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To the Graduate Council:

I am submitting herewith a thesis written by Thakor G. Patel entitled "Composition of Sorgo Juice as Related to Sirup Composition and Quality." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Technology.

Melvin R. Johnston
Major Professor

We have read this thesis and recommend its acceptance:

J. E. McCarty

Henry H. Tinberg

Accepted for the Council:

Hilton A. Smith
Vice President for
Graduate Studies and Research

COMPOSITION OF SORGO JUICE AS RELATED TO SIRUP COMPOSITION AND QUALITY

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Thakor G. Patel

August 1967

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CHAPTER I

INTRODUCTION

There are many problems involved in making high quality sorgo sirup. The first step toward industrial development, as well as toward a better homemade sirup, is a more complete knowledge of the chemical composition of the juice and sirup. On the whole, the literature indicates that earlier investigators made little attempt to correlate juice composition and sirup quality.

Sorgo production in the United States is distributed more widely than the production of sugar cane or sugar beets. Sorgo is easy to cultivate. The adaptability of the sorgo crop to many soils and climatic conditions is noteworthy (9).

Some sorgo is grown for sirup in thirty-five states, but it is grown most extensively in the southeastern states. Six states, Mississippi, Alabama, Arkansas, Tennessee, North Carolina, and Georgia, sometimes called the "sorgo sirup belt," produce about 50 percent of the total amount of sorgo sirup. Mississippi and Alabama have been the largest producers for many years (24).

The production of sweet sorgo for sirup in Tennessee is not very extensive as compared to that of some of the more common crops, but it is an important source of income on some farms and in some areas of the State. Six counties, Benton, Warren, Fayette, Tipton, Shelby, and DeKalb, produced approximately 44 percent of the State production in 1959 (16).

Benton County reported 14 percent of the total acres of sorgo grown in the State in 1959 and 23 percent of the total production. Warren County is the second largest producer in Tennessee.

No information is available pertaining to the amount of consumer demand for sorgo sirup. However, consumers prefer high quality sirup, and in order to fulfill this requirement, it is necessary to eliminate the practices contributing to the production of inferior sirup.

Early research workers reported that many factors could influence sirup quality. The chemical composition of the juice is considered to be the most influential factor affecting quality of sirup. The relationship between various constituents in the juice and the finished sirup has been most neglected and is still little understood. With this factor in mind, the objectives of this study were: (1) to determine the presence of certain chemical constituents of the juice; (2) to determine the concentration of these constituents in different internodes and sections; (3) to determine chemical composition of sorgo sirups and (4) to relate the chemical composition of the juice to the composition and quality of the sirup.

CHAPTER II

REVIEW OF THE LITERATURE

Sorgo is one of the few domesticated plants. The common name sorgo or sorghum, was derived more than four hundred years ago from the Latin word "surgo," meaning to rise or tower, in reference to the height of sorgo in comparison with that of other crops (7). The name "sorgo" is commonly used to identify cultivars of sorghum that have an abundance of sweet juice. These sweet juice cultivars are also called "sweet sorghum" or "sugar sorghum" (24).

Many facts point to the independent origin of sorgo in tropical Africa and in India, which are the two great centers of sorghum production, each occupied by an enormous number of cultivars (7). Other centers were established centuries ago in interior Asia, China, and Malaya, and more recently in southern Europe, the Americas, Australia, and other parts of the world (11). The recognized wild domesticates (and all cultivated sorgo) are limited to Africa, south of the Sahara, and range far down into the temperate zone of South Africa (3).

I. TAXONOMIC CLASSIFICATION OF SORGO

Sorgo belongs to the grass family Gramineae. The four groups of sorgo grown in the United States are:

1. Broomcorn, used in the making of brooms and brushes.
2. Saccharine or sweet sorgo, grown for use in sirup and

sugar making because of their sweet sap or juice. These sorgo are also grown for pasture, hay, silage, green-chop, and seed.

3. Nonsaccharine or grain sorgo, grown especially for starchy seeds for livestock feed. In some countries sorgo grains are used as human food.
4. Grassy sorgo, including Johnsongrass and Sudangrass, grown for livestock grazing, green-chop, silage, and hay.

II. INTRODUCTION OF SORGO INTO THE UNITED STATES

Sorgo has been used for many centuries in southern Europe but the date of its introduction into this country is uncertain. Credit is usually given to William R. Prince, a nursery man of Flushing, New York, who in 1853 brought seed from France. Two years later the Government obtained seed from various sources and distributed it widely to determine the suitability of the plant for cultivation under local conditions (7).

The widespread and increasing interest in this crop was not because of its forage or even its sirup value, but for its value as a probable source of sugar. The first African introductions were brought from Europe to this country in 1857 and grown in Georgia and South Carolina, and were soon distributed throughout the sorgo-growing region. About 1865 four other introductions were received from China. Later, about 1880, numerous introductions were received again, from both China and Africa (6). None of the latter entries has proved superior to the original strains or cultivars selected from the original introductions (3).

III. DEFINITION OF SORGO SIRUP UNDER THE FOOD AND DRUGS REGULATIONS

"Sorgo sirup is made by the evaporation of sorgo juice or the solution of sorgo concrete, and contains not more than 30 percent of water and not more than 2.5 percent of ash" (2). The term sorgo molasses, often applied to sorgo sirup, does not describe the product properly. It probably came into use because poor quality sorgo sirup, like molasses, is dark and thick and flows slowly. Sirup such as sorgo, sugar cane, and maple-sap sirups are made by evaporating the plant juice or sap without removing any of the sugar. Molasses is the liquid which remains after part of the sugar has been removed, as in the manufacture of cane sugar. When no sugar is made from sorgo, the use of the term "molasses" in this connection is incorrect (9, 29).

IV. CHARACTERISTICS OF HIGH QUALITY SIRUP

High quality sorgo sirup is characterized by the following attributes:

1. Light amber color that is almost free of opaqueness.
2. Mild, sweet flavor, nearly free of tang.
3. No colloidal sedimentation, or only sediment confined to a trace of small particles near the top of the container.
4. High viscosity, causing sirup to move slowly when poured from a container, but to be free of the jelly-like consistency usually associated with a high starch content.

5. No crystallization, or limitation of crystallization to a few small crystals (24).

V. EXTENT OF CULTIVATION OF SORGO FOR SIRUP MAKING

The adaptability of the sorgo crop to many soils and climatic conditions is noteworthy (9). Although many soil types will produce an excellent quality of sorgo sirup, the best quality of sirup cannot be produced on poorly drained or heavy soil types. Sorgo is adapted to soil and climatic conditions as diverse as those found in Minnesota, Alabama, Indiana, and New Mexico. Sorgo is grown most extensively for sirup in the southeastern states. A so-called sorgo belt extends from Virginia, North Carolina, South Carolina, and northern Georgia through Kentucky, Tennessee, Missouri, Arkansas, and Oklahoma, including also the northern part of Alabama, Mississippi, and Louisiana.

In general, the land used for sorgo grown for sirup production on individual farms is somewhat less than an acre (9, 24).

The cultivation of sweet sorgo for sirup in Tennessee is not very extensive as compared to some of the common crops, and it has never been considered an important cash crop. However, it is an important source of income on some farms and in some areas of the State (16).

In 1959, the Census of Agriculture reported a total of 2,980 acres of sorgo for sirup grown in Tennessee, with a total production of 215,378 gallons of sirup. About 63 percent of this was sold, while about 37 percent was produced for home consumption.

Six counties, Benton, Warren, Fayette, Tipton, Shelby, and DeKalb, produced approximately 44 percent of the total State production in 1959. Benton County reported 14 percent of the total acres of sorgo grown in the State in 1959, 23 percent of the total production.

VI. SIRUP MANUFACTURE

Extracting the Juice

The sorgo industry has made little progress since its introduction into the United States.

The first method for extracting the juice from stalks was by use of presses made from wood. Black locust was generally used because it was one of the harder woods. One significant change is that the wooden rollers now have been replaced by iron rollers, and today two- and three-roller mills are on the market. The extraction with two-iron roller mills yields more juice than with wooden rollers, but is not equal to that with three-iron roller mills.

Sorgo stalk ordinarily contains from 70 percent to 80 percent water and about 10 percent to 12 percent fiber, but it is impossible to extract all of the water as juice. With the three-roller mill, at least 50 percent of weight of the stalks should be extracted as juice unless the stalks are very hard and dry.

The "feed," or quantity of the stalks through the rollers, depends upon the adjustment of the distance between rollers. Juice obtained by moderate pressing is cleaner than that obtained by extreme

pressure, since with extreme pressure more impurities from the rind and joints of the stalks are extracted (5, 29).

As the raw juice runs from the mill, it contains both suspended and soluble impurities. It contains soil particles, stalk fiber particles, organic acids, starch and other complex carbohydrates, protein, pigments, gums, and waxes in addition to sugar and water (29).

Many of these constituents are deemed as undesirable impurities and must be removed or altered in some manner for production of high quality sirup. Many schemes and substances have been proposed for clarification. Some of them have proved to be useful while others remain questionable.

Filtering and Settling of the Juice

Filtration and settling is the process by which undissolved impurities are removed. As the raw juice runs from the mill, it passes through one or more wire screens to remove the larger pieces of suspended matter, such as stalk fragments, soil particles, and other extraneous material. After filtering, the juice should be allowed to settle without agitation for at least two hours (5, 14, 15, 29, 30, 32, 37).

Clarification of the Juice

The purpose of clarification is to remove objectionable substances from the raw juice.

When heat is applied to the juice much of the starch becomes soluble, but certain proteins and other nonsugar substances become coagulated and either settle to the bottom or rise to the surface. The

materials which rise to the surface are to be removed by skimming or brushing off (14, 29).

At certain seasons, and with certain cultivars of sorgo, the raw juice may be high in acid content. Lime sometimes is added to partially neutralize this acid. It also precipitates some of the organic matter. Phosphoric acid compounds, lime carbonate, milk of lime, and vegetable decolorizing carbon have been used to some extent in juice clarification (5, 30).

Various types of clays and diatomaceous earth compounds have been used as an aid in juice clarification. Webster, Davies, and Sielinger (32) reported that the greatest advantage of clay treatment lies in the reduced amount of skimming needed. One difficulty encountered with many samples was clabbering (or jellying) of the finished product upon standing. The clay treatment reduced this fault, but did not entirely eliminate it. They found that an improved sirup resulted from the use of various clays in juice clarification, although the yield of sirup was somewhat reduced. Gassler, Reid, and Cuthbert (11, 12) evaluated the qualities necessary for a clay to secure good juice clarification. They also stated that the clay may be reused once, thus reducing mechanical losses. The real problems involved in the use of clay are the necessity of having settling tanks and the effort required to transfer the heated juice to and from such tanks.

Semisirup Stage

Sherwood (21, 22) reported the starch content of the juices of fifteen cultivars of sorgo and concluded that starch was the cause of

jellying or clabbering of sorgo sirups. Willaman and Davison (35), in studying the jellying of sorgo sirups, found that 0.32 to 1.15 percent of starch was present in normal sirups and 1.17 to 3.36 percent in sirups that jelly. Walton and Ventre (29) found that starch was responsible for slow boiling and the scorching of sirup during evaporation.

Webster, Davies, and Sielinger (32) used the semisirup procedure suggested by Walton and Ventre (29) in evaluating the ability of several commercial diastatic enzymes to reduce jellying. Diastatic enzymes break down starches to sugars, thus removing one factor that causes jellying. Clabbering was reduced but not eliminated in some samples, and little improvement was noted in others. Clay treatment generally yielded better results than the enzyme treatment.

Ventre, Byall, and Walton (26) found that when the ratio of sucrose to reducing sugars in the sirup was 1.15 or greater, sucrose crystallized; when the ratio of reducing sugars to sucrose was 1.04 or greater, dextrose crystallized. They also reported that sucrose crystallization occurred most frequently in sirups made from the upper part of the sorgo stalk and dextrose crystallization occurred from the lower portion of the stalk. The use of invertase, which hydrolyzes sucrose to the simple sugars-glucose and fructose has been recommended as an aid in preventing crystallization in sirup (29). They concluded that invertase was generally effective, especially if the cultivar selected contained mostly sucrose.

Evaporation

Poor quality in sorgo sirup often results from slow boiling, scorching, or burning of the juice during evaporation. Most evaporating in early times was done in pots, kettles, and metal boxes, some of which are still being used. The fire-heated evaporator, made of thin metal (galvanized iron or copper) sometimes called pan, came into general use in about 1875. This evaporator had baffles to control the flow rate of juice. The development of the evaporator is generally considered the most significant innovation adopted by the sirup industry. The advantages of using a continuous-type evaporator over the pots, kettles, and boxes are:

1. Rapid evaporation is obtained, which is essential in making light-colored sirup.
2. The sirup is concentrated in a thin layer, thus increasing the rate of boiling and foaming and affording a better opportunity for thorough skimming.
3. Heat is applied to the bottom of the evaporator, thus imparting an upward motion to the coagulated material, whereby skimming is facilitated (30).

The disadvantages are:

1. More attention is required to maintain a properly regulated flow of juice.
2. There is increased danger of scorching the sirup and altering its color and flavor.
3. More careful attention to firing is necessary.

4. More skill is required to obtain uniform sirup density.

The degree of sugar crystallization depends partly on the density of sirup (30). Evaporation of the juice must be to the proper density. The sirup-maker thermometer can be used for determining the proper density of finished sirup. The first step in using the thermometer is to know the temperature at which water boils in the particular locality. Sugar cane sirup and sorgo sirup are usually finished respectively at temperature 12 to 13 degrees and 14 to 15 degrees higher than the boiling point of water in that locality (37).

VII. CHEMICAL ANALYSIS OF JUICE AND SIRUP

Webster, Davies, and Sielinger (31) stated that the first step toward industrial development of large scale production of sirup from sweet sorgo, as well as toward a better home-made sirup, should be a more complete knowledge of the chemical composition of juices and sirups. This information also would be essential to the improvement of more suitable cultivars for sirup production.

Extraction of Juice

Broadhead, Stokes, and Freeman (4) studied spacing of sorgo in Mississippi, and stated that yield of stalks and of sirup per acre usually decreased when the spacing between single sorgo plants was more than 6 to 8 inches in the row. Juice extraction and stalk weight decreased when plants were spaced closer than 6 to 8 inches in the row. Two plants in hills 16 inches apart and four plants in hills 24 inches

apart gave about the same brix and yield of stalks as single plants drilled 8 inches apart in the row. In each experiment the width between two rows was 40 to 42 inches.

Webster, Banefiel, and Davies (33) stated that the most important factor influencing the yield of sirup at any time is climate. They found that almost invariably a regular reduction in the percentage of extractable juice occurred during the last month of every season.

Webster, Davies, and Sielinger (31) studied the effect of various cultivars on the yield and composition of juice at different stages of maturity for the years 1943, 1944, and 1945. In their study the yield of juice was generally around 45 percent and only one cultivar (Leoti) averaged as much as 50 percent.

Coleman and Stokes (8) studied the effects of various storage periods and conditions of storage of stalks prior to grinding on the yield of juice and quality of sirup obtained from several cultivars of sorgo cane. They found that juice extraction remained constant for sorgo stalks kept wet, but decreased gradually for stalks during a storage period of two weeks. Extraction losses were due mainly to evaporation.

Harwell (13) compared the composition of juice of two sorgo cane cultivars and concluded that there was no significant difference between cultivars in percentage of juice extracted or among positions of stalk. The stalk was divided in four sections, beginning at ground level and numbering consecutively up to and including the peduncle. The lowest

volume of juice was obtained from section four of the stalk, with an increasing amount being obtained from sections three, one, and two, respectively.

Total Solids

Webster, Davies, and Sielinger (31) found that solids increased as the season progressed and most juices contained from 14 to 20 percent solids, with the notable exception of one cultivar which had 24 percent solids.

Coleman and Stokes (8) studied conditions of storage of sorgo stalks prior to grinding and found that brix values increased as extraction values decreased, mainly due to evaporation during storage.

Webster, Banefiel, and Davies (33) conducted a study on chemical composition and yield of juice as related to the time of harvest of eight cultivars of sorgo cane. In their study they found that the percentage of solids increased irregularly until near the end of the season, when a slight decrease often occurred.

Ventre and Byall (25) analyzed the different internodes of four cultivars of sorgo at different stages of growth and concluded that the percentage of dissolved solids in the juice increased with maturity. The solids progressively increased from the first to a maximum in the third or fourth internode, with a small progressive decrease in lower internodes. The uppermost internode was No. 1.

Harwell (13) analyzed different internodes of two cultivars and concluded that there was no significant difference in the percentage

of total solids and brix values between position, but a significant difference was found between cultivars Meridian 59-1 and Tracy.

Glucose, Sucrose, and Total Sugars

Webster, Davies, and Sielinger (31) found that the sugar content of the juice ranged from less than 10 percent to nearly 20 percent. In all cultivars a general decrease was found in the percentage of reducing sugar and an increase in the percentage of sucrose as the season progressed.

They also found that there was a wide range in the relationship between reducing sugars and sucrose in the sirup. Apparently the cooking process resulted in a considerable inversion of sucrose.

Coleman and Stokes (8) found that sucrose losses were negligible for stalks kept wet, and only slight for stalks stored dry. They also found that no inversion took place in the sirup, and that for some cultivars, sirup yields were increased by storage of the stalks for six days.

Webster, Banefiel, and Davies (33) studied eight cultivars at different harvest times and concluded that total sugars and sucrose increased generally throughout the season to a maximum and then remained relatively constant during the last month. Reducing sugars more often decreased as the harvest season progressed, but sometimes increased.

In the manufacture of sorgo sirup, Willaman and West (34) found that the proportion of sucrose to dextrose in the sirup depended mainly on two things: maturity of the plant and acidity during defecation and evaporation.

Ventre, Byall, and Walton (26) determined the effects of sugar and starch content on crystallization and jellying of sirup produced from juice at different stages of maturity.

In the study of sixty-seven different samples of sirup made from various parts of stalks and ten samples made from whole stalks, they concluded that (1) the starch content and jellying of sorgo sirups are correlated and upper portion of the stalk produces sirups with higher starch content; (2) dextrose crystallization occurs most frequently in sirups made from the lower portions of the stalk; (3) sucrose crystallization occurs most frequently in sirups made from upper parts of the stalk; and (4) jellying and crystallization of either sucrose and dextrose may occur in the same sirup. They also found that sucrose crystallized when the ratio of sucrose to reducing sugars in sirup was 1.15 or greater, and dextrose crystallized when the ratio of reducing sugar to sucrose was 1.04 or greater. As a factor in the quality of sorgo sirup, crystallization of dextrose is as important as crystallization of sucrose.

Harwell (13) determined the amount of certain chemical components contained in the juice of two cultivars of sorgo cane and concluded that position and cultivars caused a significant difference in the percentage of total sugars. He also stated that there were significant differences in free glucose among different cultivars and positions.

pH and Titratable Acidity

The effect of cultivar on yield and composition of juice was studied by Webster, Davies, and Sielinger (31). They found that the pH

value varied from 4.95 to 5.30. They also found that pH values increased as the season progressed, but not to the extent of the increase found in titratable acidity, which showed a marked increase as the season progressed.

Webster, Banefiel, and Davies (33) studied the yield and composition of sorgo juice in relation to time of harvest and found that titratable acidity normally increased during the harvest season.

Parson (19) reported that the calcium salt of aconitic acid was deposited on the surface of evaporation pans used to concentrate sorgo juices which had previously been neutralized.

Willey and Maxwell (36) found citric, malic, acetic, tartaric, oxalic, and formic acids in sorgo juice along with large amounts of aconitic acid.

Ventre, Ambler, Henry, Byall, and Paine (27) reported aconitic acid occurring in sorgo juice, both free and combined as calcium and magnesium salts. They presented a commercially feasible method for the extraction of aconitic acid from sorgo sirup. They also said that titratable acidity increased when aconitic acid content increased.

Measuring the quantity of organic acids of sorgo plants, Madar and Webster (18) confirmed the presence of aconitic, oxalic, malic, citric, acetic, and tartaric acids. Fumeric acid was also present. They found that there were great differences in the quantity of organic acids among cultivars. The quantity of organic acids ranged from 0.410 mEq./ml. of sirup in Sugar Drip cultivar to 0.662 mEq./ml. of sirup in Leoti cultivar.

Willaman, West, and Bull (34) reported that oxalic, malic, citric, and tartaric acids were invariably present in sorgo plant.

Ventre and Byall (25) analyzed the different internodes of four cultivars of sorgo at different stages of growth and concluded that the titratable acidity per gram of solids for all cultivars and stages of maturity studied was highest in the first internode and decreased rapidly in the internodes constituting the upper third of the stalk. The uppermost internode was No. 1.

Ash, Nitrogen, and Alcohol Insoluble Solids

Webster, Davies, and Sielinger (31) found that the percentage of ash increased gradually as the season progressed. They also stated that apparently a considerable amount of ash was removed in the skimming, for the increased percentage in the sirup over that of the juice was only about one-half of that indicated by the degree of concentration of juice.

At the time of publication of this paper, data for nitrogen content were incomplete, but they stated that they had some difficulty in processing the samples of high nitrogen content.

Willaman, West, and Bull (34) reported that nonprotein (amid) nitrogen was very high in sorgo juice, even in mature cane. This is an important contributing factor in the difficulties of defecating sorgo juice for either sirup or sugar production.

CHAPTER III

MATERIALS AND METHODS

I. MATERIALS

The sorgo cultivar utilized in this study was Tracy, grown on Sequatchie loam, 0 to 2 percent slopes, at the Plant Science Farm, University of Tennessee, Knoxville. Planting was done during the first week of May 1966. Spacing between rows was 3 feet and the population 45,000 plants per acre. Fertilizer was applied as ammonium nitrate and 0-20-20 for a total application of 120-120-120 per acre. P and K were broadcast and disced in, and N was side-dressed. The crop was harvested during the third week of August 1966 at soft to medium-hard dough stage of maturity.

II. METHODS OF ANALYSIS

Preparation of Juice and Sirup

Fifty stalks were selected at random and cut at the nodes. Internodes were numbered consecutively from the base up to and including the peduncle, and segregated into batches according to number for pressing. From each batch, ten internodes were selected at random and the length and diameter of the internodes were measured. After each batch was weighed, the internodes were passed through a three-roller press, and the juice collected, strained, and weighed. The percentage of

juice extracted was calculated. The juice was frozen immediately after pressing in an Air Blast freezer at -20°F. (-28.9°C.) and stored in the same room (-20°F. or -28.9°C.) until analysis was made.

The remaining stalks were cut into four sections. Some stalks did not have twelve internodes, and because of this, cutting of the sections was started from the top. Section 4 is composed of positions 9, 10, 11, and 12; section 3, positions 6, 7, and 8; section 2, positions 4 and 5; and section 1, positions 1, 2, and 3. The cut pieces were segregated in batches according to section number for pressing. After each batch was weighed, the pieces were passed through a three-roller press, and the juice was collected, strained, and weighed. The percentage of extracted juice according to section was calculated. Immediately after pressing, the juice was frozen in tin cans in an Air Blast freezer at -20°F. (-28.9°C.) and stored in the same freezing room (-20°F. or -28.9°C.) until cooking.

Before cooking, juice was kept at room temperature overnight for reconstitution. After reconstitution the juice was boiled for five minutes, celite was added at the rate of one pound of celite per forty pounds of juice, and the juice then allowed to settle overnight in a refrigerated room at 36°F. (2.2°C.). Clear juice was decanted without disturbing the settled material, and weighed. The percentage of loss was calculated.

The juice was divided into three sublots for cooking from sections 1, 2, and 3; and two from section 4. Cooking was done in steam-jacketed kettles. The end point was checked by utilizing

a candy thermometer. The finished sirup was weighed, and the fold of concentration was calculated. The finished sirup was poured into one-pound glass jars and stored for analysis.

Chemical Analysis

A 10 g. sample was used to determine the ash content of the juice, and a 1 g. sample was used to determine the ash content of the sirup. The sample was weighed into a tared platinum dish. The juice was evaporated to sirup consistency in a water bath to prevent caramelization. The sample was then transferred to a muffle furnace, and ignited for four hours at 1022°F. (550°C.), transferred to a desiccator, cooled, and weighed. The amount of material remaining was calculated and expressed as percent ash (1).

For determining alcohol-insoluble solids (AIS), a 20 g. sample was weighed into a 600 ml. condensor flask; 140 ml. of 80 percent ethyl alcohol was added, and the mixture was boiled for 30 minutes with a reflux condensor. The flask was then removed from the condensor and the AIS were filtered on No. 1 Whatman filter paper by use of an aspirator. AIS were rinsed with two portions of 80 percent ethyl alcohol (1).

The filtered sample was then transferred to a tared evaporating dish and placed in the oven for two hours at 212°F. (100°C.). After drying, the dish was removed from the oven, cooled in a desiccator, and weighed. The percentage of AIS was calculated from insoluble material after drying.

A 10 g. sample was used to determine the total solids of the juice, and a 1 g. sample was used to determine the total solids of the sirup. The sample was weighed into a tared evaporating dish containing 5 to 10 g. of quartz sand and evaporated to dryness in a water bath. The sample was then transferred to a 158°F. (70°C.) vacuum-oven operated at 20 inches of mercury for 18 hours where drying was completed. The sample was then transferred to a desiccator, cooled overnight, and weighed. The percentage of total solids was calculated from the amount of insoluble material (1).

The pH was determined on raw juice and sirup by using a Beckman Zeromatic pH meter.

Brix, or soluble solids of the juice and sirup, was determined by using an Abbe Refractometer. The temperature was noted. The readings were corrected to 58°F. (20°C.) by use of conversion tables (1).

Total acidity was determined with samples of 20 g. of juice and with samples of 10 g. of sirup. Each sample was weighed into a 150 ml. beaker, and sufficient distilled water added to bring the total volume to 50 ml. The mixture was then titrated with .1N NaOH to a pH of 8.1 using the pH meter. The results were expressed as ml. of .1N NaOH required to neutralize 100 g. of sample (1).

Nitrogen percentage was determined by the Kjeldahl method. Samples of 15 g. of juice and 1 g. of sirup for the same were taken. Basically the H_2SO_4 (1) converts nitrogen to ammonium sulfate during the digestion process. The ammonium sulfate was treated with strong NaOH and heated to distill ammonia which was collected in saturated boric

acid solution (with mixed indicator of methyl red and methylene blue). The boric acid solution with the ammonia was treated with standard acid and the percentage of nitrogen was calculated from the titration data.

Glucose was determined colorimetrically by employing the Fermco S.F.G. Test, Method II, using the enzyme preparation chromogen (10). Optical densities were measured by using Bausch and Lomb Spectronic 20 colorimeter set at 540 mμ. The optical densities were converted to percentage of glucose by using a standard curve.

Glucose produced from sucrose was determined by using invertase enzyme, measuring glucose as described above, and deducting the amount of glucose found before inversion from the amount found after inversion.

Hydrolysis of sucrose by the action of dilute acids or enzymes, gives equal quantities of glucose (Dextrose) and fructose (Levulose), the mixture being called invert sugar (17).

Free glucose plus two times glucose determined from the conversion of sucrose gave the total sugars.

Each factor measured was statistically analyzed by employing 4 x 2 factorial design (four sections and two determinations) in juice and 4 x 3 factorial design (four sections and three cookings) in sirup. The effect of factors studied was tested for significance by analysis of variance. Significance among means was determined by use of Duncan's Multiple Range Test. The missing data of the third cooking of section four was taken as the mean of the previous two cookings of the same section.

Differences in flavor of the sirup were determined organoleptically by triangle taste test (20). All the samples were served in a dark room because of differences in color of sirup made from the juice of different sections. The significance of differences was determined by referring to the table of probabilities (20).

Color and clarity were tested by passing ordinary 15 W. cool white fluorescent light through the sirup in a test tube. Artype 1202 letter 'O' was used as Bench-mark, which was viewed through the sirup in the test tube against the light. The members of the panel were asked to rank color from yellow to pale orange, and clarity from poor to most clear by giving highest points to pale orange and to most clear.

CHAPTER IV

EXPERIMENTAL RESULTS

In one phase of the research represented herein, the cane stalk was divided into twelve parts by cutting at the nodes. To facilitate the discussion of the results, the various internodes will be referred to as positions. Numbering of the positions was started with the one nearest the ground (position 1) and numbering consecutively up to and including the peduncle (position 12). In another phase of the investigation, the stalk was divided into four sections. Section 1 was composed of positions 1, 2, and 3; section 2, positions 4 and 5; section 3, positions 6, 7, and 8; and section 4, positions 9, 10, 11, and 12.

The analysis of variance (Tables I and II) indicated a significant difference among sections in percent soluble solids (brix), AIS, total solids, ash, total acidity, nitrogen, free glucose, glucose from sucrose, and total sugars of both juice and sirup. Interactions of sections and cookings showed a significant difference for above variables. There was no significant difference among cookings except brix.

I. PERCENTAGE OF JUICE EXTRACTED

The percentage of juice extracted from each of the four sections of stalk of the cultivar used in this study was 44, 44, 40, and 30 percent

TABLE I

RELATIONSHIP OF THE CHEMICAL ANALYSIS OF JUICE TO SECTION OF STALK (STEM)

Sources of Variance	d.f.	Mean Squares								
		Brix Value	% Alcohol Insoluble Solids	% Total Solids	% Ash	Total Acidity ml.	% Nitrogen	% Free Glucose	% Glucose from Sucrose	% Total Sugars
Among Sections	3	1.4246**	0.7684**	1.8734**	0.0058*	119.2313**	0.0004**	6.1146**	0.7549*	8.0833**
Among Determination	1	0.0013	0.0001	0.0050	<0.0001	0.0113	<0.0001	<-0.0001	0.0091	0.0450
Residual	3	0.0012	0.0002	0.0050	0.0003	0.0246	<0.0001	0.0417	0.0654	0.1283

*Means significant at 0.05 level of probability.

**Means significant at 0.01 level of probability.

TABLE II

RELATIONSHIP OF THE CHEMICAL ANALYSIS OF SIRUP TO SECTION OF STALK (STEM)

Sources of Variance	d.f.	Mean Squares								
		Brix Value	% Alcohol Insoluble Solids	% Total Solids	% Ash	Total Acidity ml.	% Nitrogen	% Free Glucose	% Glucose from Sucrose	% Total Sugars
Among Sections	3	34.2111*	13.3615**	61.7393**	0.1767*	1970.0937**	0.0235**	162.5345**	344.2396**	620.3988**
Among Cooking	2	25.9696*	0.0048	9.6175	0.0148	242.2604	0.0005	0.4288	2.4146	6.5886
Among Section X Cooking	6	6.4314**	0.0090	3.6143**	0.0329**	130.8438**	0.0004**	1.7894**	3.6147**	9.9922**
Residual	12	0.0025	0.0002	0.0113	0.0004	0.1354	<0.0001	0.0617	0.1618	0.8563

*Means significant at 0.05 level of probability.

**Means significant at 0.01 level of probability.

from sections 1, 2, 3, and 4, respectively. The percentage of juice extracted for the four sections was 39 percent. The positions yielding the highest and lowest percent extraction were positions 5 and 12, with 46 and 26 percent, respectively. The diameter of internodes ranged from 17 mm. in position 2 to 7 mm. in position 12. The length of internodes ranged from 121 mm. in position 1 to 478 mm. in position 12. The average weight of internodes was highest, 46 g. at position 3; and lowest, 16 g. at position 11 (Tables IV, V, and VI, in the Appendix).

II. BRIX

Duncan's Multiple Range Test (Table III) showed no significant difference for brix content between sections 1 and 2, but a significant difference between sections 3 and 4, while the same test for sirup showed significant differences among the four sections.

The brix content was highest in section 3 with 22.50 percent total soluble solids, and lowest in sections 1 and 2 with 20.80 percent total soluble solids in each section. Total soluble solids were highest (23.80 percent) in position 7, and were lowest (17.50 percent) in position 3 (Table VI, in the Appendix). The mean value of total soluble solids for the four sections was 21.50 in this cultivar.

III. ALCOHOL INSOLUBLE SOLIDS

The results of Duncan's Multiple Range Test (Table III) for the juice showed no significant difference between sections 1 and 2, but a significant difference between sections 3 and 4, while the same test for sirup showed significant differences among all sections.

TABLE III

RESULTS OF DUNCAN'S MULTIPLE RANGE TEST (JUICE AND SIRUP)

	JUICE				SIRUP			
	Mean of Section*				Mean of Section*			
	1	2	3	4	1	2	3	4
Brix value	20.80^{a}	20.75^{a}	22.50^{b}	21.80^{c}	78.4^{a}	77.3^{b}	76.4^{c}	72.9^{d}
% alcohol insoluble solids	0.486^{a}	0.579^{a}	1.39^{b}	1.755^{c}	1.123^{a}	1.322^{b}	1.980^{c}	4.367^{d}
% total solids	20.65^{a}	20.75^{a}	22.65^{b}	21.95^{c}	79.1^{a}	78.2^{b}	74.0^{c}	72.6^{d}
% ash	0.656^{a}	0.539^{b}	0.556^{c}	$0.552^{b,c}$	1.665^{a}	1.733^{b}	1.743^{b}	2.051^{c}
Total acidity ml.	18.6^{a}	20.3^{b}	21.9^{c}	35.0^{d}	78.4^{a}	84.5^{b}	87.3^{c}	121.4^{d}
% nitrogen	0.13^{a}	0.11^{b}	0.11^{b}	0.14^{a}	0.38^{a}	0.31^{b}	0.29^{c}	0.43^{d}
% free glucose	6.875^{a}	8.625^{b}	6.875^{a}	4.375^{c}	21.883^{a}	16.566^{b}	13.650^{c}	9.500^{d}
% glucose from sucrose	3.06^{a}	4.44^{b}	4.19^{b}	4.18^{b}	4.59^{a}	16.83^{b}	19.07^{c}	21.30^{d}
% total sugars	13.1^{a}	17.0^{b}	15.3^{c}	12.8^{a}	31.1^{a}	50.2^{b}	$51.7^{b,c}$	52.0^{c}

NOTE: Means followed by the same letter are not significantly different at 0.05 level of probability.

*1 = section near ground, 4 = section on top.

AIS content was lowest in section 1 with 0.49 percent, and highest in section 4 with 1.76 percent, which was 3.6 times greater than the previous. Section 4 contained 42 percent of the total AIS found in this cultivar. The ratio of AIS in the upper two sections to that in the lower two sections was 3.1 to 1 (Table V, in the Appendix).

IV. TOTAL SOLIDS

Duncan's Multiple Range Test for total solids in the juice and sirup (Table III) showed significant differences among all sections. This cultivar had an overall average for the four sections of 21.50 percent total solids. Position 7 contained the highest amount of total solids with 24.20 percent, while position 3 contained the lowest amount of the total solids with 17.60 percent (Table VI, in the Appendix).

V. ASH

The results of Duncan's Multiple Range Test for ash content in the juice showed no significant difference between sections 3 and 4 and sections 2 and 4, or for sirup between sections 2 and 3, but a significant difference was shown between sections 1 and 4.

Ash content in section 1 was highest (0.65 percent), and in section 2 was lowest (0.52 percent). According to positions, position 1 contained the highest amount of ash with 0.78 percent and position 9 contained the lowest amount of ash with 0.47 percent (Tables V and VI, in the Appendix).

VI. TOTAL ACIDITY

Duncan's Multiple Range Test for the total acidity content in juice and sirup (Table III, page 29) showed significant differences among all sections.

The quantity of .1N NaOH required to neutralize 100 g. of juice was highest in section 4 and lowest in section 1, with 35.00 and 18.60 ml., respectively. In looking at the high and low values for total acidity, as related to positions on the stalk, position 12 required 41.50 ml., while position 3 required only 15.00 ml. of .1N NaOH to neutralize 100 g. of juice (Tables V and VI, in the Appendix).

VII. NITROGEN

Duncan's Multiple Range Test showed no significant difference for nitrogen in the juice between sections 2 and 3, sections 1 and 3 and sections 1 and 4. The same test for sirup showed significant differences among all sections (Table III).

Data of Tables V and VI (Appendix) showed highest percent of nitrogen in section 4 (0.14 percent). According to positions, position 12 contained 0.18 percent nitrogen and position 2 contained 0.09 percent which were highest and lowest, respectively.

VIII. FREE GLUCOSE

The results of Duncan's Multiple Range Test for percentage of free glucose in juice and sirup (Table III) showed significant

differences among all sections except section 1 and 3 in the juice, which showed no significant difference.

The average percentage of free glucose ranged from a high of 8.63 percent in section 2 to a low of 4.38 percent in section 4. The observation of this experiment indicated that 82 percent of the total free glucose was produced in section 1, 2, and 3 while section 4 produced 18 percent. Accordingly, section 1 and 2 contained 1.4 times the free glucose content as section 3 and 4. Section 1, 2, and 3 contained about 5.2 times the free glucose as section 4.

IX. GLUCOSE FROM SUCROSE

Duncan's Multiple Range Test for percentage of glucose from sucrose in the juice showed no significant differences among sections 2, 3, and 4. The same test for sirup showed no significant difference among the four sections (Table III, page 29).

The percentage of glucose derived from inversion of sucrose was lowest in section 1 with 3.06 percent, and sections 2, 3, and 4 were almost the same with about 4.30 percent. According to positions, glucose from the inversion of sucrose was highest in position 7 and lowest in position 1, with 9.00 and 0.68 percent, respectively (Tables V and Vi, in the Appendix).

X. TOTAL SUGARS

The results of Duncan's Multiple Range Test for percentage of total sugars found in the juice showed no significant difference between

sections 1 and 4, and for sirup showed no significant difference between sections 2 and 3, and between 3 and 4.

Section 2 contained highest total sugars with 16.99 percent and section 4 contained lowest total sugars with 12.72 percent. Looking at the positions of stalk, position 7 contained highest percent (24.20) of total sugars and position 1 contained lowest percent (8.12) of total sugars (Tables V and VI, in the Appendix).

XI. pH

The pH value ranged from 5.50 in section 1 to 5.20 in section 4. According to positions, position 3 had highest pH of 5.60 and position 11 had lowest pH of 5.10 (Tables V and VI, in the Appendix).

XII. CORRELATION COEFFICIENTS

Significant correlation coefficients were found for several of the chemical analyses studied (Tables VIII and IX, Appendix).

There were positive correlation coefficients of 0.805 in juice and 0.757 in sirup between total acidity and AIS.

Ash and total acidity showed a positive correlation coefficient of 0.605 in sirup.

There were negative correlation coefficients of -0.896 in juice and -0.480 in sirup between total acidity and free glucose.

The highest positive correlation coefficient was 0.995 in juice between brix and total solids and the highest negative correlation coefficient was -0.976 in juice between AIS and pH.

XIII. ORGANOLEPTIC EVALUATION

Organoleptic evaluation showed no significant difference in flavor of sirups made from the juice of different sections. Intensity of the color increased from yellow to orange red from top (section 4) to bottom (section 1). Clarity was increased from top (section 4) to bottom (section 1).

CHAPTER V

DISCUSSION

It is necessary to start with high quality juice to obtain high quality sirup. Literature on sirup manufacturing indicates that there are several chemical factors in the juice which are important in sirup manufacturing. The most often discussed factors are the AIS, ash, and total acidity content of the juice, which are considered to be the most influential factors contributing to the quality of the finished sirup. When these constituents are present in the juice in large enough quantities as to be detrimental to the manufacture of a high quality sirup, they are classified as impurities.

Table V in the Appendix showed that section 4 of the stalk contained the highest amount of AIS and total acidity. The observed high amount of AIS in section 4 agrees with the results of studies by Walton et al. (29) which indicated that the top part of the stalk contained more starch than the remainder. In the present work jellying occurred in section 4, which had the higher starch content. In earlier work on the effects of starch on the finished sirup, it was found that a high starch content in the juice resulted in slow boiling and scorching of the sirup, and that starch was the causative agent in jellying (29). In the present experiment, it was also found that there was slow boiling in section 4; this may be attributed to high starch content. The

finished temperature was 220°F. (104.4°C.) for section 4, and 224°F. (106.6°C.) for section 3, while that for sections 1 and 2 both was 227°F. (108.3°C.). It was found more difficult to defecate juice in section 4.

Theoretically, the acidity content of sirup may be estimated as the acidity content of the juice times the fold of concentration. In this analysis, acidity content in sirup was found to be less than that of juice. This may be attributed to the presence of volatile acids in the juice. For further investigation of hypothesis, the following test was conducted. The sample of juice was evaporated three times with water being added at the end of every evaporation to keep the volume the same. After three evaporations the sample was analyzed and found to contain less acidity than that of raw juice. Acidity content of juice can also adversely affect the quality of finished sirup. The organoleptic evaluation of sirup showed that there was no significant difference among sirups made from the juice of different sections. Analysis of variance showed highly significant differences for acidity among sections for juice and finished sirup. This also indicated the presence of volatile acids.

Since the high starch content or high total acid is not markedly defined, the research work of several persons on total acid and starch is not successfully utilized by sirup manufacturers. In addition, further work is also required for the isolation and identification of various acids present in sorgo juice.

The ratio of sucrose to reducing sugars in section 1 was 1:1.1; in section 2, 1:1; in section 3, 1:0.8; and in section 4, 1:0.5. The

overall ratio of sucrose to reducing sugars was 1:1.2 in this cultivar. No crystallization occurred in any sirup made from juice of different sections. Walton and Ventre (29) found that crystallization results from an excess of reducing sugars or sucrose. Ventre, Byall, and Walton (26) found that the ratio of sucrose to reducing sugars of 1:1 best for no crystallization.

The total solids content closely paralleled the brix values in both juice and sirup.

Data in Table V in the Appendix indicated that section 4 of the stalk yielded the lowest volume of juice. The percentage of juice extracted from the four sections was 44, 44, 39, and 30 for sections 1, 2, 3, and 4, respectively. Section 4 required 3.4 lb., section 3 required 2.5 lb., section 2 required 2.3 lb., and section 1 required 2.3 lb. of cane to produce 1 pound of juice. Section 4 was considerably longer and required more time for extraction. More difficulty in defecating juice was experienced in section 4. Jellying also occurred in sirup made from the juice of section 4. Clarity of the sirup made from the juice of section 4 was poorest.

Although there was no significant difference in taste, considering the above factors it would seem advisable to utilize this section in another manner.

Two of the factors considered detrimental to high quality sirup, AIS and total acidity, showed a positive correlation coefficient of 0.805 in juice and 0.757 in sirup.

CHAPTER VI

SUMMARY

A study was made to determine the amount of certain chemical components in sorgo cane juice in relation to the chemical composition and quality of finished sirup.

Under conditions of this experiment the following findings were made:

1. The diameter of the internode ranged from 17 mm. of internode number 2 to 7.0 mm. of internode number 12, and length of internode ranged from 121 mm. of internode number 1 to 478 mm. of internode number 12. Section nearest ground was number 1.

2. The lowest volume of juice was obtained from section 4, with increasing amounts being obtained from sections 3, 2, and 1, respectively.

3. Section 4 of the stalk contained high AIS, total acid, and ash content. Jellying occurred in sirup made from the juice of section 4.

4. No crystallization occurred in any sirup made from the juice of different sections.

5. There were significant differences among sections for brix, AIS, total solids, ash content, total acidity, nitrogen, free glucose, glucose from sucrose, and total sugars in both juice and sirup.

6. AIS and total acidity showed a positive correlation coefficient of 0.805 in juice and 0.757 in sirup.

7. Organoleptic evaluation indicated no significant differences in sirup made from the juice of different sections.

8. This cultivar averaged 14.49 percent total sugars and 21.43 percent soluble solids.

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BIBLIOGRAPHY

BIBLIOGRAPHY

1. A.O.A.C. 1960. Official Methods of Analysis. 9th ed. Assoc. Offic. Agr. Chemists, Washington, D.C.

2. Bitting, A. W. 1870. Art of Canning, p. 715-721, The Trade Press-room, San Francisco, Calif.

3. Brande, E. W. 1947. Progress with sugar sorgo. In Yearbook of Agriculture, 1943-1947, p. 344-352. U.S.D.A., U. S. Govt. Printing Office, Washington, D. C.

4. Brosdhead, D. M., I. E. Stokes, and K. C. Freeman. 1963. Sorgo spacing experiments in Mississippi. Agron. J., 55, 164-166.

5. Bryan, A. H., and S. W. Shearwood. 1924. Sorgo sirup manufacture. U.S.D.A. Farmers Bul. 1389.

6. Carlton, R. B. 1906. Saccharine sorghum for forage. U.S.D.A. Farmers Bul. 246.

7. Carlton, R. B. 1910. The history and distribution of sorghum. U.S.D.A. Bureau of Plant Ind. Bul. 175.

8. Coleman, O. H., and I. E. Stokes. 1964. Storage studies of sorgo. U.S.D.A. Tech. Bul. 1307.

9. Cowgill, H. B. 1930. Sorgo for sirup production. U.S.D.A. Farmers Bul. 1619.

10. Fermco test S.F.G. 1965. Tech. Bul. No. 9. Fermco Laboratories, Inc., Chicago, Illinois.

11. Gaessler, W. A., J. D. Reid, and F. L. Cuthbert. 1940. Short cuts in sorghum making. Farm Science Reporter (Iowa State College), 2, No. 3, 12-13.

12. Gaessler, W. A., J. D. Reid, and F. L. Curthbert. 1941. The use of Iowa clays for clarification. Iowa State College J. of Sci., 15, 287-299.

13. Harwell, J. O. 1965. Composition of sorghum cane juice intended for sirup production. Master of Science Thesis. University of Tenn., Knoxville.

14. Helm, C. A., and R. Beasley. 1942. Growing sorghum and making sorghum sirup. Mo. Agr. Exp. Sta. Bul. 235.

15. Henrickson, C. E. 1958. Production of sorghum sirup. Ky. Agr. and Home Economics Bul. 559.

16. Keller, L. H. 1963. Cost and returns from producing and processing sorghum sirup. Univ. of Tenn. Agr. Exp. Sta. Bul. 363.

17. Loescke, H. W. 1942. Outlines of Food Technology, p. 295, Reinhold Publishing Co., New York.

18. Madar, C., and J. E. Webster, 1954. Quantitative measurements of the organic acids of sorghum sirup. Food Tech. 8, March, 171-173.

19. Parsons, H. B. 1882. Aconitic acid in the scale from sorghum sugar pans. Amer. Chem. J. 4, 39.

20. Roessler, E. B., J. Warren, and J. E. Guyman. 1963. Significance in triangular taste tests. Food Research, 13, 503-505.

21. Sherwood, S. F. 1923. Starch in sorghum juice. J. Ind. Eng. Chem., 15, 727-728.

22. Sherwood, S. F. 1923. Jellying of sorghum sirup. Effect of malt diastase upon the filtration of sorghum juice. J. Ind. Eng. Chem. 15, 780-782.

23. Snedecor, G. W. 1946. Statistical Methods. 4th ed., p. 214-252, Iowa State University Press, Ames, Iowa.

24. Stokes, I. E., O. H. Coleman, and J. L. Dean. 1957. Culture of sorgo for sirup production. U.S.D.A. Farmers Bul., 2100.

25. Ventre, E. K., and S. Byall. 1937. Distribution and variation with maturity of dissolved solids, sucrose, and titratable acidity in the sorgo stalk. J. Agr. Res., 55, 553-562.

26. Ventre, E. K., S. Byall, and C. F. Walton. 1939. Jellying and crystallization of sirups made from different parts of the sorgo stalk at different stages of maturity. J. Agr. Res., 59, 139-150.

27. Ventre, E. K., J. A. Ambler, A. C. Henry, S. Byall, and H. S. Paine. 1946. Extraction of aconitic acid from sorgo. Ind. Eng. Chem., 38, 201.

28. Vinall, H. N., J. C. Stephens, and J. H. Martin. 1936. Identification, history and distribution of common sorghum varieties. U.S.D.A. Tech. Bul. No. 506.

29. Walton, C. F., and E. K. Ventre. 1938. Farm production of sorgo sirup. U.S.D.A. Farmers Bul., 1791.

30. Walton, C. F., E. K. Ventre, M. A. McCalip, and C. A. Fort. 1941. Farm production of sugar cane sirup. U.S.D.A. Farmers Bul., 1874.

31. Webster, J. E., F. Davies, and J. Sielinger. 1946. Chemical composition of juices and sirups from sorghum grown at Stillwater, Oklahoma in 1943, 1944, and 1945. Okla. Agr. Mech. College Bul., T-25.

32. Webster, J. E., F. Davies, and J. B. Sielinger. 1953. Sorghum sirup manufacturing tests. Okla. Agr. Exp. Sta. Bul. B-406.

33. Webster, J. E., D. Banefiel, and F. Davies. 1954. Yield and composition of sorghum juice in relation to time of harvest in Oklahoma. Agron. J. 46, 157-160.

34. Willaman, J. J., R. M. West, and C. P. Bull. 1919. Sorghum and sorghum sirup manufacture. Minn. Agr. Exp. Sta. Bul. 187.

35. Willaman, J. J., and F. R. Davison. 1924. Starch in sorghum sirup. J. Ind. Eng. Chem., 16, 609-610.

36. Willey, H. W., and W. Maxwell. 1890. Organic acids in the sorghum cane. Amer. Chem. J., 12, 216.

37. Woodle, H. A., and C. V. Phagan. 1942. Sugar cane and sorghum sirup for home use. Clemson Agr. College and U.S.D.A. Ext. Ser. Bul. 105.

APPENDIX

TABLE IV

AVERAGE WEIGHT, DIAMETER, LENGTH OF INTERNODE AND WEIGHT OF JUICE OBTAINED FROM THE SEVERAL INTERNODES OF TRACY SORGO

Internode	Average Weight of Internode g.	Average Diameter of Internode mm.	Average Length of Internode mm.	Average Weight of Juice g.
1	24.9	16.6	120.7	10.05
2	42.4	16.9	179.8	17.78
3	44.5	16.1	200.7	18.24
4	43.0	15.0	233.9	17.54
5	41.5	13.9	263.9	18.54
6	36.2	13.8	249.7	15.69
7	30.3	12.6	205.2	12.77
8	25.2	11.7	193.8	10.01
9	23.7	10.7	191.5	8.66
10	18.0	9.2	198.4	6.10
11	14.7	8.8	192.0	4.06
12	18.0	7.2	477.5	4.63

TABLE V

CHEMICAL COMPOSITION OF RAW SORGO CANE JUICE FROM DIFFERENT SECTIONS OF STALK OF TRACY CULTIVAR

Section	% Extraction	Brix	pH	% AIS	% Total Solids	% Ash	Total Acidity (ml. in NaOH)	% Nitrogen	% Free Glucose	% Glucose from Sucrose	% Total Sugars
1	40.0	20.8	5.50	0.50	20.6	0.66	18.50	0.12	6.75	3.12	13.0
		20.8		0.48	20.7	0.65	18.70	0.12	7.00	3.00	13.0
2	43.9	20.8	5.45	0.59	20.8	0.52	20.50	0.11	8.75	4.25	17.3
		20.7		0.57	20.7	0.56	20.25	0.11	8.50	4.62	16.7
3	43.1	22.5	5.33	1.38	22.6	0.56	21.75	0.11	7.00	4.00	15.0
		22.5		1.40	22.7	0.55	22.10	0.11	6.75	4.37	15.0
4	29.6	21.8	5.18	1.76	21.9	0.55	35.00	0.14	4.25	4.35	13.0
		21.8		1.75	22.0	0.56	35.00	0.14	4.50	4.00	12.5

TABLE VI

CHEMICAL COMPOSITION OF RAW SORGO CANE JUICE FROM DIFFERENT INTERNODES OF STALK OF TRACY CULTIVAR

Inter-node	% Extraction	% AIS	Brix	pH	% Total Solids	% Ash	Total Acidity (ml. in NaOH)	% Nitrogen	% Free Glucose	% Glucose from Sucrose	% Total Solids
1	40.3	0.52	21.5	5.50	21.8	0.80	16.15	0.09	6.75	0.75	8.25
		0.58	21.4		21.7	0.76	16.60	0.10	6.75	0.62	7.99
2	41.9	0.51	20.5	5.53	20.8	0.68	22.00	0.09	6.25	2.00	10.25
		0.51	20.4		20.8	0.68	23.00	0.09	6.25	2.00	10.25
3	41.0	0.43	17.5	5.60	17.7	0.42	15.25	0.12	8.33	4.67	17.67
		0.43	17.4		17.6	0.44	15.00	0.13	8.32	4.55	17.42
4	40.8	0.54	19.5	5.58	19.9	0.42	19.75	0.11	8.05	5.07	18.19
		0.54	19.8		19.9	0.42	19.45	0.11	8.06	5.19	18.44
5	44.6	0.65	19.5	5.55	19.8	0.39	19.50	0.12	7.00	8.12	23.25
		0.66	19.4		19.8	0.41	19.10	0.12	7.50	7.75	23.00
6	43.4	0.82	21.5	5.43	22.0	0.40	20.25	0.10	6.25	6.87	19.19
		0.84	21.4		21.9	0.41	21.05	0.10	6.25	7.12	20.49
7	42.2	1.26	23.8	5.32	24.20	0.41	23.5	0.13	6.25	8.87	23.99
		1.26	23.9		24.18	0.38	23.1	0.13	6.25	9.12	24.49
8	39.7	2.40	23.3	5.22	23.76	0.56	26.8	0.14	6.25	6.87	19.99
		2.34	23.4		23.54	0.53	26.2	0.14	6.75	6.50	19.75

TABLE VI (continued)

Inter-node	% Extraction	% AIS	Brix	pH	% Total Solids	% Ash	Total Acidity (ml. in NaOH)	% Nitrogen	% Free Glucose	% Glucose from Sucrose	% Total Solids
9	36.6	1.82	22.0	5.20	22.80	0.44	24.8	0.13	5.25	3.62	12.49
		1.84	22.3		22.32	0.50	24.1	0.13	5.25	3.62	12.49
10	33.8	2.31	23.3	5.15	24.05	0.57	39.0	0.12	4.00	4.37	12.74
		2.24	23.4		23.96	0.58	37.6	0.12	4.25	4.12	12.49
11	27.8	1.78	22.3	5.12	22.79	0.55	41.0	0.15	3.50	5.00	13.50
		1.79	22.3		22.77	0.57	40.6	0.15	3.50	5.00	13.50
12	25.6	1.18	20.5	5.28	20.70	0.66	41.0	0.18	3.50	3.87	11.24
		1.15	20.6		20.65	0.69	41.5	0.18	3.60	3.90	11.40

TABLE VII

CHEMICAL COMPOSITION OF SORGO SIRUP MADE FROM THE JUICE FROM DIFFERENT SECTIONS OF TRACY CULTIVAR

Section	Cooking	Brix	pH	% AIS	% Total Solids	% Ash	Total Acidity (ml. in NaOH)	% Nitrogen	% Free Glucose	% Glucose from Sucrose	% Total Sugars
1	1	77.8	6.63	1.05	78.9	1.51	70.0	0.37	21.5	3.80	29.0
		78.0		1.04	78.9	1.51	70.5	0.37	22.0	4.00	30.0
	2	80.5	6.58	1.16	80.5	1.77	94.0	0.38	21.5	6.00	33.5
		80.5		1.15	80.3	1.72	93.5	0.39	21.0	6.00	33.0
	3	76.8	6.63	1.15	78.1	1.75	71.0	0.38	22.5	3.50	29.5
		76.8		1.19	77.9	1.73	71.0	0.38	22.8	4.25	31.3
2	1	78.0	6.73	1.33	78.2	1.85	84.0	0.32	16.5	17.0	50.5
		78.0		1.35	78.3	1.81	84.5	0.32	16.3	15.8	47.8
	2	78.0	6.73	1.34	78.4	1.78	86.5	0.31	16.8	15.3	47.3
		78.0		1.37	78.5	1.80	87.0	0.32	17.0	15.1	47.2
	3	75.3	6.73	1.28	75.2	1.58	91.0	0.30	16.5	19.0	54.5
		75.3		1.26	75.3	1.58	91.0	0.30	16.3	18.8	53.8
3	1	77.5	6.73	1.99	77.0	1.91	80.6	0.31	15.3	18.3	51.8
		77.6		1.99	77.9	1.89	80.6	0.32	15.0	18.0	51.0
	2	77.5	6.70	2.06	76.0	1.70	85.0	0.30	13.5	18.5	50.5
		77.5		2.06	76.3	1.71	85.0	0.29	13.8	19.1	52.0

TABLE VII (continued)

Section	Cooking	Brix	pH	% AIS	% Total Solids	% Ash	Total Acidity (ml. in NaOH)	% Nitrogen	% Free Glucose	% Glucose from Sucrose	% Total Sugars
3 (cont.)	3	70.5	6.73	1.89	70.8	1.63	88.0	0.26	12.3	20.5	53.3
		70.5		1.89	70.6	1.62	88.0	0.26	12.0	20.0	52.0
4	1	72.5	6.60	4.42	72.1	2.05	119.0	0.42	9.0	22.4	53.7
		72.6		4.40	72.0	2.10	120.0	0.42	9.50	21.5	52.5
	2	73.3	6.60	4.32	72.9	2.00	123.0	0.43	9.50	20.4	50.2
		73.3		4.33	72.8	2.05	123.0	0.44	10.0	20.9	51.7

TABLE VIII

CORRELATION COEFFICIENTS FOR DIFFERENT CHEMICAL ANALYSES STUDIED IN SORGO JUICE

	Brix	pH	% Alcohol Insoluble Solids	% Total Solids	% Ash	Total Acidity ml.	% Nitrogen	% Free Glucose	% Glucose from Sucrose	% Total Sugars
% Extraction	0.535	0.970**	-0.913**	-0.572	0.390	0.874**	-0.746*	0.904*	0.314	0.524
Brix		0.689	0.828*	0.995**	0.402	0.506	0.148	0.469	0.341	-0.114
pH			-0.976**	-0.728	0.543	-0.830*	0.582	0.815*	-0.470	0.355
% Alcohol Insoluble Solids				0.854**	-0.503	0.805*	0.523	0.793*	0.430	-0.346
% Total Solids					-0.469	0.525	0.149	0.475	0.403	-0.087
% Ash						-0.086	0.284	-0.020	-0.911**	-0.571
Total Acidity ml.							0.748*	-0.896**	0.174	-0.656
% Nitrogen								-0.919**	-0.366	-0.935**
% Free Glucose									0.654	0.817*
% Glucose from Sucrose										0.606

*Significant at 0.05 level of probability.
**Significant at 0.01 level of probability.

TABLE IX

CORRELATION COEFFICIENTS FOR DIFFERENT CHEMICAL ANALYSES STUDIED IN SORGO SIRUP

	pH	% Alcohol Insoluble Solids	% Total Solids	% Ash	Total Acidity ml.	% Nitrogen	% Free Glucose	% Glucose from Sucrose	% Total Sugars
Brix	0.058	-0.668**	0.919**	-0.331	-0.319	0.297	0.760**	0.657**	0.570**
pH		-0.497*	0.099	-0.426*	-0.690**	-0.862**	0.039	0.286	0.437*
% Alcohol Insoluble Solids			-0.778**	0.837**	0.757**	0.092	-0.862	0.658**	0.518**
% Total Solids				-0.521**	-0.276	0.324	0.871**	-0.743**	-0.640**
% Ash					0.605**	0.161	-0.667**	0.526**	0.426*
Total Acidity ml.						0.436*	-0.480*	0.289	0.176
% Nitrogen							0.412*	-0.662**	-0.757**
% Free Glucose								-0.931**	-0.847**
% Glucose from Sucrose									0.983**

*Significant at 0.05 level of probability.
**Significant at 0.01 level of probability.

VITA

The author was born on March 1, 1940, in Surat, India. He received his B.S. (Agri.), from Sardar Vallabhbhai Vidyapeeth, Anand, in 1964. In 1964 he came to the University of Tennessee, Knoxville, Tennessee, and worked for his M.S. in Food Technology.

He was married to Miss Asha K. Patel on May 16, 1964.