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W. L. BLIZZARD, *Director* LOUIS E. HAWKINS, *Vice Director*

CHEMICAL COMPOSITION OF JUICES AND SIRUPS FROM SORGHUMS GROWN AT STILLWATER, OKLAHOMA IN 1943, 1944 AND 1945

JAMES E. WEBSTER, FRANK DAVIES, AND JOHN SIEGLINGER
Departments of Agricultural Chemistry Research
and Agronomy

Stillwater, Oklahoma

CHEMISTRY IS BASIS OF BETTER SORGHUM SIRUP FOR FACTORY AND FARM HOME USE.

Sorghum sirup is often mentioned among the Oklahoma products having possibilities for agricultural-industrial development within the State. The potential market includes not only the sirup itself, but also manufactured products such as candy in which it might be a raw material. Homemade sorghum molasses would also find greater use in farm home living if satisfactory varieties of cane were known and the difficulty of making a satisfactory product could be reduced.

The first step toward industrial developments based on the sweet sorghums, as well as toward a better homemade sirup, is knowledge of the chemical composition of the juice and sirups from the various varieties. This knowledge is also essential to the plant breeder seeking to develop improved varieties.

The chemical data presented in this bulletin were obtained during the first three years of a comprehensive research project aimed at finding the varieties of sweet sorghum best adapted for sirup production in Oklahoma, at breeding improved varieties if possible, and at determining the most satisfactory method of producing quality sirup under Oklahoma conditions. The existing lack of chemical data on the composition of sorghum juices or sirup produced in the Southwest indicated that immediate publication of the first three years' data would be helpful in the current industrial development of this area, although the breeding and sirup-making work will be continued and will be supported by further chemical analyses.

Variety recommendations based on tests to date are available in Oklahoma Extension Leaflet OP-96. New strains developed in the breeding program will be ready for first sirup tests in the fall of 1946. Final results of sirup manufacturing research cannot be published until some of the methods being tried can be further tested. Meanwhile, the Station workers will be glad to answer inquiries from those who encounter problems in sirup making.

TABLE OF CONTENTS

Chemical Composition of Juices and Sirup from Sorghums Grown at Stillwater, Okla., in 1943, 1944, and 1945.

By JAMES E. WEBSTER, FRANK DAVIES,
and JOHN SIEGLINGER*

The production of sorghum sirup in Oklahoma was for many years a small but worthwhile farm industry. Production declined, however, from 750,000 gallons in 1919 to 112,000 in 1943. Wartime restrictions on the use of sugar, and increased interest in development of industry based on Oklahoma crops, led to renewed interest in sirup making; and a comprehensive project on that subject was started at the Oklahoma Agricultural Experiment Station. This bulletin reports the chemical phases of this project for the years 1943, 1944 and 1945.

REVIEW OF LITERATURE

The most often quoted and most extensive bulletin dealing with sirup manufacture is Farmers Bulletin 1791 (9). Directions are given for harvesting the cane and producing the sirup employing a variety of procedures. Details also are included for preparing a sirup lay-out including the construction and operation of the evaporator. Included is a table showing the carbohydrate content of juices from various varieties grown at several locations in the United States, none of which, however, are comparable to Oklahoma conditions.

A paper by Sherwood (6) reports the starch content of 15 varieties of sorghum juices at harvest time as ranging from 0.142 to 0.852 percent with an average of 0.366 percent. He mentions that starch may be of value in retarding crystallization and that it probably is responsible for the phenomenon known as jellying. Included also are the percentages of sucrose and reducing sugars, with sucrose usually the predominating type present at harvest time. However, there were notable exceptions. For instance, juice from the Honey variety contained about 7 percent of sucrose and 4 percent of reducing sugars.

* Respectively, Associate Research Chemist, Associate Agronomist (Sorghums), and Agronomist (Sorghums).

Ventre and Byall (7) analyzed the different internodes of four varieties of sorghums at different stages of growth and concluded that the percentage of dissolved solids in the juice increased with maturity. Sucrose also increased in the same manner and in the same relative proportion in the different internodes. They recommend topping the cane to reduce the acidity or tang in the juice.

The manufacture of sirup has been developed by some commercial concerns until the product compares favorably with any type of sirup available on the market. Not as much is known about the problems involved in farm production of sirup, particularly in Oklahoma. Willaman and Easter (11) conducted a study of the factors affecting color in sirup and concluded that color development is proportional to the temperature and independent of the initial pH, unless there is a large amount of invert sugar present when the initial pH is a factor; and that most color production in the sirup is due to the presence of fructose. An article by Walton, Ventre and Byall (10) describes results showing that the use of high-diastatic malt extract in processing the sirup materially improved the quality of sirups made from several sorghum varieties at several stages of development. Chemical data include the sucrose and reducing sugars, ash, and starch content of the several sirups. Most of the sirups contained appreciable amounts of starch.

The use of clay in the clarification of sorghum sirup was studied in detail by Gaessler et al. (3). They found that a preliminary treatment of the cold juice with small amounts of clay greatly reduced the labor of skimming and gave a better quality of sirup although the yield was reduced about 6 percent.

Several publications, chiefly from Experiment Stations, describe the procedure for making sorghum sirup and often include additional information (2, 4, 12).

EXPERIMENTAL

VARIETIES. Varieties that had been grown in this area or were generally recommended for growth here received major attention during this study and were grown all three years. In addition the tests included several varieties not commonly grown here that were thought to have special promise or represented recent introductions. These were included for only one or two years, depending upon their performance.

The varieties tested may be divided into three groups:

Early maturing, those reaching the hard dough stage in about 100 days: Leoti, Colman, Collier, and Kansas Orange.

Medium maturing, requiring from 100 to 120 days: Red X, Iceberg, and Sumac 1712.

Late maturing: White African, Sugar Drip, Honey, Gooseneck, and C. P. Special.

SOIL AND CULTURE. The plantings were located along Cow Creek near Stillwater on the Station's Agronomy farm. The surface soil on the west half of the area is a very fine sandy loam and the east half is a clay loam (Yahola series). Sub-surface drainage is good. Rows were planted 42 inches apart and the spacing of plants in rows averaged 4 to 6 inches. General good cultural practices for sorghum were followed and the fields were kept well cultivated and free from weeds.

HARVESTING AND EXTRACTING THE JUICE. With the exception of the first year, when total yields were taken, all plants were headed and the stalks stripped in the field. Each lot for pressing consisted of all the plants from a representative 100-foot section of a row. Acre yields were calculated from the yields from these 100-foot sections. The topped canes were immediately brought in from the field and pressed in a horizontal three-roller power mill having a capacity of 75 gallons per hour. The stripped and headed stalks were weighed before crushing, and the juice was weighed after crushing; and these figures were used to calculate the percentage yield of juice. All tests were run on freshly harvested stalks cut early in the morning and seldom more than two hours elapsed from the time the stalks were cut until the juice was settling in the laboratory where the sirup was made.

PREPARATION OF SIRUP. Immediately after reaching the laboratory the juice was strained through several layers of cheesecloth and poured into 5-gallon Pyrex bottles and allowed to sediment. The first two years all samples were allowed to settle for only two hours before the clear juice was siphoned off. The third year all untreated samples were allowed to stand four hours before siphoning, which longer time seemed slightly to improve the quality of the sirup.

The juice was boiled down in a laboratory size pan essentially like that described by Walton and Ventre (8). (See Fig. 1.) Natural gas was used for heating and three Fisher burners were employed which made possible delicate adjustments of the flames. Approximately five gallons of juice were used for each batch although some treated samples contained considerbly less than this volume. All calculations of yield were by weight, both the settled juice and finished sirup being accurately weighed. The basic treatment involved only a simple concentration of the juice with concomitant skimming, until the finished product had a density of at least 76° Brix (20° C.). This involved boiling-down the juice until a temperature of about 108° C. was reached. Different varieties reacted differently to this boiling, and with some varieties it was almost impossible to reach ths temperature without scorching and burning the sirup. The finished product was drawn off into jars and bottles while still hot.

Samples for chemical analysis were kept sterile throughout, but the remainder of the samples—in one-half gallon jars —were packed without subsequent sterilization after density determinations (20° C.) had been run on the cooled product. The sirups were stored in sealed jars and allowed to stand until later in the year (4 to 6 months) when they were opened and samples removed for organoleptic tests.

Various modifications of this basic procedure were used at different times. Some samples were treated with diastase using the semi-sirup method described in U. S. D. A. Bulletin 1791 (9). Various types of commercial diastase preparations were used such as Clarase and Pangestion but no differentiation will be made in reporting the results. A few samples were treated with invertase solution, also by the semi-sirup method. Such tests were not run on an extensive scale because at that time the chief aim of the project was to find how the varieties would react rather than to study methods of improving the sirup.

Many runs were made on juices that had been treated with clay. Kaolin was the only clay used the first two years. During 1945, an Oklahoma field clay was used for most of the

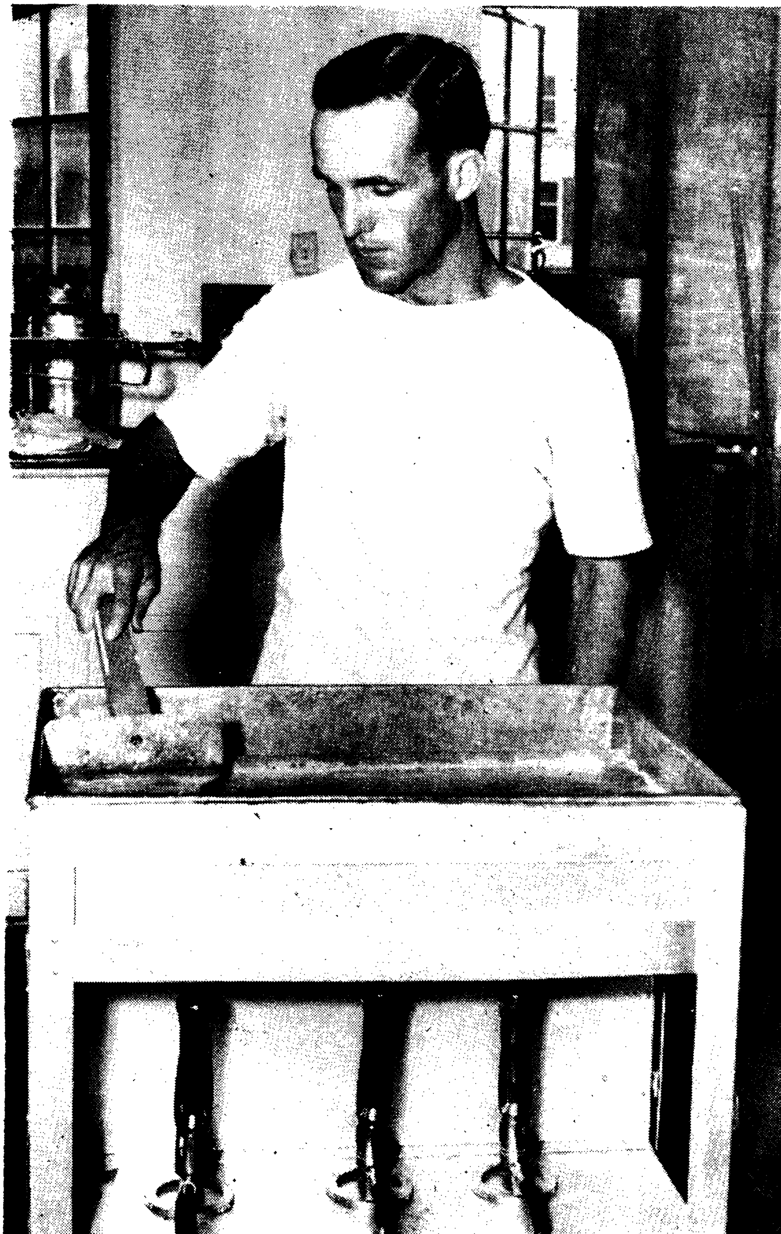

Figure 1

treatments, although for some fuller's earth was used. At first the raw clay or kaolin was stirred into the juice and the juice allowed to sediment for two hours. This procedure resulted in serious losses due to the large volumes of sediment that had to be discarded and therefore the procedure was changed to the method suggested by Gaessler et al. (3), in which a clay suspension was added until flocculation occurred. Several samples were treated in this way and then a modified heat and clay treatment was tried which proved very successful. Details of this procedure are being worked out and will be reported in a later paper; in this report it will be referred to as "heated clay" treatment.

ORGANOLEPTIC TESTING OF SAMPLES. At the time the batches were withdrawn from the pan two separate 4 oz. samples were first collected, one for chemical tests to be run later and one for observation and testing; while the remainder of the batch was drawn off into a half-gallon jar. The samples to be used for chemical testing were kept unopened until they were to be analyzed; the other 4 oz. samples were opened at intervals for observation and tasting during the winter months. The large samples were kept until the middle of the winter when they were opened, sampled by the authors, and then representative samples were removed from 8 to 10 of the varieties and distributed with a score card to interested persons who sampled them in their homes and reported their opinions of the various samples. The authors' judgments were also recorded upon separate sheets and the quality tests reported herein are a composite of these different organoleptic tests. Testing was purposely delayed until the samples had had an opportunity to set and thus give some indication as to their appearance after storing.

CHEMICAL TESTS, PHYSICAL MEASUREMENTS. Brix densities were secured using hydrometers of narrow range (15°) and readings were made at 20° C. *Electrical conductivity* was measured using one of the new self-contained instruments manufactured by the Industrial Instruments Company. No conductivity measurements are recorded in the tables but they are briefly discussed under chemical analysis. *Hydrogen ion* measurements were made employing the Coleman glass electrode on samples of juice removed after the two- or four-hour settling period had elapsed.

CHEMICAL TESTS, CHEMICAL MEASUREMENTS. All of the determinatons on juices were made on samples siphoned off immediately after the settling period had elapsed so they would correspond to the material actually used in sirup making. *Titratable acidity* was run on 5 ml. samples diluted to 400 ml. with H_2O and titrated with 0.1 N NaOH using phenolphthalein for the indicator. Results recorded in the tables are expressed in terms of 0.1 N alkali required to neutralize 100 ml. of juice. *Solids* and *ash* values were secured on 25 ml. of the fresh juice and about 2 grams of the sirup. All determinations were made in platinum dishes and the samples were dried to constant weight at 105° C. In order to reduce caramelization to a minimum the samples were first dried on a steam hot plate at about 70° C. The sirup samples were further dried using 5 hour intervals in the oven at first and then 2 hour intervals between weighing. All samples were ashed at low red heat (600° C.) until a white feathery ash resulted. *Total nitrogen* was run on 25 ml. samples of the juice using the conventional Kjeldahl-Gunning procedure as described in the A. O. A. C. Methods (1). *Reducing sugars* were determined on samples of juice preserved in alcohol. The alcohol was removed from an aliquot of the sample by repeated evaporations to low volume over a steam bath. The resultant water solution was clarified with neutral lead acetate, filtered and finally deleaded with potassium oxalate and reducing sugar determinations were made on aliquots of the solution using the Shaffer-Hartman method described in the book by Morrow (5). An aliquot of this cleared solution was inverted—HCl with standing over night—and the neutralized solution was used for total sugars determinations.*
Sucrose was secured by calculation from the total and reducing sugars values. Sugar determinations were made on the sirup after the samples had been dissolved in hot water and deleaded as described above. *Non-sugar solids* values were secured by subtracting the total-sugar percentages from the oven dry solids percentages.

* Note that this includes the value for reducing sugars and sucrose after inversion, and is not the same as the total sugar values given in the tables which are obtained by adding together reducing sugar and sucrose percentages.

RESULTS AND DISCUSSION

The discussion that follows is based upon the data given in the tables at the back of the bulletin and upon the organoleptic tests which are not recorded as such because of their varied and voluminous nature.

Juice Analyses

YIELD OF JUICE. Even though a power mill was used and the roll clearance was small, the yields were somewhat low when compared to some literature reports. Generally the yield was around 45 percent and only one variety (Leoti) averaged as much as 50 percent. These yields, however, may be considered good for this area where August and September are normally months of low rainfall. In fact, severe droughts occurred during two of the three years.

SOLIDS (BRIX AND OVEN DRY). Results for these two methods compare very well and probably only Brix readings are required; in fact for one year only the Brix values were secured. The need for ash percentages, however, makes it seem worthwhile to continue running both determinations. Usually there was an increase in total solids as the season progressed, but this was accompanied by a concomitant drop in yield of juice. In determining total yield of sirup, however, the major factor is the yield of juice per acre. For most of the varieties tested, there was an optimum stage of maturity where maximum acre yields of juice were secured, after which the yield declined, sometimes quite rapidly. This point varied with the seasons and there appeared to be no index by which it might be predicted ahead of time. The late maturing varieties did not show this decrease as much as the earlier maturing varieties. Most juices contain from 14 to 20 percent of solids with the notable exception of Collier juice which usually contained more than 20 percent of solids and samples have run as high as 24 percent of solids.

ASH. The percentages of ash varied in much the same manner as did the solids, increasing gradually as the season progressed. Some varieties however, varied much more than others. The variety Collier consistently contained more ash than any other variety, while the Sumac variety consistently remains low in ash even when the solids are relatively high.

ACIDITY. Determinations for pH were not run on all of the samples, but generally speaking the samples varied within the range pH 4.95 to 5.30. Ordinarily the pH of the samples became more acid as the season progressed but the change here was not as great as changes in titratable acidity. Much greater changes were shown in the titratable acidity and here also there was an increase in values as the season progressed and in a few instances the increase was very marked. In fact, in some varieties the acidity had doubled or even tripled. Collier, Red X, and White African juices were usually more acid than the other varieties and this acidity subsequently appeared in the definitely acid flavor of the finished product. Conversely Honey and Sumac were relatively low in total acidity and this also seemed to affect the finished product in that these two varieties yielded a mild tasting sirup. Sugar Drip and Leoti also usually had a low value but there was greater annual variation shown than for the two preceding varieties.

ELECTRICAL CONDUCTIVITY. Such determinations were run on most of the samples one year or another, but these data did not seem to have any practical significance for these tests that could not be secured from other values, and they are not recorded in the tables.

REFRACTIVE INDEX. Determinations were run on all samples as soon as they were strained in the laboratory. These data also are not included in tables because they follow the same trend as shown by the Brix readings. Such data were collected chiefly for use in another study to check the relationship between refractive index and total sugar content of the juices. The data are not given in this bulletin but a study of graphs indicates that the total sugars as determined by chemical methods run about 3 percent below the solids content of the juice as calculated from the refractive indices.

SUGARS. The sugar content of the juices varied from less than 10 percent to nearly 20 percent. As with most of the other constituents, maturity brought with it a concomitant increase in sugars. In all varieties there was a general decrease in percentage of reducing sugars and an increase in percentage of sucrose as the season progressed. There were very great varietal differences in the ratio of the two types of sugars. Collier juice was notable for the very low percentage of reducing sugars that it always contained. Other varieties that contained large proportional amounts of sucrose are Leoti, Red X, Iceberg, C. P. Special, Kansas Orange, and Gooseneck. Sumac and Honey were notable in that they usually contained a preponderance of reducing sugars and other varieties fell in between these extremes. As will be pointed out in later discussions it is probeble that the relatively large proportion of reducing sugars in these two varieties helps account for the mild flavor of the sirup.

NON-SUGAR SOLIDS will be covered in the discussion of sirups.

NITROGEN. Data for nitrogen are incomplete but the results available seem quite significant. (Collier juice always contained relatively high percentages of nitrogen, and most of the other varieties contained relatively large percentages at the latest sampling dates.) Almost invariably the samples that were most difficult to process were those that were high in nitrogen. Such samples were troublesome to finish and required much greater care in handling if scorching was to be avoided. Data reported in this bulletin indicate that a juice low in nitrogen is much to be preferred, other factors being equal.

Sirup Analyses

ASH. There was considerable difference in ash values although any one variety remained in the same general range. Two varieties, Red X and White African were especially high in ash content, while Sugar Drip and Iceberg were consistently low. Apparently a considerable amount of ash was removed in the skimming, for the increased percentage in the sirup over the juice was only about one-half of that indicated by the degree of concentration of the juice. That is, the juice was concentrated about ten times while the concentration of ash was only about five times. In almost every instance the heated clay treatment resulted in a decreased ash content of the sirup.

SOLIDS. Percentages secured by oven drying indicate that not all of the samples were concentrated to the desired degree. There was a wide variation in the ease with which samples could be brought up to the desired finishing point (108° C.) and frequently it was necessary to discontinue processing before the desired temperature was reached to prevent samples from scorching. Non-sugar solids varied over a very wide range even for one variety. Undoubtedly a part of this was due to variations in degree of skimming employed for the various samples. Seasonal factors also seemed to play a major role in these results; for instance, all varieties were high in non-sugar solids during 1945 and were much lower in 1944. Method of treatment did not seem to be a major factor in determining this value; not as much, in fact, as might have been expected, for the heated clay treatment almost completely eliminated skimming.

SUGARS. Most samples of sirup that had reached the desired density of 76° Brix contained 60 to 65 percent of sugars. There was a wide range in the relationship between reducing sugars and sucrose in the sirup. Apparently the cooking-off process resulted in a considerable inversion of sucrose for even Collier sirup contained large amounts of invert sugar, far in exceess of the proportions in the raw juice. No generalized statement can be made regarding the distribution between the two types of sugars but in general most samples contained more sucrose than reducing sugars. Sumac and Honey sirups were the only ones of the better varieties that normally contain a greater percentage of reducing sugars than of sucrose. Both of these varieties generally are recognized as having a desirable flavor, and the sugar distribution is undoubtedly a factor in this placement.

Effect of Treatment of Juice

DIASTASE. Several samples of sirup were produced by the semi-sirup method using diastaste, and no difficulty was experienced in its use. However, the treatments did not prevent jellying of the sirup samples. Until further tests with diastase are performed, the value of its use in Oklahoma is questionable. Other enzyme treatments were too few to merit discussion.

CLAY TREATMENTS. The use of clay clarification was beneficial to most samples, improving the clarity of juice and reducing to some degree jellying and clabbering of the sirup.

The heated clay treatment was outstanding in its results and some of the best appearing sirups were produced through its use. Skimming was reduced and sedimentation in the sirup was largely prevented even in the earliest maturing samples, which were often difficult to process. Detailed work is in progress on this method and an account of this work will be published later.

VARIETY DISCUSSION

LEOTI. This is one of the earliest maturing varieties and usually samplings were begun with it. A high yield of juice was secured from the stalks and the juices were relatively easy to process. This variety produced an excellent quality of sirup which was rated highly by the testers. Clabbering was generally absent, but considerable sedimentation occurred, particularly in the first two years. This probably can be prevented by producing sirup at the optimum harvest time. Sirup from this variety was always high in sucrose and much crystallization occurred when a high density sirup was produced in 1945. Sirup from this variety probably will require treatment with invertase if crystallization is to be completely prevented. The most objectional feature of this variety was its comparatively low yield, 100 to 125 gallons per acre. This variety can be recommended for Oklahoma on the basis of early maturity and quality sirup.

RED X. This variety is medium maturing and yielded an average percentage of juice but the yield of sirup per acre was relatively low (80 to 120 gallons). The juice and finished sirup contained a relatively high percentage of sucrose although crystallization did not occur in any of the samples. Samples of sirup usually were brownish in color and often jelled or clabbered. The sirups were mostly judged as average to poor and often acid and tangy to taste. Because of the often poor quality of sirup and relatively low yield of sirup per acre, this variety is not at present recommended. Selection is being continued and a better strain may be developed.

COLLIER. This is an early variety that gives an average yield of juice and a somewhat larger yield of sirup per acre when harvested at its optiumum (averages around 125 gallons). Usually this sirup was thick and clabbered and had a poor appearance. Nearly all of the reports on sirup quality were unfavorable and it has been almost impossible to process the juice and bring the sirup to a high density. More than in any other variety, sucrose is the predominating sugar in the juice. The juice was also higher in nitrogen than any other juice, and in addition had a high titratable acidity. Very probably this combination of factors accounted for the difficulty of processing and poor quality of sirup. The sirup from this variety can be definitely classed as undesirable. However, it has been retained in the tests because the juice was higher in sugar than any other variety, and it is therefore being used for breeding and also as a test variety for trying out new methods of processing the juice.

WHITE AFRICAN. This is a medium late maturing variety which, when somewhat immature, yielded a high percentage of juice, but later as the plant matured the yield became considerably less. Sirup yields may be expected to average 125 to 150 gallons per acre at maximum yield. The juice contained varying percentages of reducing sugars and the sirup likewise. Most samples of sirup were dark brown and had a tendency to clabber. The sirup was stronger and more tangy than that of other varieties and definitely had an acid taste. The relatively poor appearance and strong taste of this sirup resulted in its being classified as average or poor by most testers. If a strong, flavorful sirup is wanted, this variety most nearly meets the requirements; but it is doubtful if it will meet with general acceptance.

SUMAC 1712. This is a medium late variety that yields a good percentage of juice and has yielded 90 to 125 gallons of sirup to the acre. Reducing sugars predominated in the juice and sirup and the juice had a uniformly low acid content. The juice from this variety was easiest of all to process and has always yielded a liquid sirup of a red to brown color. This sirup has remained liquid even when highly concentrated and there has been little or no sedimentation or crystallization. The taste is mild to slightly acid and very pleasing. This sirup was always rated high by testers and in 1945 it was often placed first. Because of its pleasant taste, ease of production, and liquid form, this variety rates near the top of all sirups and its only serious defect is the average yield that has been secured. This variety should prove popular as a home variety, i. e., one grown on two or three acres by a farmer for his own use.

HONEY. This is a late maturig variety that yielded a high percentage of juice and under optimum conditions may yield as much as 200 gallons of sirup per acre and should give an average yield of 150 to 175 gallons. Reducing sugars predominated in the juice and the total acidity was quite low. This combination of factors tended to give Honey a sweet, non-acid flavor well-liked by most persons. The sirup samples were invariably rated good or better by the tasters and certainly it is one of the better varieties. Chief objection to the sirup is that the samples often clabbered. If this defect can be cured or overcome, Honey should then become one of the leading varieties.

SUGAR DRIP. This is a late maturing variety that has always given a high yield of juice and an average yield of sirup (125 to 150 gallons per acre). The sugar in the juice was predominantly sucrose and also the sirup usually contains a larger percentage of sucrose than most of the others. The acidity was variable; immature samples of juice contained much less acid than the mature samples. Sugar Drip sirup was more variable than any other variety. Some samples in some years have been ranked first in quality; in other years (1945) the samples were uniformly ranked poor. Clabbering was common and the juice from the later maturing samples was very hard to process, possibly again correlated with the very high nitrogen content of the mature juices. With the present information it is impossible to properly rate this variety, so divergent have been the results. Potentially it is an important variety but the results here indicate the need for further testing and evaluating.

COLMAN. This is an early variety but the yield here (50 to 60 gallons per acre) was so low that it has been eliminated from test plantings.

ICEBERG. This variety was a later addition to the tests and data are incomplete. It is a medium maturing variety that should yield perhaps 150 gallons of sirup per acre. The juice contained chiefly sucrose and the finished sirup was high in sucrose, hence there is some danger of crystallization when stored for long periods. The sirup was sweet and mild and was highly regarded by the testers, particularly in 1945. This variety is considered very promising and further extensive tests will be conducted with it.

KANSAS ORANGE. This variety also was started later than most of the others and the data are incomplete. However, preliminary results indicate only an average yield of about 100 gallons per acre. The sirup was sweet and mild and was rated very high by the testers. The juice has been easy to process and has yielded a liquid sirup which has not clabbered. This variety also merits further tests; however, the low yield of sirup may prove the deciding factor in considering its relative value.

C. P. SPECIAL. This variety seems too late for use in Central Oklahoma and it is not being continued in the tests. One sample was judged as poor to average both as to taste and appearance.

GOOSENECK. Two types were grown in 1945 and fair samples of sirup were made from each but the quality did not compare favorably wtih several of the other varieties since they were dark and crystallized badly. Sirup yield was good, however, and further tests will be made of this variety.

TABLE I

Chemical Composition of Sorghum Juices From Plantings in 1943, 1944, and 1945; Stillwater, Oklahoma

Year	Yield of juice	Brix reading	Oven solids	Ash	pH	Titratable acidity (.1N alk.)	Sugars Reducing	Sugars Sucrose	Sugars Total	Non-sugar solids	N	Sirup per acre*
	pct.		pct.	pct.	pct.			pct.	pct.	pct.	pct.	gal.
						LEOTI						
1943 8/11	53.5	13.9	13.59	0.42	5.10	18.4	5.52	6.28	11.80	1.79	0.02	----
8/13	52.4	13.8	14.20	0.42	5.35	17.4	4.75	6.36	11.10	3.10	0.02	84.3
8/25	55.7	16.9	16.72	0.47	5.06	26.0	4.43	10.53	14.96	1.76	0.02	96.0
8/26	50.0	17.3	----	----	5.04	34.6	4.00	10.76	14.76	----	----	99.7
9/23	40.8	20.8	19.00	0.62	----	61.0	1.00	14.97	16.27	2.73	----	87.9
1944 8/15	44.6	13.4	----	0.59	----	21.4	4.74	6.42	11.16	----	----	67.4
8/22	46.5	13.6	----	0.58	----	35.6	4.07	7.06	11.13	----	----	103.2
1945 8/27	50.8	16.8	15.90	0.54	5.00	37.3	2.55	10.51	13.06	2.45	0.05	118.3
8/31	51.6	17.3	15.88	0.60	4.90	45.4	1.91	13.50	15.41	2.80	0.07	125.8
						RED X						
1943 8/16	48.0	15.4	14.17	0.73	5.19	33.6	2.89	9.46	12.35	1.72	0.06	78.0
8/23	47.1	17.0	15.67	0.65	5.00	36.2	3.16	10.80	13.96	1.71	0.04	89.6
9/1	37.5	20.9	21.15	0.90	----	53.6	1.58	15.64	17.22	3.93	0.08	79.1
1944 8/18	42.6	14.0	----	0.66	----	28.0	3.73	7.03	10.76	----	----	80.3
8/28	44.3	16.6	----	0.64	----	45.8	1.92	11.31	13.23	----	----	121.4
1945 8/28	46.8	16.5	15.45	0.58	5.00	35.0	2.97	9.66	12.63	2.82	0.05	94.7

* Calculated to a sirup density of 76° Brix.

TABLE I—(continued)

							COLLIER						
1943	8/16	44.5	20.4	18.46	0.78	5.12	48.8	1.07	15.28	16.35	2.11	0.19	124.8
	8/17	45.3	20.5	18.06	0.73	5.10	50.4	1.10	16.71	17.81	0.25	0.13	101.6
	8/26	43.3	20.7	19.46	0.68	4.97	52.6	1.55	14.81	16.36	3.10	0.18	93.0
	9/23	34.3	25.0	21.11	0.91	----	66.2	0.89	18.18	19.07	2.04	0.16	73.6
1944	8/16	42.3	18.7	----	0.90	----	48.4	1.93	12.60	14.53	----	----	121.2
	8/22	42.2	19.4	----	0.83	----	57.0	1.35	13.04	14.39	----	----	123.7
1945	8/28	47.9	20.5	17.57	0.71	4.91	51.5	1.39	13.90	15.29	2.28	0.16	----
	9/14	42.7	22.8	21.75	0.93	4.88	61.1	0.97	----	----	----	0.10	----
							WHITE AFRICAN						
1943	8/20	48.8	13.5	12.37	0.54	5.05	22.4	5.02	6.67	11.69	0.68	0.04	110.4
	8/30	45.2	15.7	14.31	0.61	5.01	34.2	5.05	8.08	13.13	1.18	0.07	125.0
	9/27	39.2	20.0	18.60	0.87	----	52.6	2.61	13.81	16.42	2.18	0.12	169.9
	10/5	----	17.0	14.28	0.90	----	40.6	2.47	10.18	12.65	1.63	0.11	----
1944	8/23	40.7	12.2	----	0.50	----	25.4	5.35	4.93	10.28	----	----	83.7
	8/31	43.0	13.4	----	0.52	----	21.0	7.01	3.59	10.60	----	----	150.4
	9/12	39.2	15.4	----	0.81	----	31.2	4.35	8.14	12.49	----	----	125.9
1945	9/7	49.5	16.7	15.60	0.66	4.92	43.4	3.18	9.36	12.54	3.06	0.06	136.3
							SUMAC, 1712						
1943	8/17	47.3	14.4	13.70	0.48	5.38	20.0	6.84	6.12	12.96	0.74	0.03	83.5
	8/25	51.7	17.3	16.00	0.55	5.23	24.4	10.31	4.69	15.00	1.00	0.04	145.7
	9/27	41.0	22.4	19.23	0.73	----	53.6	3.24	14.68	17.92	1.31	0.14	133.7
1944	8/18	42.9	11.8	----	0.45	----	17.4	8.27	1.37	9.64	----	----	96.8
	8/24	42.8	12.5	----	0.49	----	23.4	7.08	3.19	10.27	----	----	96.0
	9/4	44.3	14.7	----	0.52	----	23.0	7.30	5.51	12.81	----	----	140.6
1945	9/6	48.8	16.5	16.31	0.47	5.09	22.4	6.31	6.49	12.80	3.51	----	124.9

TABLE I—(continued)

HONEY													
1943	9/1	43.0	14.6	13.93	0.31	----	18.0	8.90	3.92	12.82	1.11	0.04	109.2
	9/14	46.6	15.6	14.54	0.40	5.40	17.4	7.25	6.32	13.57	0.97	0.08	----
1944	8/24	46.6	11.8	----	0.70	----	19.0	6.57	2.50	9.07	----	----	111.1
	8/31	46.6	13.7	----	0.66	----	23.0	4.65	5.57	10.22	----	----	171.1
	9/12	41.9	15.6	----	0.57	----	25.0	6.21	7.24	13.45	----	----	183.1
1945	9/11	52.4	15.7	15.11	0.45	5.15	20.4	6.28	6.02	12.30	2.80	0.04	204.7
SUGAR DRIP													
1943	8/20	52.8	15.5	14.58	0.46	5.02	16.2	6.24	6.88	13.12	1.46	0.04	143.7
	8/30	47.8	18.4	17.80	0.47	5.19	26.0	5.59	10.11	15.70	2.10	0.05	152.2
	10/5	----	20.4	19.17	0.71	----	40.6	2.30	14.11	16.41	2.76	0.14	----
1944	8/23	46.9	13.8	----	0.49	----	21.4	6.90	4.80	11.70	----	----	118.6
	8/28	46.7	13.8	----	0.38	----	16.2	6.18	5.65	11.83	----	----	135.6
	9/4	47.3	15.9	----	0.55	----	24.0	5.24	8.68	13.92	----	----	156.2
1945	9/10	49.7	18.6	18.14	0.48	5.00	23.4	4.35	10.66	15.01	3.13	0.05	138.5
	9/15	----	18.5	16.27	0.66	4.98	38.3	2.55	10.91	13.46	2.81	0.15	----
COLMAN													
1943	8/14	50.7	12.1	----	----	5.30	17.4	5.17	4.76	9.93	----	0.02	66.5
1944	8/15	38.2	12.0	----	----	----	25.4	6.43	3.20	9.63	----	----	51.4
ICEBERG													
1944	8/21	44.0	16.5	----	0.44	----	20.4	3.68	8.17	11.85	----	----	132.3
	9/1	44.3	18.4	----	0.56	----	40.4	4.21	12.06	16.27	----	----	132.3
1945	9/5	51.6	18.0	17.32	0.51	5.00	24.4	4.03	10.33	14.36	2.96	0.05	195.8
C. P. SPECIAL													
1944	9/1	45.3	13.6	----	0.65	----	25.4	3.68	7.00	10.68	----	----	154.1
KANSAS ORANGE													
1945	9/4	46.3	17.1	16.80	0.44	4.99	25.5	5.33	8.17	13.50	2.34	0.04	105.5
GOOSENECK (2 types)													
1945	8/30	49.7	19.6	18.66	0.70	4.94	47.40	2.56	12.66	15.22	3.44	0.10	142.1
	8/30	50.6	15.2	14.43	0.47	5.08	29.90	4.15	7.94	12.09	2.34	0.03	143.0

TABLE II

Chemical Composition of Sorghum Sirups From Plantings in 1943, 1944, and 1945; Stillwater, Oklahoma

Year*		Treatment**	Sugars: Reducing	Sugars: Sucrose	Sugars: Total	Ash	Oven Solids	Non-sugar Solids	Yield per acre†
			pct.	pct.	pct.	pct.	pct.	pct.	gal.
LEOTI									
1943	8/11		30.24	31.79	62.03	2.11	67.44	5.41	--
	8/11	Kaolin	30.21	36.39	66.20	2.21	70.74	4.54	--
	8/13		28.72	33.28	62.00	2.01	72.22	10.22	84.3
	8/25		27.75	35.71	61.46	1.96	71.29	9.83	96.0
	8/26	Kaolin	20.53	39.43	59.96	2.23	66.30	6.34	99.7
	9/23		43.42	7.56	50.93	3.28	60.21	9.23	87.9
1944	8/15		30.05	35.16	65.21	3.16	71.75	6.54	67.4
	8/22		28.21	36.79	65.00	3.11	72.87	7.87	103.2
1945	8/27		17.45	44.87	62.32	2.41	70.78	8.46	118.3
	8/31	Fullers Earth	16.41	42.66	61.77	2.88	72.52	10.75	125.8
	8/31		14.65	45.13	59.07	2.78	74.88	15.81	126.7
RED X									
1943	8/16		19.16	38.56	57.72	3.07	69.22	11.50	78.0
	8/23		19.93	36.94	56.87	3.31	66.40	9.53	89.6
	8/23	Diastase	21.07	39.90	60.97	3.18	68.33	7.36	99.0
	8/23	Invertase	38.51	19.67	58.18	3.13	64.49	6.31	96.7
	9/1	Diastase	35.89	23.35	59.24	3.35	70.06	10.82	79.1
1944	8/18		26.24	41.34	67.58	3.19	71.38	3.80	80.3
	8/28		15.90	41.89	57.79	3.41	66.37	8.58	121.4
1945	8/28		16.38	37.31	53.69	2.36	64.79	11.10	94.7

* The year and day will identify these samples with the corresponding juice samples from Table I.

** Where no treatment is indicated, the samples were prepared by simple evaporation and skimming.

† Calculated to a sirup density of 76° Brix.

TABLE II—(continued)

			COLLIER						
1943	8/16		Sample scorched badly						124.8
	8/17		12.99	37.91	50.90	2.53	64.75	13.85	101.6
	8/26	Diastase	15.10	43.66	58.76	2.69	62.71	3.94	93.0
	9/23		15.40	35.15	50.55	2.55	61.99	11.44	73.6
1944	8/16		13.79	48.13	61.92	3.14	70.18	8.26	121.2
	8/22	Diastase	24.52	37.26	61.87	3.06	69.81	7.94	123.7
1945	8/28		12.48	42.61	55.09	2.57	69.80	14.71	181.7
	9/14	Fullers Earth	8.70	39.44	48.14	2.74	64.98	16.84	....
	9/14	Heated Clay	8.24	43.20	51.44	2.68	63.84	12.40	....
			WHITE AFRICAN						
1943	8/20		32.48	29.55	62.03	2.81	68.20	6.17	110.4
	8/30		27.45	32.09	59.54	3.08	71.82	12.28	125.0
	9/27		38.57	7.95	46.52	3.02	59.29	12.77	169.9
1944	8/23		34.82	28.05	62.87	3.03	69.55	6.68	83.7
	8/31		43.09	18.95	62.04	2.96	68.43	6.39	150.4
	9/12		27.87	37.34	65.21	3.10	74.68	9.47	125.9
1945	9/7	Fullers Earth	20.47	39.24	59.73	2.86	72.48	12.75	136.3
	9/7		20.07	35.08	55.15	2.81	69.73	14.58	148.6
	9/7	Heated Clay	19.61	33.96	53.57	2.80	71.83	18.26	185.0
			SUMAC, 1712						
1943	8/17		35.42	24.67	60.09	2.19	67.76	7.67	83.5
	8/25	Diastase	33.61	27.79	61.40	2.23	70.46	9.06	145.7
	9/27		15.98	36.77	52.75	2.40	58.05	5.30	133.7
1944	8/18		53.66	9.49	63.15	2.69	65.27	2.12	96.8
	8/24	Pectinase	48.46	17.22	65.68	2.93	66.95	1.27	96.0
	9/4		41.93	26.32	68.25	2.57	70.32	2.07	140.6
1945	9/6	Fullers Earth	32.95	30.46	63.41	1.95	75.07	11.66	124.9
	9/6		33.33	30.06	63.39	1.87	74.20	10.81	100.2

TABLE II—(continued)

			HONEY						
1943	9/1		46.50	16.94	63.44	1.67	71.21	7.77	109.2
	9/14		36.53	23.46	59.99	2.04	66.23	6.24	----
1944	8/24		48.71	16.76	65.47	2.13	69.13	3.66	111.1
	8/31		34.12	29.69	63.81	4.29	75.78	11.97	171.3
	9/12		32.17	30.01	62.18	2.45	69.65	7.47	183.1
1945	9/11		34.69	33.00	67.69	2.07	74.88	7.19	204.7
	9/11	Fullers Earth	29.99	30.06	60.05	2.43	68.05	8.00	222.3
	9/11	Heated Clay	35.52	28.90	64.42	1.66	71.28	6.86	221.8
			SUGAR DRIP						
1943	8/20		35.56	28.74	64.30	1.91	74.46	10.16	143.7
	8/30	Diastase	28.10	33.09	61.19	1.89	69.91	8.72	152.2
	10/5		15.20	25.18	40.38	1.80	49.28	8.90	----
1944	8/23		41.13	26.68	67.81	2.09	69.14	1.33	118.6
	8/28	Pectinase	37.34	28.28	65.62	1.95	72.50	7.25	135.6
	9/4		28.13	38.39	66.52	2.48	74.39	7.87	156.2
	9/4	Kaolin	29.60	37.52	67.12	2.43	74.34	7.22	176.8
1945	9/10	Fullers Earth	15.58	44.01	59.59	1.95	73.74	14.19	138.5
	9/10		28.25	38.39	63.64	1.60	79.17	15.53	----
	9/10	Heated Clay	20.98	38.32	59.30	1.28	73.85	14.55	133.2
	9/15		14.49	43.88	58.37	1.94	69.54	11.17	----
	9/15	Heated Clay	16.33	30.74	47.07	2.17	58.69	11.62	----
			COLMAN						
1943	8/14		35.49	25.47	60.96	1.98	69.18	8.22	66.5
1944	8/15		36.96	26.55	63.51	4.26	71.13	7.62	51.4
			ICEBERG						
1944	8/21		23.98	43.42	67.40	2.04	74.33	6.93	132.3
	9/1		24.98	39.65	64.73	1.88	71.45	6.82	132.3
1945	9/5	Fullers Earth	20.97	40.22	61.19	1.91	72.59	11.40	195.8
	9/5	Heated Clay	23.63	39.10	62.73	1.32	73.81	11.08	---

TABLE II—(continued)

			C. P. SPECIAL						
1944	9/1		27.38	35.30	62.68	3.48	71.38	8.70	154.1
			KANSAS ORANGE						
1945	9/4	Fullers Earth	24.95	38.31	63.26	1.91	76.32	13.06	105.5
	9/4		27.41	32.96	60.37	1.79	73.12	12.75	97.7
			GOOSENECK (2 types)						
1945	8/30		Crystallized—could not be run						142.1
	8/30		25.02	36.75	61.77	2.68	75.19	13.42	143.0

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