J. Agric. Sci. Mansoura Univ., 27(1): 395 - 404, 2002

STUDY ON SWEET SORGHUM CROP AS A NEW RENEWABLE SUCROSE SUBTITUTE.

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ABSTRACT

Three cultivars of sweet sorghum (Umbrella, Leoti, and Planter) were used to replace cane sugar as a new sweetener in food processing. The extracted juice of aforementioned cultivars were treated with calcium hydroxide solution (liming), sulphur dioxide (sulphitation) and phosphoric acid (phosphatation) then with charcoal to improve quality of raw juice. The treated juice was concentrated to produce sweet sorghum syrup. Some physical and chemical properties of extracted and treated juice as well as the resultant syrup was studied. It was found that the Planter cultivar juice has the highest sucrose content (14.2%), high purity (66.05%) and low in non-sucrose substances (7.3%). Also using sulphatation treatment led to produce a favorable syrup that could be replaced sucrose in preparing guava nectar. It was found that up to 50% of sucrose replacement, non-significant differences were observed concerning sensory properties in comparing with control sample.

From the previous results it could be recommended to increase the cultivated area of the Planter variety to be for substituting sucrose in food processing.

Keywords: Sweet sorghum, Syrup, Sugar Syrup, Juice-quality, Refining, Purification, Fruit nectar, Sweeteners, Sucrose.

INTRODUCTION

Sweet sorghum, sorgo, (*Sorghum biocolor* (L) *Moench*) is considered one of the important sugar crops as a new source of sugar production. Sweet sorghum may be to substitute sugar cane due to it has high sugar content and juice yield besides lower requirements of water and nitrogen than sugar cane. Additional it cultivated on a wide type of soils and has short period of vegetation (Nour, *et al.,* 1971 and Anon, 1986). Therefor magnificent attention is being focused toward the crop as a renewable source for producing of sugar, syrups, biofules products … etc (Hunter and Anderson, 1997). The annual crop production of overall world raised to 62,827,000 Mt. at 1999 in comparing with 57,124,000 Mt. at 1991 (FAO, 1999).

Physical and chemical criteria of sorgo juice were studied by many investigators (Bapat, *et al.* (1987), Ma and Nige (1992) and Purnonmo & Sumantrie (1996). They found a wide variations regarding quality parameters of extracted juice. Sucrose, that the principal component of juice, ranging from 8.4% to 15.1%. While reducing sugars are between 1.98% to 10.0% as well as total sugars content are in the range 10.54% to 13.5%. Purity percentage, extraction yield and total soluble solids (T.S.S.%) were determined by Wilhelm and Aso (1987), El-Gharbawy, *et al.* (1990) and Kurlkarni, *et al.* (1995). They mentioned that the purity (%) was in the range, 41.0 – 76.0%, extraction yield was varied from 41.6.to 57.0% while T.T.S% was between (14.09 to 20.50%). Other components of juice, i.e., starch and ash were found in mean 0.72 and 1% respectively as reported by Duncan, *et al.* (1984) and Allam, *et al.* (2001).

Raw juice of sweet sorghum contains different soluble and insoluble matters, i.e. pectin, waxes, gums, plant pigments, nitrogenous compounds … etc. These impurities make the juice turbid, too dark color as well as not fit to produce attractive syrup. So different treatments were used to reduce non-sugar substance to increase purity and color development of juice. Lime milk, ($Ca(OH)_2$) solution, is considered the main clarifying agent that can remove most these impurities, Purrnomo and Sumantri 1996 and Abbas, *et al.* 1997). Sulphur dioxide also was used by Mathure (1986) and Kulkarni, *et al.* (1995) to purify sweet sorghum juice. Besides purification role it act as a bleaching agent which improves color so leads to give a brightness juice. In addition, either phosphoric acid or calcium phosphate (phosphation treatment) is used as an auxiliary defecant that achieved highest efficiency of juice purity. Also, due to hydrolysis affect on sucrose content, it tend to inhibit recrystallization of sucrose and caramelization of sweet sorghum syrup (Mathur, 1986).

Removing of juice impurities caused changes on characteristics of purified juice, i.e., T.T.S, purity, sucrose and reducing sugars content … etc. The difference is depend on the used cultivar, properties of raw juice as well as condition of purification treatments as point out by Anon, (1986), Taha, *et al.* (1994) and Hefni, *et al.* (1997). The resultant purified juice was used to produce sorgo syrup (70.0 – 75.0%T.S.S.) to replace sugar cane. The syrup content of sucrose, reducing sugars as well as total sugars are in the range (27.27 – 47.4%), (23.45 – 46.4%) and (63.0 – 65.4%) respectively. The variations toward sugars content of syrup are depend on cultivar, characteristics of purified juice, as stated by McClure and Alen (1979), Malinovskii and Simlovenko (1988) and Hunter and Anderson (1997).

Different studies were carried out to use sweet sorghum syrup instead of sucrose for some food products like wise cake processing (Amal, *et al*., 2000) syrup table (Anon, 1986). Furthermore the syrup was used in candies as well as roasted peanut (Krishnaveni, *et al*., 1990), Jaggary sugar was obtained by Purnomo and Sumantri (1996). Also Levits, *et al*. (1996) were succeeded to produce glucose fructose syrup by using sorgo juice.

In view of increasing requirement of sugar in Egypt calls for seeking a sucrose substitutes. Therefore this study was designed to investigate physical and chemical characteristics of sweet sorghum juice of some cultivars. Also the effect of using liming, sulphatation and phosphatation treatment to purify raw juice on quality of purified juice were studied. The treated juice samples were concentrated and obtained syrup was used as substitute sucrose in preparing guava nectar.

MATERIALS AND METHODS

Materials:

Three cultivars of sweet sorghum were provided by Agric. Res. Center, Fac. of Agric., El-Azher Univ., Assuit, Egypt.

Calcium hydroxide, sodium metabisulphite, hydrochloric acid, charcoal as well as phosphoric acid were supplied by Gomheria Co., for Chemicals, Egypt.

Methods:

Juice extraction: Juice of stripped stalks of the mentioned cultivars of sweet sorghum was extracted as described by Dogget (1988).

Purification of extracted juice: The resultant juice samples were purified according to Mathur (1986) and modified as follows:

1. Liming procedure: Calcium hydroxide solution (lime milk, 10%) was added to preheated juice (70 – 75ºC) up to pH 6.6 – 6.8, then heated to 95ºC ± 2ºC in water bath.
2. Sulphatation process: The extracted juice at (70 – 75ºC) was treated by lime milk (10%) to pH 9.5 – 9.7, then immediately sulphur dioxide, producing by adding Hcl 50% to sodium metabisulphite was bubbling to decrease pH to 7.0 – 7.2. The treated mixture was heated to 95ºC± 2ºC.
3. Phosphatation treatment: Phosphoric acid (25%) was added to raw juice to reach 3.5 ± 0.1 of pH, after that phosphated juice was heated to 65 – 70ºC, then the treatment was continued as in sulphatation process.

The treated juice samples were leaved to precipitate of juice impurities, then filtered through cotton wool pad to remove the formed sludge.

Preparation of sweet sorghum syrup: The clarified juice of planter cultivar were mixed with activated charcoal at (ratio 2%) and maintained for 2 hrs. at 60ºC. The treated sample were filtered over diatomaceous earth (filter aid), then concentrated using vacuum rotary evaporator at 45ºC up to 75% T.S.S.

Preparation of guava nectar: Guava nectar was prepared as described by Mohamed, *et al.*, (2000) using sucrose (control). On other experiments, syrup of Planter cultivar was used instead of sucrose at ratio 25, 50, 75 and 100 %.

Analytical Methods: Characteristics of raw and purified juice as well as syrup samples were studied as follows:

Physical properties: Extraction yield of juice percentage was calculated as given by Amal, *et al.* (2000). Total soluble (T.S.S. %) was measured using Abbe refractometer at 20ºC as described by Plews (1970). Color was determined at 299 nm using spectrophotometer (Model 204 uv./visible Spectrophotometer) as given by Salem & Hegazi (1978), pH value was measured using pH meter Model 671 P. Jenco. Purity (%)*****, as well as non – sucrose substances (N.S.S) and titratable acidity were determined as given by A.O.A.C. (1995).

Chemical constituents determination: Sucrose, reducing sugars, total sugars, ash, starch content, as well as non-sucrose substances and titratable

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$$\text{* Purity (\%)} = \frac{\text{Sucrose \%}}{\text{T.S.S. \%}} \times 100$$

acidity of sweet sorghum juice and resultant syrup were determined according to A.O.A.C. (1995).

Sensory evaluation of guava nectar: Properertis of guava nectar (taste, color, flavor) were performed by 10 panelists. The obtained data statistically analyzed as described by Gomez and Gomez (1984).

RESULTS AND DISCUSION

Physical properties of raw juice:

Table (1) show that the physical properties are according to the used cultivars. The highest extraction yield, T.S.S (%) and purity were found to be in Planter variety (55.20, 21.50 and 66.05%) followed by Leoti (50.5, 20.6 and 60.34%) and Umbrella (47.9, 20.0 and 56.09%) respectively. The same trend was observed regarding with the purity where Planter cultivar is the highest one.

Table (1): Physical properties of raw juice.

Crop Cultivar	Property				
	Juice Yield (%)	T.S.S.(1) (%)	Purity (%)	pH	Color (OD.)2
Planter	55.2	21.5	66.05	4.80	2.26
Leoti	50.5	20.6	60.34	4.93	2.73
Umbrella	47.9	20.2	56.09	5.10	2.46

1) T.S.S.: Total soluble solids. **2) OD.: Optical density at 299 nm.**

Also the pH value was 4.8 in Planter and up to 4.93 and 5.1 in Leoti and Umbrella varieties respectively. The variation in pH value could be attributed to the transformation and accumulation of organic acids in crop especially at ripe stage of maturity (Abd El-Bari, 1976). Concerning color the lowest intensity of color was given by Planter variety (2.26) than the rest cultivars. The variation towards color intensity could be attributed to the nature and content of plant pigments, besides to some chemical reactions in juice.

Chemical characteristics of raw juice:

The chemical constituents of different extracted juice samples were recorded in Table (2).

Table (2): Chemical constituents of raw juice.

Crop Cultivar	Constituent						
	Sucrose (%)	Red.[(a)] sugar (%)	Total sugars (%)	N.S.S.[(b)] (%)	Ash (%)	Starch (%)	Titr.[(c)] Acid.
Planter	14.20	2.00	17.54	7.30	1.10	0.64	5.3
Leoti	12.43	2.71	16.10	8.17	1043	0.86	4.7
Umbrella	11.33	3.19	14.92	8.67	1.68	0.77	4.2

a) Reducing sugars. **b) Non-sucrose substances.**
c) Titratable acidity: ml. (0.1 NaoH)/10 gm. sample.

The results reveals that Planter variety has the highest value of sucrose (14.2%) which correlated to the purity and lowest percentage of reducing sugars. While the other cultivars (Leoti and Umbrella) contained lower content of sucrose (12.43 and 11.33%) respectively. But Umbrella variety has the highest value of reducing sugars (3.19%). These findings are in coincide with data given by Purnomo & Sumantri (1996) and Hunter & Anderson (1997). Table (2) illustrate that ash and starch content were low in Planter variety (1.1, 0.64%) respectively in comparison with other varieties. These results are in good agreement with those postulated by Smith and Reeves (1981).

The titratable acidity value of sorgo juice under study is in order Planter > Leoti > Umbrella (5.3, 4.7 and 4.2) respectively and coincide with pH results.

According to the aforementioned findings it could be concluded that the variations at physical and chemical characteristics may be attributed to variety of sweet sorghum, agriculture management, environmental conditions … etc.

Effect of different purification treatments on physical property of juice:

The changes in physical properties of purified juice are presented in Table (3). Results indicated that liming treatment samples has the highest purity followed by sulphatation, then phosphatation. The same trend was found concerning T.S.S.(%).

Table (3): Physical properties of purified juice of different varieties of sweet sorghum.

Variety	Treatment	Property			
		T.S.S. (%).	Purity (%).	PH	Color (OD.)
Planter	Raw juice	21.5	66.05	4.80	2.26
	Liming	20.8	66.92	7.24	1.35
	Sulphatation	20.3	65.66	7.00	0.87
	Phosphatation	19.6	64.44	7.13	1.13
Leoti	Raw juice	20.6	60.33	4.93	2.73
	Liming	19.3	62.69	7.30	1.73
	Sulphatation	18.5	63.51	7.06	1.40
	Phosphatation	17.9	63.35	6.80	1.26
Umbrell	Raw juice	20.0	56.09	5.10	2.46
	Liming	18.5	60.00	7.32	1.49
	Sulphatation	17.3	61.79	6.93	1.10
	Phosphatation	16.0	62.31	6.80	1.24

The increasing of purity could be attributed to minimize the inversion of sucrose. On contrary color of treated sample using liming treatment recorded the highest value of color intensity but sulphatation treatment achieved the lowest intensity. That results appeared that addition of calcium hydroxide solution led to yield a dark juice due to it effect on juice sugars. In opposite using of sulphatation process caused superiority of color brightness in view of bleaching effect of sulphur dioxide. The same findings were postulated by Kulkarni, *et al.* (1995).

Generally, it could be concluded that the changes as to physical properties were according to cultivars and conditions purification treatments.

Effect of different purification treatments on chemical composition of juice:

Table (4) illustrated that sucrose content of purified juice of all cultivars decrease is in order phosphatation > sulphiphatation > liming treatment at all cultivars. In contrast using of liming procedure gave lowest percentage of reducing sugars. Also greater percentage of reducing sugars was found in Umbrella juice than Leoti, but Planter variety has the lowest content of all purification treatments.

Table (4): Chemical composition of purified juice of sweet sorghum varieties.

Treatment	Constituent						
	Sucrose (%)	R. Sugar (%)	T. Sugar (%)	N.S.S. (%)	Ash (%)	Starch (%)	Titr. Acidity
Planter variety							
Raw juice	14.20	2.00	17.54	7.30	1.10	0.64	5.30
Liming	13.92	2.83	18.79	6.88	0.98	0.50	4.10
Sulphatation	13.33	3.29	18.32	6.97	0.70	0.39	4.60
Phosphatation	12.63	4.10	18.00	6.97	0.63	0.27	5.30
Leoti variety							
Raw juice	12.43	2.71	16.10	8.17	1.43	0.86	4.70
Liming	12.10	3.62	17.88	7.20	1.30	0.72	3.50
Sulphatation	11.75	4.81	18.39	6.75	1.11	0.52	5.30
Phosphatation	11.34	5.11	17.20	6.56	1.20	0.33	6.00
Umbrella							
variety	11.33	3.19	14.92	8.67	1.68	0.77	4.20
Raw juice	11.10	4.02	15.23	7.40	1.43	0.60	3.00
Liming	10.69	5.13	17.17	6.61	1.05	0.43	6.00
Sulphatation	9.97	6.30	16.90	6.09	1.00	0.29	6.90
Phosphatation							

It could be concluded that the variations in both sucrose and reducing sugars content of purified juice may be attributed to the rate of sucrose inversion that is in the following order phosphatation > sulphatation > liming procedures of juice purification. Besides, sugars content affected with initial percentage of raw juice.

Concerning ash content liming treatment achieved the highest result than other treatments of purification. The results may be referred to the remained calcium ions and salt in purified juice. As to starch content the same trend was also observed. Using phosphatation treatment produced the lowest content of starch in all used varieties. These results are in basis of starch decomposition due to conditions of purification treatment.

Regarding to titratable acidity an increase was noticed using phosphatation treatment, but liming process caused lowest value. These findings may be attributed to the formation of some acidic compounds in purified juice. The previous results are in agreement with those given by Abbas *et al.* (1997).

From the aforementioned results and discussion it could be concluded that samples of sweet sorghum juice which purified using sulphatation treatment has superior of color, purity and sugar content. So it were concentrated to get syrup has 75% T.S.S. and some physico-chemical characteristics are illustrated in Table (5) for the used cultivars.

Table (5): Physcio-chemical characteristics of syrup samples from different cultivar juice.

Characteristic	Cultivars					
	Planter		Leoti		Umbrella	
	T.J.*	Syrup	T.J.*	Syrup	T.J.*	Syrup
Color (OD.)	0.70	1.10	1.13	1.55	0.95	1.48
Purity (%).	65.66	65.68	63.51	63.39	61.79	61.59
Sucrose (%).	13.33	49.26	11.75	47.54	10.69	46.19
N.S.S. (%).	6.97	25.74	6.75	27.46	6.61	28.81
Ash (%).	0.70	3.10	1.11	3.50	1.05	4.42
Titratable acidity	4.60	19.80	5.30	21.90	6.00	28.30

*** Treated juice.**

The results appeared that concentration of juice caused an increase of color intensity. Sucrose content of resultant syrup samples are varied from (49.26 to 46.19%) and are in agreement with those stated by McClure & Alen (1979) and Hunter and Anderson (1997). A slight increase was appeared as to ash content and titratable acidity.

Results from Table (5) indicated that syrup of Planter variety has highest value of purity and sucrose content (65.66%, and 49.26%) comparing with (63.51 and 47.54%) and (61.79 and 46.19%) for Leoti and Umbrella respectively. On contrary syrup of the former cultivar has lowest color intensity, N.S.S.% as well as ash content (1.10, 25.74% and 3.10% respectively) against to (1.55, 27.46 and 3.50%) as well as (1.48, 28.81% and 4.42%) of Leoti and Umbrella respectively.

From the aforementioned results it could be concluded that Planter variety gave favorable syrup quality parameters for food processing in comparing with either Leoti or Umbrella cultivar.

Sensory evaluation of the prepared guava nectar:

The produced syrup was replaced sucrose at ratio zero (control), 25, 50, 75 and 100%. Results of organoleptic evaluation (Table 6) revealed variations toward taste, color, and flavor of prepared guava nectar. Concerning previous factors of nectar quality, non significant differences were appeared when sucrose was replaced with sorgo syrup up to 50% except of flavor that revealed a slightly difference. In contrast, increasing of substitution ratio to 75% or 100% a highly significant difference was found except color, which still accepted till 75% of sucrose replacement.

Table (6): Organoleptic attributes of guava nectar using sorgo syrup.

Sweeteners	Score (10)			Total Score (30)
	Taste	Color	Flavor	
Suc. 100%	9.2[a]	9.0[a]	9.1[a]	27.3[a]
Suc.75%+Syr.25%	8.1[a]	8.6[a]	8.4[a]	25.1[a]
Suc. 50%+Syr.50%	7.7[a,b]	8.3[a,b]	7.5[b]	23.8[a,b]
Suc.25%+Syr.75%	6.6[b,c]	8.0[a,b]	6.8[c]	21.4[b,c]
Syr.100%	5.7[c,d]	7.7[b,c]	6.1[c,d]	19.5[c,d]
L.S.D at 0.05	1.1	0.78	0.86	2.3

Suc.: Sucrose. **Syr.: Syrup.**

The overall acceptability (%)* of the resultant nectar samples were 92.0, 87.14, 78.35 and 71.43%, by using sorgo syrup at ratio 25.0, 50.0, 75.0 and 100% instead of sucrose respectively. Generally it could be said that replacement of sucrose by sorgo syrup up to 50% yielded acceptable guava nectar samples.

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$$\text{* Overall acceptability (\%)} = \frac{\text{Total score of sample}}{\text{Total score of control}} \times 100$$

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دراسة عن محصول الذرة السكرية (السورجم) كمصدر جديد لإنتاج بديل للسكروز.

السعيد على عطية
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أجرى هذا البحث باستخدام ثلاثة أصناف من الذرة السكرية (Umbrella, Leoti, Planter) كبديل لقصب السكر فى إنتاج شراب السورجم لاستخدامه فى تصنيع الأغذية٠

وقد تم تنقية العصير الخام المستخلص من هذه الأصناف السابقة باستخدام لبن الجير (التجيير) بمفرده أو باستخدام لبن الجير وثانى أكسيد الكبريت (الكبرته) أو لبن الجير وحامض الفوسفوريك (الفسفتة) للتخلص من الشوائب الموجودة بالعصير الخام وبالتالى تحسين جودته ثم تركيز العصير الرائق حتى الوصول إلى ٧٥% مواد صلبة ذائبة كلية٠

وتم دراسة بعض الخواص الطبيعية والكيمائية للعصير والشراب المصنع منه وأظهرت النتائج:-

1- صنف الذرة السكرية Planter يحتوى على أعلى نسبة من السكروز (٢ر١٤%) وأعلى نقاوة (٠٥ر٦٦%)، وأقل نسبة من المواد الصلبة الغير سكرية (٣ر٧%)٠
2- باستخدام طرق التنقية الثلاثة السابقة وجد أن أفضل معاملة هى المعاملة بالجير ثم ثانى أوكسيد الكبريت هى أفضل المعاملات خاصة من ناحية اللون والنقاوة لانتاج شراب يحل محل السكروز فى تحضير مشروب الجوافة٠
3- أنه لاتوجد فروق معنوية بين شراب الجوافة الصنع باستخدام السكروز أو الناتج من استبدال السكروز بشراب السورجم بنسبة ٥٠% فيما يتعلق بالخواص الحسية مقارنة بعينة الكنترول (١٠٠% سكروز)٠

مما سبق فإننا نوصى بالتوسع فى زراعة صنف الذرة السكرية Planter لإنتاج شراب سكرى بديل للسكروز٠