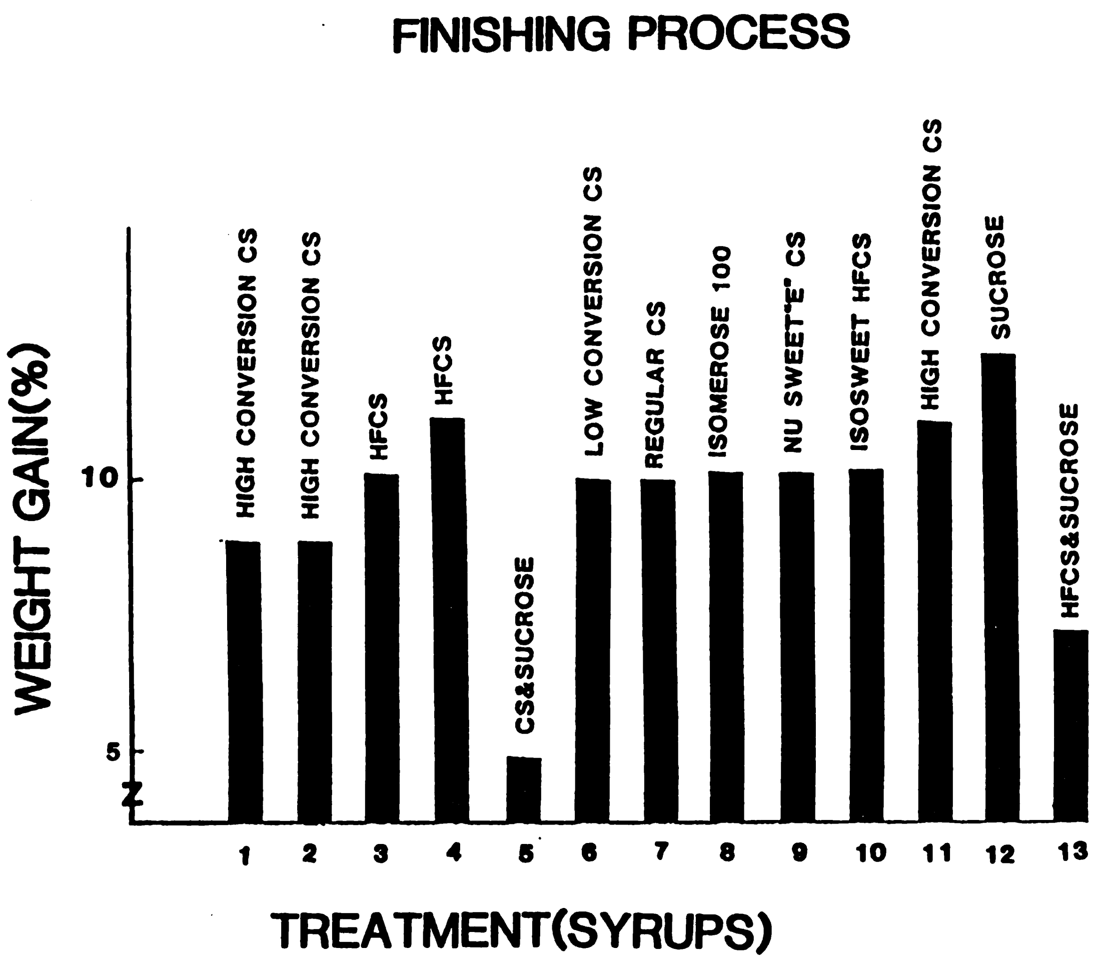


Figure 11. Per cent weight gain after 7 days of finishing. Each figure is the mean of three replicates.

Table 5. Comparison of percent weight change after 3 months at three different storage temperatures.

No.	Sample	Temperature		
		44°F	72°F	89°F
1	HICON CS	7.09ab*	1.85de	-2.87i
2	HI CON CS	4.91cde	0.92def	0.84defg
3	HFCS	7.23ab	5.82a	1.69cde
4	HFCS	4.06ef	3.13bc	3.17ab
5	CS SUCROSE	5.86b	2.68bc	2.42abc
6	LOW CON CS	7.30a	3.40b	0.03gh
7	REG CS	5.82bc	-0.03g	0.09fgh
8	ISOMEROSE	3.59ef	0.79ef	0.26efg
9	NUESWEET	5.42cd	1.16de	-0.08gh
10	ISOSWEET	2.99f	3.53b	1.92bcd
11	HICON CS	1.47g	0.21f	1.47cdef
12	SUCROSE	3.24f	0.94def	3.93a
13	HFCS SUCROSE	5.09cd	2.35bcd	1.56cde

S.E. = 0.2951

Min. Sign. Diff. = 1.43

*Numbers followed by the same letter are not significantly different at $\alpha = 0.05$.

by the differences in weight changes. The reasons for these differences are due to the physical and chemical properties of each type of sweetener, because differences in such things as molecular weight will cause differences in osmotic pressure and the ability of cells to absorb the sweetener. It can also be seen that lower conversion syrups have higher viscosity values than higher D.E. products, all other factors of temperature and concentration being the same. This is to be expected in view of the carbohydrate distribution of the various syrups. Lower D.E. products have proportionately greater concentrations of polysaccharides which influence the development of greater viscosity than is the case with dextrose, maltose, and maltotrose. Viscosity data on a variety of corn syrups are shown in Appendix E (Tables C1-C2). For example, sample number 1 (High conversion corn syrup) which has a D.E. value of 43 and Brix of 85 has a higher viscosity value than high fructose corn syrup with a D.E. value of 64 and Brix value of 62.7. Even though viscosity is an important physical characteristic of a syrup in respect to penetration rate, other physical characteristics have to be considered, such as solubility, osmotic pressure, concentration and processing temperature. These factors will be discussed later.

Results of the analysis of variance for the effect of different treatments, storage time and temperatures on weight changes are shown in Table 6. Treatments, temperature and time each have a significant effect on weight changes, as do all the interactions between these factors (Figure 12). Sample number 5 has significantly higher weight gain than sample number 1 (High conversion corn syrup), 2 (High conversion corn syrup), 7 (Regular corn syrup), 8 (isomerose), 9 (nusweet "6") and 11 (High conversion corn syrup) at $\alpha = 0.05$ level. Sample number 6 (Low conversion corn syrup) and 4 (High fructose corn syrup) have significantly higher weight gain than sample number 1 (High conversion corn syrup), 7 (Regular corn syrup), 8 (isomerose) and 11 (High conversion corn syrup at $\alpha = 0.05$ level. Sample number 13 has significantly higher gain weight than sample number 1 (High conversion corn syrup) and 11 (High conversion corn syrup) at $\alpha = 0.05$ level. Sample number 10 (isosweet) has significantly higher gain weight than sample number 11 (High conversion corn syrup) at $\alpha = 0.05$ level.

One of the main factors considered during this experiment was the effect of storage time and temperature on weight changes and textural quality of the products. The influence of temperature on product yield after three months storage can be seen in Figure 13. Significant differences in yield were found to exist between samples stored at the lowest and highest temperature, but not between the other temperature combinations. The effect

Table 6. 3-ways analysis of variance the effect of treatments, storage time and storage temperature on the percent weight change.

Source of variation	DF	M.S.	F	Significance
Main Effects	16	95.964	5.356	0.001*
Treatment	12	28.886	37.63	0.001*
Storage Temperature	2	469.708	602.2	0.001*
Storage Time	2	124.686	4.708	0.02
Interactions				
Storage Temp. x Treatment	24	24.506	31.42	0.001*
Storage Temp. x Storage Time	4	5.118	0.193	0.5
Treatment, Storage x Time	24	12.956	0.443	0.5
Treatment Storage Temp. x Storage Time	48	10.331	0.390	0.5

Storage temperature: 94^{o}F (6.6^{o}C), 72^{o}F (22.2^{o}C), 89^{o}F (31.7^{o}C).

Storage time: One month, two months, three months

*α = 0.05

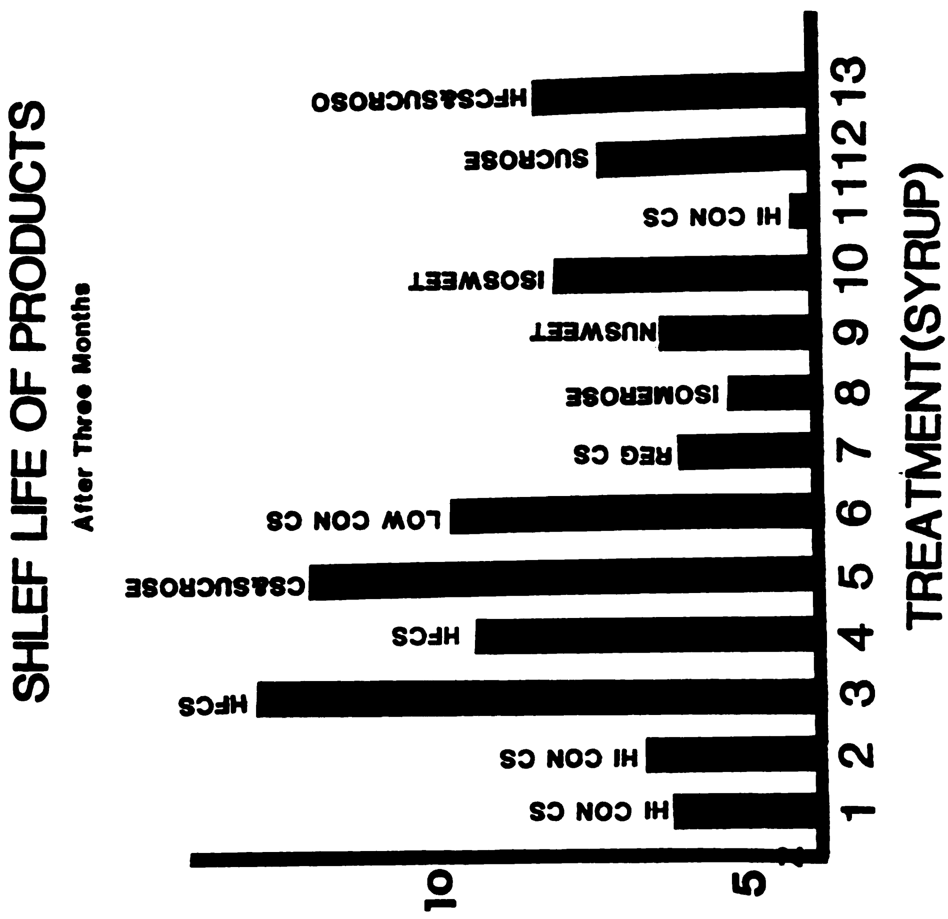


Figure 12. Per cent weight gain after three months storage. Each figure is the mean of twenty-seven replicates.

of short term storage on weight changes is shown in Figure 14. No significant differences in yield were found between samples after three months of storage but the trends toward lower yield with increased storage time indicated that significant changes may occur with longer storage (Appendix D - Tables 1-4).

Since the weight gain for each treatment was different, especially after three months storage, at three temperatures, several factors which might be related to this effect were investigated. Viscosity, osmotic pressure and degree of solubility were considered for each group of sweeteners. In general, viscosity is related to the degree of conversion of a syrup, with the higher conversions having lower viscosity because the conversion process breaks down polysaccharides. The osmotic pressure of any sweetener is directly related to its molecular weight with lower molecular weight compounds having a greater osmotic pressure in solution (Figure 15).

Sugar Chemistry, 1974, whows the osmotic pressure for glucose, a monosaccharide and sucrose, a disaccharide at different sugar concentrations. The pressure exerted by the monosaccharide is about double that of the disaccharide at the same weight concentration because at equal percentage concentrations there are twice as many monosaccharides present in the solution. There is a direct relationship between osmotic pressure and D.E. value for

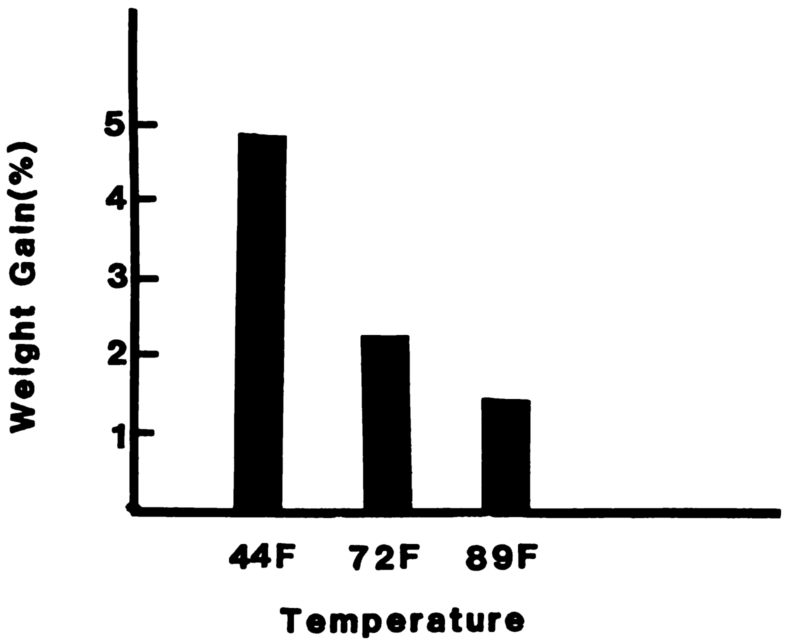


Figure 13. The influence of temperature on the percent weight gain of maraschino cherries after three months storage.

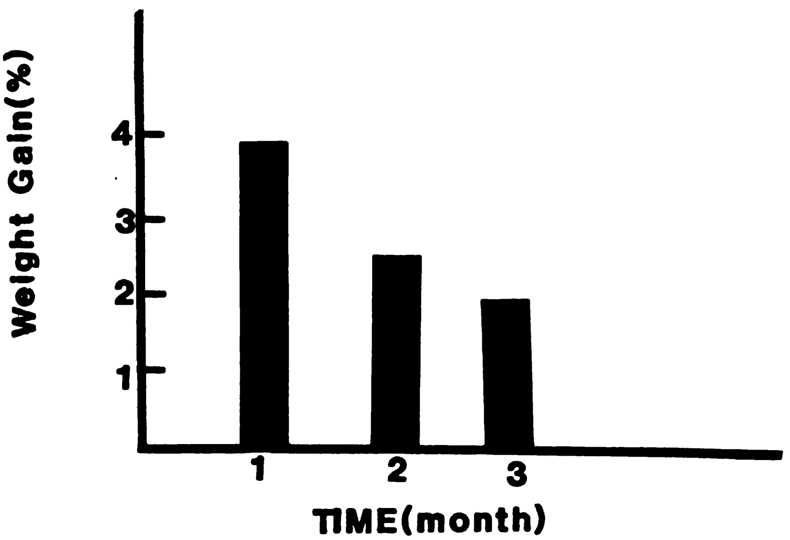


Figure 14. The influence of storage time on percent weight gain of maraschino cherries.

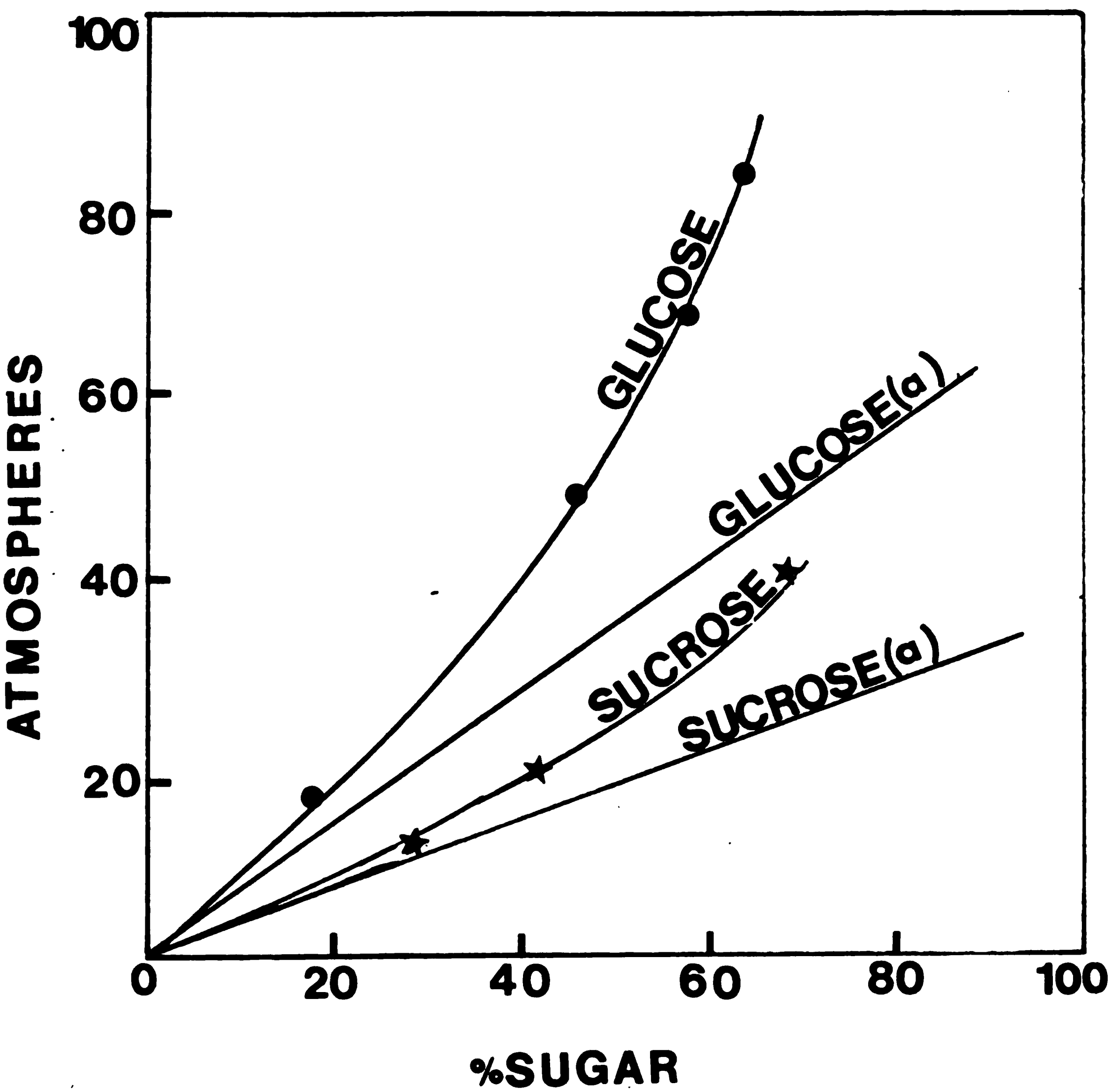


Figure 15. Calculated and observed osmotic pressures of glucose and sucrose solutions.

corn syrups (Mahdi, 1963) (Figure 16). Therefore, sweeteners with a high degree of conversion and high D.E. would be expected to have a higher osmotic pressure.

Solubility is another factor which may effect the penetration rate of a sweetener. The solubilities of several syrups at different temperatures are shown in Figure 15, (Brich et al., 1972). During finishing, all the treatments were subjected to a constant temperature of 140^{o}F (^{o}C). It can be seen in Figure 17 that fructose at this temperature is more soluble than glucose of sucrose. Therefore, syrups which contain higher levels of fructose than sucrose or glucose should have a higher solubility rate.

The comparison between weight gain during the finishing process and after three months storage suggests that treatments which did not have a high weight gain were still absorbing sugar during storage and penetration was not completed at the end of the finishing operation. For example, samples number 5 (50/50 corn syrup/sucrose) and 13 (50/50 HFCS/sucrose) had significantly lower weight gain than the rest of the treatments. However, at the end of the three months storage at three different temperatures, these samples had a significantly higher weight gain than most of the other treatments. This is interesting, but probably has little economic significance because the processor gets paid on the weight basis of the product at

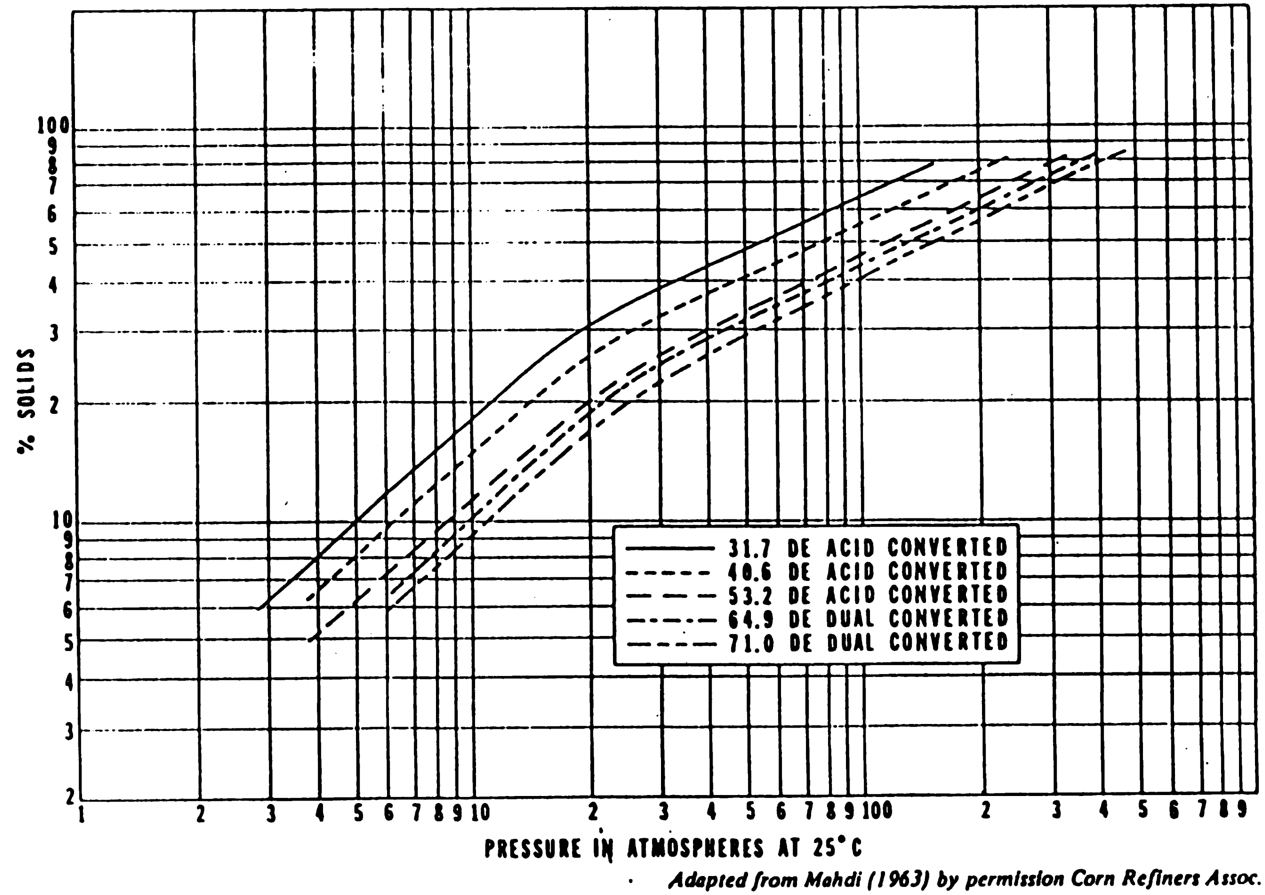


Figure 16. Osmotic pressure of corn syrups.

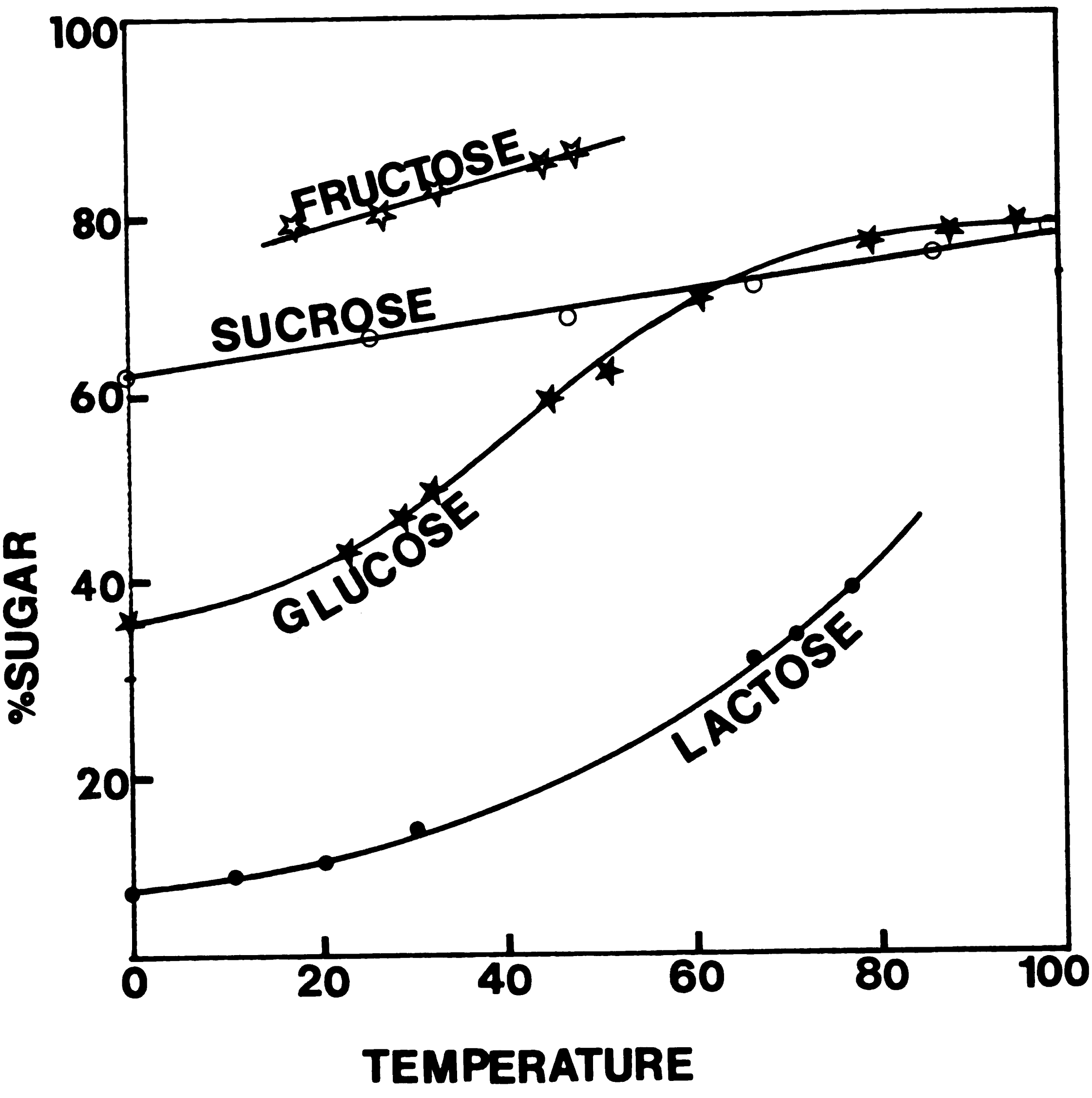


Figure 17. Approximate solubility of various sugars at different temperatures. Source: Birch et al., 1972.

the end of the finishing process and has little interest in weight gain which takes place after packaging.

After three months of storage, firmness of the cherry samples, as measured by the chatillon pressure tester, was found to vary significantly between sweetener types and with storage temperature (Figure 18 and Table 7). Analysis of variance shows that treatments and storage temperature did have significant effects on the firmness of the product (Table 8). According to the analysis of variance, samples 2, 3, 6, 12 and 13 were significantly firmer than sample 9 but no significant differences existed between the rest of the samples.

After three months storage all the treatments except numbers 8 and 9 were firmer than the original brined stock from which the maraschinos were processed. It can be seen in Table 9 that products which were stored at 44^{o}F (66^{o}C) are firmer than those stored at 72^{o}F (22.2^{o}C) or 89^{o}F (31.7^{o}C) but the only statistically significant differences are between the high and low storage temperatures. In general, products which were stored at 89^{o}F (31.7^{o}C) had a lower weight gain and softer texture, than those stored at lower temperature. This was not unexpected, since the higher temperature would tend to accelerate the breakdown of cellular tissue, which would decrease firmness and the ability of tissue to absorb sweetener and gain weight.

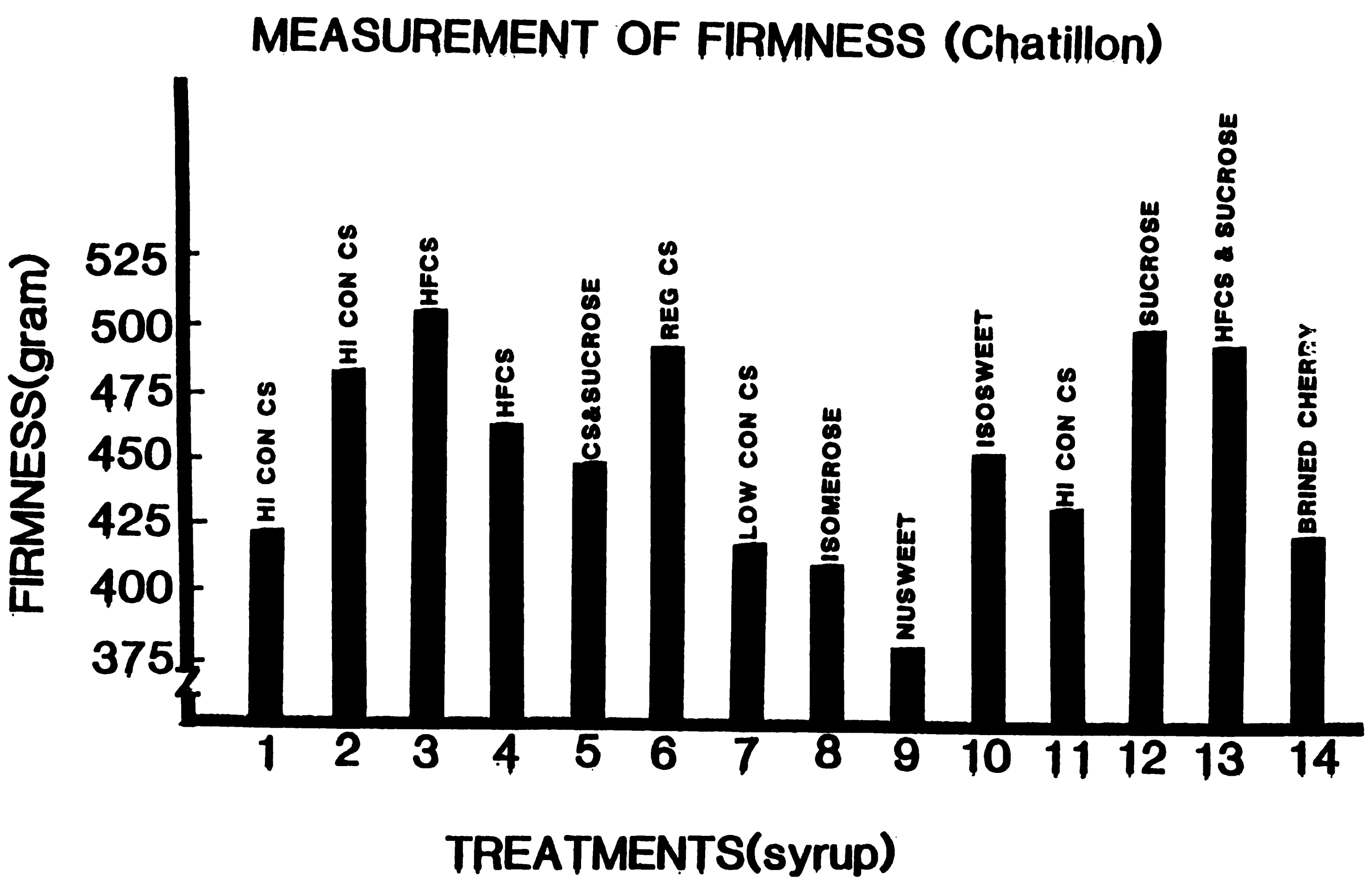


Figure 18. This figure shows the effect of different treatments on the firmness of maraschino cherries after 3 months as measured by the manual chatillon pressure tester. Each figure is the mean of six replicates.

Table 7. 2-way analysis of variance, mean square for firmness of maraschino cherries, measured by manual puncture (Chatillon).

Source of Variation	DF	Mean Square	F	Signif of F
Main Effects	14	9082.905	3.018	0.003*
Syrup	12	8956.046	2.976	0.005*
Temperature	2	9844.063	3.271	0.049*
2-way Interactions				
Syrup Temperature	24	1326.285	0.444	0.982*

s.e. = 22.39

mim. sign. diff. = 111.54

*α = 0.05

Table 8. One-way analysis of variance, square mean and F-ratio for firmness of maraschino cherries after three months storage at storage temperature of 44°F (6.6°C) as measured by Kramer sheer press.

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob
Between Treatments	13	409879.4643	31529.0896	34.119	0.0000
Within Treatments	14	12937.5000	924.1071		
Total	27	422816.9643			

s.e. = 2.15

min. sign. diff = (q 0.05, 14, 14) (2.15) = 12.1

Table 9. Effect of temperature on firmness of maraschino cherries after three months storage, as measured by manual puncture (chattilon)

Temperature	44 F (6.6 C)	72 F (22.2 C)	89 F (31.7 C)
Firmness (gram)	474.92 (26)	448.72 (26)	436.90 (26)

s.e. = 10.7589

min. sign. diff. = 38.0384

Treatments did have significant effects on the firmness of the final products. Results for individual treatments are shown in Figure 19. As the results show, sample number 1 (High conversion corn syrup), and sample number 2 (High conversion corn syrup) were significantly firmer than the rest of samples. Sample number 10 (isosweet "E") is significantly firmer than sample Number 3 (HFCS), 6 (Low conversion corn syrup), 9 (Nusweet), 8 (isomerose) and sample number 5 (50/50 corn syrup/sucrose). Sample number 11 (High conversion corn syrup) is significantly firmer than sample number 3 (HFCS), 6 (Low conversion corn syrup), 9 (Nusweet "E"), and sample number 8 (isomerose). Samples number 4 (HFCS), 7 (regular corn syrup) and sample number 12 (sucrose) are significantly firmer than samples number 6 (low conversion corn syrup). 8 Iisomerose) and sample number 9 (Nusweet "E"). Samples number 3 (HFCS). 5 (50/50 corn syrup/sucrose), 13 (50/50 HFCS/sucrose) and 14 (brined cherries which used as raw product in this study) are significantly firmer than sample number 9 (Nusweet "E").

Both methods of measuring firmness, Chatillon and TR-3 Texture coder show, sample number 9 (nusweet "E") is softer than the rest of the products and also did not have a good shelf-life during storage (Appendix E).

Taste panels were conducted in order to determine sensory reaction to flavor, texture, sweetness and the degree of like or dislike, of the finished products.

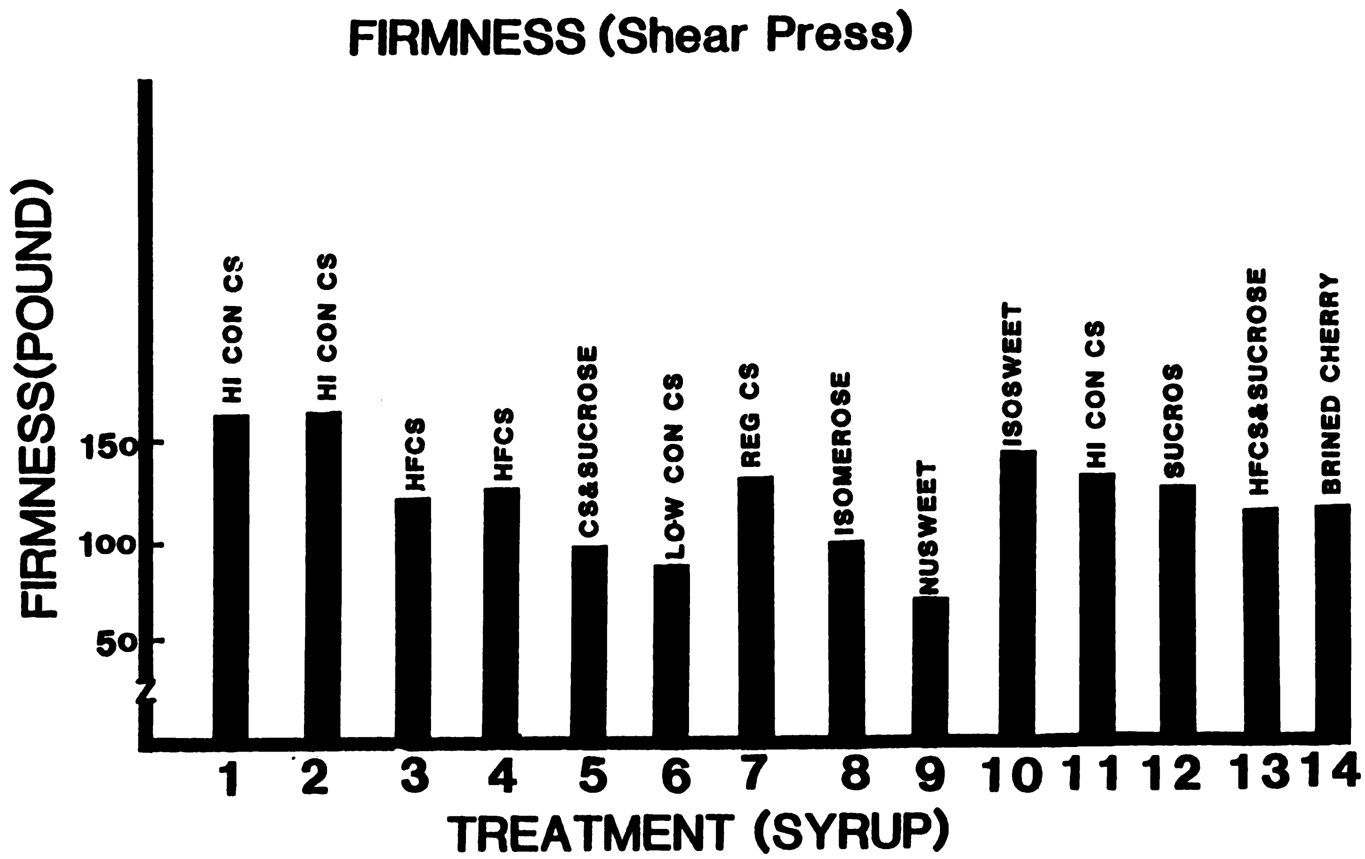


Figure 19. Measurement of firmness after three months at storage temperature of 44°F. Figures for firmness are pounds force needed to deform 100 grams of cherries for each treatment. Each figure is the mean of three replicates.

Judges were asked to compare treatments with a reference sample made with sucrose and then rate the intensity of each factor as more or less than the reference. An analysis of variance indicated significant difference existed between judges so the data were subjected to an analysis of co-variance, using the panelists as one of the covariants. Results of this analysis for each factor (flavor, sweetness, texture, liking) are shown in Appendix F (Tables F1 - F4). Taste panelists did not detect great differences in the sweetness level of the various treatments, although they did indicate that samples 10 and 12 were sweeter than samples 1, 6, 7 and 11. The panelists did not find significant differences in sweetness between any of the other treatments (Table 12). Panelists also did not detect significant flavor or firmness differences between samples, although the more objective, analytical tests indicated that distinct differences in firmness did exist. This is not particularly surprising, however, because subjective sensory analyses do not always agree with the more objective measurements, especially when untrained panelists are used. A wide range of preferences can be seen between treatments but the panelists indicated that samples 5 and 12 were the most acceptable. In both instances, the sample contained sucrose.

Table 10. Sensory evaluation of maraschino cherry when sucrose was used as reference*

Treatment	Syrup a	Sweetness b	Flavor c	Texture d	Liking e
1	100 HICONCS	1.91	1.67	2.55	1.40
2	100 HICONCS	2.51	3.20	3.64	3.31
3	100 HFCS	2.86	2.74	2.55	2.61
4	100 HFCS	3.63	3.21	3.49	2.93
5	50 CS 50 SUC	4.16	3.61	2.94	4.03
6	100 LOW CONES	0.62	1.32	1.95	0.75
7	100 REG CS	1.41	1.83	3.44	1.84
8	100 ISOMEROSE	2.83	3.37	2.81	3.00
9	100 NUSWEET	2.36	2.56	2.19	2.55
10	100 ISOSWEET	5.78	3.21	3.40	3.36
11	100 HICONES	1.41	2.70	3.21	2.32
12		5.00	5.00	5.00	5.00
13	50 HFES 50 SUC	5.93	4.73	3.09	5.53

a = HICON CS = 62 DE

b = Min. Sign. Diff. = 2.795 Significant at 99% probability level.

c = " " " = 3.580

d = " " " = 2.64

e = " " " = 3.48

[a]HFES = 42% Fructose. Suc = Sucrose

Low CON CS = 43 D.E. ISOSWEET, NUSWEET, ISOMEROSE = D.E. not applicable.

*Sucrose had a value of 5.00 less than 5.00 was indicated as less sweet more than 5.00 was indicates as more sweet.

SUMMARY AND CONCLUSIONS

The application of some corn syrups and high fructose corn syrups as sweetening agents for a marachino type cherry was successful and showed good promise as an alternative source of sweetness. It was found that weight gain could be improved during the finishing operation by using slightly higher temperature and increasing the brix level of sweetener solution gradually over a little longer period of time.

In a commercial operation, cherries will usually gain about 5-8 percent in weight by the end of the finishing operation, but in this study the weight gain was about 15 percent.

There is no doubt that extended shelf life will require certain modifications in the way the product is handled, both during the processing and storage. Consideration of refrigerated storage would greatly increase the shelf life, as shown by the storage studies. In general, texture was improved and in most instances the over all quality of products stored at the lower temperature was better. However, it is questionable whether the quality improvement was great enough to convince maraschino finishers to go to refrigerated storage. In those products where corn syrups of HFCS were used as the sole sweetener, weight gains were significant and texture was generally very good. After three months storage all the products had approximately the same weight, but as mentioned before the producer is not concerned with weight gains after finishing. This study suggests that in maraschino type cherries it is better to use 100 percent substitution of sucrose, rather than to partially substitute sweeteners as is commercially being done, at present.

Future studies might be aimed at improving the flavor of maraschinos produced from some of these sweeteners and further investigating the effects of the sweeteners in flavor, by utilizing trained taste panelists.

APPENDICES

APPENDIX A

Sweetener Characteristics

Table A1 - Characteristics of corn products corn syrup 1632

Corn Syrup 1632 is a high conversion, high fermentable syrup of fairly low viscosity.

Typical Analysis:

Baume'	43.0
Dry Substance (1%)	81.7
Dextrose equivalent (D.F.)	64.0
Color	White to eight straw
pH	4.8
Starch	Negative
Ash (% sulfated)	0.35
SO_2 (ppm)	40

Handling Properties:

Temp. ^oF	Lbs/Gal	Viscosity (cps)
80	11.80	22,000
100	11.80	6,000
120	11.74	2,000

Recommended Storage Temperature: 90^{o}F

APPENDIX A (cont)

Sweetener Characteristics

Table A2 - Characteristics of corn products corn syrup 1132.

Corn syrup 1132 is a regular conversion, normal viscosity syrup.

Typical Analysis:

Baume'	43.0
Dry Substance (1%)	80.3
Dextrose equivalent (D.E.)	43.0
Color	White
pH	4.8
Starch	Negative
Ash (% sulfated)	0.3
SO_2 (ppm)	40

Handling Properties:

Temp. °F	Lbs/Gal	Viscosity (cps)
80	11.85	56,000
100	11.79	14,500
120	11.73	4,900

Recommended temperature: 100°F

APPENDIX A

Sweetener Characteristics

Table A3 - **Characteristics of corn product, invertose, High-fructose corn syrup 2643**

Invertose, High Fructose corn syrup 2643 is a high fermentable, low viscosity.

Typical Analysis:

Dry Substance (1%)	71
Color	Water White
pH	4.0

Sediment, floe, microbiological - Meets all Food and Bottling industry specification

Handling Properties:

Requires minimal heat during normal turnover.

APPENDIX A (cont)

Sweetener Characteristics

Table A4 - Characteristic of Isosweet: 100 High Fructose Corn Syrup

Isosweet 100 is a high conversion corn syrup that is enzymatically derived and isomerized to yield a saccharide composition consisting primarily of dextrose and fructose.

Typical Analysis:

Dry Substance (1%)	71.0
Dextrose equivalent (D.F.)	Not Applicable
Color	White
pH	4.0
Starch	Negative
SO_2 (ppm)	4.0
Density (wt/gal: at 80°F)	
lbs as is	11.19
lbs. solids	160

Handling Properties:

It is recommended that ISOSWEET 100 be stored at a temperature of 80° - 90°F. Within this range, color development and crystallization are minimized or eliminated.

APPENDIX A (cont)

Sweetener Characteristics

Table A5 - Characteristics of Staley Industrial Products Isosweet, 5500 high fructose corn syrup.

Isosweet 5500 is producted by a multiple enzyme conversion process and is caregully refined to conform to the highest standards of color, clarity, flavor and ash.

Typical Analysis:

Dry Substance (1%)	77 $\pm$ 0.5
pH	3.5
Ash, sulfated %	0.01
Color	White
Density (wt/gal: at 80°F)	
lbs as is	8.89
lbs. solids	11.55
Dextrose equivalent (D.E.)	Not Applicable
Viscosity centripoises at 80°F	670

Handling Properties:

It is recommended that ISOSWEET 5500 be stored at a temperature between 75° - 85°F.

APPENDIX A (cont)

Sweetener Characteristics

Table A6 - Characteristics of Staley industrial product Sweetose 440.

Sweetose 440 is a high conversion acid enzyme and has fairly low viscosity.

Typical Analysis:

Baume'	44
Dry Substance (1%)	83.8
Dextrose equivalent (D.E.)	64.0
Color	
pH	5.0
Weight, lbs./gal. at 100°F.	11.93
Viscosity, poises at 100°F	155
Ash sulfated (%)	0.02

Handling Properties:

It is recommended sweetose 440 to be stored and handled at 100°F.

APPENDIX A (cont)

Sweetener Characteristics

Table A 7 - Characteristics of Clinton industrial Isomerose, 100 brand (High Fructose Corn Syrup).

ISOMEROSE, 100 brand high fructose corn syrup is produced by a multiple enzyme process which makes use of advanced immobilization technology.

Typical Analysis:

Dry Substance (1%)	71
Color	White
Density lbs/gal at 85^{o}F	11.14
Density lbs/gal at 85^{o}F.	7.91
pH	
Ash sulfated (%)	0.03

Handling Properties:

It is recommended to store and handled the ISOMEROSE 100 Brand High Fructose corn syrup at 85^{o}F.

APPENDIX A (cont)

Sweetener Characteristics

Table A8 - Characteristics of Clinton products, regular corn syrup.

This product is converted by acid-enzyme type of conversion and has medium range viscosity.

Typical Analysis:

Baume'	43
Dry Substance (1%)	80.3
Dextrose equivalent (D.E.)	4.7
pH	
Density lbs/gal at 100°F	11.8
Color	White to Yellow
Ash sulfated (%)	0.4

Handling Properties:

It is recommended to store and handle this product at 100°F.

APPENDIX A (cont)

Sweetener Characteristics

Table A9 - Characteristics of clinton products, nusweet "E" corn syrup.

NUSWEET "E" is made by a dual or acid-enzyme process. NUSWEET "E" may be characterized as a syrup with low viscosity and high fermentability, sweetness, and osmotic pressure.

Typical Analysis:

Baume'	43
Dry Substance (1%)	82
Dextrose equivalent (D.E.)	62
pH	4.7
Density lbs/gal at 100°F	11.8
Ash sulfated (%)	0.4

Handling Properties:

It is recommended to store and handle this product at 85° - 95°F.

NUSWEET "E", clinton

APPENDIX A (cont)

Sweetener Characteristics

Table A10 - Characteristics of corn products. Celulose 2606 (liquid 10 dextrose) 2606*.

CELULOSE, liquid dextrose 2606 is available at various solids for convenience is storage and handling.

Typical Analysis:

Dextrose equivalent (D.E.)	99.5
Color	Water to Light Straw
pH	4.2
Ash sulfated (%)	0.1
Dry Substance (1%)	68.5

Handling Properties:

Holding Temp. ^{o}F 120 - 125^{o}.
Lbs/Gal 10.91 at 120^{o}F.

* This special product was used in the beginning of the experiment, but since even at cooling temperature (44^{o}F), molds were grown on the surface and also in the depth of sweetener. It was preferred to not continue using it. Also it was highly fermentable.

APPENDIX B

Weight Changes During Finishing Process

Table B1 - Per cent weight changes for various treatment during the maraschino finishing operation.

	Time (day)	2	3	4	5	6	7
Treatments	HICONES	2	6	7	10	12	14
	HICONES	2	6	9	10	13	14
	HFCS	3	5	9	12	14	17
	HFCS	4	7	10	12	14	16
	HFCS + SUC	0	2	3	6	8	14
	LOW CONES	5	7	9	11	12	15
	REG CONES	4	7	9	10	13	13
	ISOMEROSE	5	7	9	12	14	16
	NUSWEET	4	7	10	12	14	16
	ISOSWEET	5	7	9	12	14	16
	HICONES	4	7	9	13	14	16
	SUCROSE	6	7	10	14	15	18
	GS + SUC	2	4	5	6	10	12

* Each number is a mean of three replicates

APPENDIX C

Viscosities of various syrups at various temperatures

Table C1 - VISCOSITIES OF CORN SYRUPS IN POISES

DE	Baumé	Type of Conversion	60°F	80°F	90°F[2]	100°F	110°F[2]	120°F	140°F	160°F
27	42	Acid-enzyme	2800	790	420	222	152	93	36	14
31	42	Acid-enzyme		600	330	184	115	71	40	
36	42	Acid			–	74	-	27.5	11.5	5.6
36	43	Acid		800	370	180	103	60	23	10
42	42	Acid	1220	280	120	54	31	20	8.6	4.2
42	43	Acid	3000	590	260	124	70	42	17	7.4
42	44	Acid	5900	1050	560	330	175	100	35	14
42	45	Acid		7500	2550	1000	500	260	80	30
42	43	Acid-enzyme[1]	3400	580	280	145	82	49		
48	43	Acid-enzyme[1]		425	220	115	62	38		
54	42	Acid	672	154	64	29	17.5	11	5	2.4
54	43	Acid	1770	365	150	70	41	25	9.8	4.4
54	44	Acid	5900	1050	470	235	120	65	24	9
62	43	Acid-enzyme		300	140	70	41	24	11	-
62	44	Acid-enzyme		592	290	148	78	43	15	
64	41	Acid-enzyme		34	20	12	7.4	5.1	-	
64	42	Acid-enzyme		81	44	25	14.5	9.5	–	–
64	43	Acid-enzyme		220	115	60	32.5	20.5		–
64	44	Acid-enzyme		790	375	180	90	54		–
70	43	Acid-enzyme		170	90	48	29	17		–

Source: American Maize-Products Co.

[1] High maltose.

[2] Values at 90° and 110° mostly interpolated.

APPENDIX C (cont)

Viscosities of various syrups at various temperatures

Table C2 - VISCOSITY OF ACID-CONVERTED CORN SYRUPS

Solids (%)	Temp (°F)	35.4 DE Centipoises	35.4 DE SSU[1] Units	42.9 DE Centipoises	42.9 DE SSU Units	53.7 DE Centipoises	53.7 DE SSU Units	75.4 DE Centipoises	75.4 DE SSU Units
20	80	2.24	9.4	2.04	8.7	1.94	8.1	1.70	7.0
	100	1.78	7.5	1.45	6.1	1.45	6.1	1.33	5.5
	120	1.35	5.7	1.14	4.8	1.12	4.7	1.06	4.4
	140	1.12	4.8	0.92	3.9	0.91	3.9	0.83	3.5
35	80	6.31	24.9	4.75	18.7	4.95	19.4	3.22	12.4
	100	4.52	17.9	3.29	13.0	3.35	13.2	2.74	10.6
	120	3.35	13.4	2.51	10.0	2.51	9.9	2.07	8.0
	140	2.66	10.7	1.99	8.0	1.88	7.5	1.57	6.1
50	80	30.0	110.5	19.5	71.9	18.4	67.6	11.8	42.8
	100	18.5	68.4	12.0	44.5	11.6	42.9	7.9	28.8
	120	12.9	48.0	8.5	31.7	7.7	28.6	5.5	20.1
	140	9.4	35.1	6.3	23.6	5.4	20.2	3.2	11.8
65	80	398	1,364	237	815	159	55	77	27
	100	182	626	119	411	83	29	45	16
	120	108	374	69	239	47	17	26	9
	140	68	236	43	150	29	10	16	6
75	80	10,000	32,717	5,390	17,678	2,140	7,010	741	2,442
	100	3,020	9,930	1,880	6,189	807	2,651	331	1,096
	120	1,260	4,162	817	2,704	372	1,230	159	529
	140	620	2,058	389	1,294	191	635	83	277
80	80	126,000	401,836	59,600	190,690	17,800	56,931	4,570	14,716
	100	29,900	95,900	15,000	48,247	5,010	16,119	1,550	5,016
	120	8,910	28,736	4,840	15,626	1,800	5,811	603	1,960
	140	3,350	10,857	1,860	6,040	785	2,549	282	921
85	80	7,080,000	22,109,800	1,410,000	4,412,311	537,000	1,685,068	83,200	[illegible]
	100	1,000,000	3,137,900	227,000	712,802	85,200	268,532	17,000	54,136
	120	188,000	593,204	50,100	157,973	20,000	63,326	4,270	13,664
	140	44,900	142,465	13,000	41,202	6,310	20,076	1,660	5,335

Source: Erickson *et al.* (1966).
[1] Saybolt Seconds Universal by calculation.

APPENDIX D

Storage Studies

Table D1 - Per cent weight change of maraschino cherries after 1, 2, and 3 months storage as means of all temperatures.

	Time (months)		
Treatments	1	2	3
HICONES	4.52	0.37	1.18
HICONES	5.08	-0.05	1.64
HFCS	5.76	4.58	4.40
HFCS	5.82	2.57	1.98
GC + SUCROSE	2.76	5.27	2.92
REG CONES	4.73	3.35	2.64
LOW CONES	2.08	2.47	1.33
ISOSWEET	2.29	1.47	0.88
NUESWEET	3.73	1.76	1.02
ISOMEROSE	4.25	3.09	1.10
HICONES	1.22	1.14	6.79
SUCROSE	5.14	2.05	0.38
HFCS + SUCROSE	2.37	3.27	3.37

Each figure is the mean of 9 replicates.

This table shows weight changes at all temperatures for all treatments at one month, two months, and three months storage.

Negative number means percent weight loss at various storage time.

APPENDIX D (cont)

Storage Studies

Table D2 - Per cent weight changes of maraschino cherries after 1 month storage at various temperatures.

	Storage Temperature		
Treatments	44°F(66°C)	72°F(22.2°C)	89°F(31.7°C)
HICONES	9.63	5.88	-0.94
HICONES	6.62	6.23	2.38
HFCS	8.11	4.69	4.49
HFCS	5.91	6.67	4.88
HFCS + SUCROSE	7.15	1.63	-0.51
REG CONES	8.01	3.65	2.52
LOW CONES	5.56	0.38	0.29
ISOMEROSE	4.36	1.86	0.65
NUSWEET "E"	8.99	1.00	1.21
ISOSWEET	3.65	6.26	2.82
HICONES	1.98	-0.96	2.65
SUCROSE	6.01	1.42	7.99
CS + SUCROSE	4.28	3.85	-1.13

Effect of three temperature on the weight change of cherries after one month. One number is a mean of three replicates.

Positive number gain weight.

APPENDIX D (cont)

Storage Studies

Table D3 - Per cent weight changes after 2 months storage at various temperatures.

	Storage Temperature		
Treatments	44°F(66°C)	72°F(22.2°C)	89°F(31.7°C)
HICONES	5.91	1.39	-6.20
HICONES	2.85	-1.46	-1.53
HFCS	6.28	6.60	0.86
HFCS	2.99	1.03	3.67
HFCS + SUCROSE	5.54	3.77	6.50
REG CONES	6.42	4.06	-0.43
LOW CONES	6.94	2.20	-1.74
ISOMEROSE	2.52	1.24	0.65
NUSWEET "E"	3.54	1.35	0.38
ISOSWEET	3.09	4.34	1.86
HICONES	1.12	1.11	1.19
SUCROSE	2.02	1.00	3.12
CS + SUCROSE	6.10	0.31	3.39

Effect of three different temperatures on the weight changes of each treatment after two months. Each number is the mean of three replicates.

APPENDIX D (cont)

Storage Studies

Table D4- Per cent weight changes after 3 months storage at various temperatures.

	Storage Temperature		
Treatments	44°F(66°C)	72°F(22.2°C)	89°F(31.7°C)
HICONES	5.72	-1.73	-0.46
HICONES	5.25	-2.01	1.67
HFCS	7.31	6.17	-0.27
HFCS	3.25	1.69	0.97
HFCS + SUCROSE	4.89	2.62	1.26
REG CONES	7.46	2.48	-2.01
LOW CONES	4.94	-2.65	1,72
ISOMEROSE	3.90	-0.74	-0.52
NUSWEET "E"	3.73	1.15	-1.83
ISOSWEET	2.23	0.00	1.08
HICONES	1.29	0.49	0.58
SUCROSE	1.68	0.39	-0.94
CS + SUCROSE	4.78	2.89	2.43

Effect of temperature on the weight change of each treatment after three months. Each number is the mean of three replicates.

APPENDIX E

Textural Properties of Finished Products

Table E1 - The effect of various temperature on the firmness of the maraschino cherries after three months storage*.

	Temperatures	44^{o}F(66^{o}C)	72^{o}F(22.2^{o}C)	89^{o}F(31.7^{o}C)
Treatments	HICONES	427.9	433.3	405.0
	HICONES	477.8	484.2	491.0
	HFCS	515.7	517.6	484.9
	HFCS	462.0	466.5	466.0
	HFCS + SUCROSE	507.2	411.0	426.7
	REG CONES	457.9	389.0	405.2
	LOW CONES	486.4	506.1	479.5
	ISOMEROSE	459.6	437.2	340.7
	NUSWEET "E"	408.5	363.3	369.0
	ISOSWEET	474.7	466.7	431.7
	HICONES	463.3	420.1	410.2
	SUCROSE	498.2	490.9	505.3
	CS + SUCROSE	534.6	447.1	464.3

* Firmness was measured by chatillon and each number is the mean of two replicates. Each figure is the needed force in gram to deform 20 cherries.

APPENDIX F

Sensory Evaluation

Table F1 - Analysis of co-variance for sweetness mean square and F-value for sweetness

SWEET BY TREAT WITH REP		TREATMENT REPLICATE			
SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF. OF F
Covariates	0.841	1	0.841	0.341	0.561
Replicates	0.841	1	0.841	0.341	0.561
Main Effects	436.735	11	39.703	16.060	0.001
Treatment	436.735	11	39.703	16.060	0.001
Explained	436.576	12	36.465	14.750	0.001
Residual	395.539	160	2.472		
Total	833.115	172	4.844		

APPENDIX F (cont)

Sensory Evaluation

Table F2 - Analysis of co-variance for flavor mean square and F-value for flavor.

FLAVOR BY TREAT WITH REP	TREATMENT REPLICATE				
SOURCE OF VARIATION	SUM OF SQUARE	DF	MEAN SQUARE	F	SIGNIF. OF F
Covariates	2.740	1	2.740	0.677	0.412
Rep	2.740	1	2.740	0.677	0.412
Main Effects	143.901	11	13.082	3.230	0.001
Treat	143.901	11	13.082	3.230	0.001
Explained	146.641	12	12.220	3.017	0.001
Residual	647.980	160	4.050		
Total	794.620	172	4.620		

APPENDIX F (cont)

Sensory Evaluation

Table F3 - Analysis of co-variance for texture mean square and F-value for texture.

TEXTURE BY TREAT WITH REP		TREATMENT REPLICATE			
SOURCE OF VARIATION	SUM OF SQUARE	DF	MEAN SQUARE	F	SIGNIF. OF F
Covariates	52.670	1	47.718	21.685	0.001
Rep	52.670	1	47.718	21.685	0.001
Main Effects	47.760	11	4.251	1.932	0.039
Treat	47.760	11	4.251	1.931	0.039
Explained	94.478	12	7.373	3.578	0.001
Residual	352.080	160	2.201		
Total	448.558	172	2.596		

APPENDIX F (cont)

Sensory Evaluation

Table F4 - Analysis of co-variance for liking mean square and F-value for liking.

LIKING
BY TREAT
WITH REP

TREATMENT
REPLICATE

SOURCE OF VARIATION	SUM OF SQUARE	DF	MEAN SQUARE	F	SIGNIF. OF F
Covariates	2.835	1	2.835	0.737	0.392
Rep	2.835	1	2.835	0.737	0.392
Main Effects	252.188	11	22.926	5.960	0.001
Treat	252.188	11	22.926	5.960	0.001
Explained	255.024	12	21.252	5.525	0.001
Residual	615.425	160	3.846		
Total	840.444	172	5.061		

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