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Innovative use of Sweet sorghum juice in the beverage industry

[1*]Datta Mazumdar, S., [1]Poshadri, A., [2]Srinivasa Rao, P., [2]Ravinder Reddy, C. H. and [2]Reddy, B.V.S

[1]*NutriPlus Knowledge (NPK) Program, Agribusiness and Innovation Platform (AIP)*
[2]*Dryland Cereals Research Program*
International Crops Research Institute for Semi-Arid Tropics (ICRISAT), India

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Abstract

Sweet sorghum juice, obtained from low water consuming, drought resistant, short duration and seed-propagated sweet sorghum crop, was explored as a source to obtain syrup which can be used as sugar alternative for meeting certain requirements of the beverage industry. Value addition, through conversion of the juice to syrup and beverages, offers farmers an excellent opportunity to improve farm income and productivity in semi arid regions. In this study a new method to produce clarified sweet sorghum juice is demonstrated. The sweet sorghum juice was clarified using pre heating followed by vacuum filtration using a filter aid. The clarified juice was concentrated to syrup with acceptable sensory qualities. Flavoured beverage formulations were optimised using the clarified juice and syrup. Nutritional and sensory properties of the developed beverages showed that the samples were acceptable to the consumers and rated at par with a commercially available beverage. This work has immense industrial and social significance.

Introduction

Sweet Sorghum [*Sorghum bicolor* (L.) Moench] belongs to kingdom Plantae, family Poaceae and genus *Sorghum*. Sweet sorghum is similar to sorghum except for the sugary juice rich stalks and suitable for cultivation worldwide wherever temperatures do not fall below 15^{o}C. Sweet sorghum is a multipurpose crop for simultaneous production of (i) grain from its ear head used as food (ii) sugary juice from its stalk for making syrup, jaggery or ethanol and (iii) bagasse and green foliage as an excellent fodder for animals, as biomass for gasification system, as organic fertilizer or for paper manufacturing (Reddy *et al*., 2005; Reddy *et al*., 2009; Srinivasa Rao *et al*., 2009). Moreover, sweet sorghum has a great tolerance to a wide range of climatic and soil conditions. It is a short duration crop of 110-130 days as compared to 12-18 months in case of sugarcane, thus amenable for crop rotation. In addition its water and fertilizer requirement are much less, resulting in lower cost of cultivation than sugarcane.

Sweet sorghum is a plant with C_4 photosynthetic pathway, so its photosynthetic rate and dry matter production in g/m^2/day per unit of inputs are more than those of other sugar producing crops like sugarcane and sugar beet. These characteristics make sweet sorghum an ideal crop for syrup and jaggery production. Besides having rapid growth, high sugar accumulation and biomass production potential, sweet sorghum has wider adaptability and can be grown in regions up to 40° latitude, south and north of equator. The sugar content in the juice extracted from sweet sorghum varies from 16–23°Brix (Reddy *et al*., 2005). Sweet sorghum also plays an important role in the production of ethanol, especially in dry areas where other crops are not easily grown (McLaren *et al*., 2003). The sweet sorghum juice has a balanced nutritional profile containing protein, essential amino acids, minerals etc. (FAO, 1994). Thus given its physico-chemical characteristics and nutritional profile a wide spectrum of utilization in the food and pharmaceutical industry is also possible.

To further exploit its potential to develop value added products, the use of sweet sorghum as an ingredient in the food and pharmaceutical industry needs to be explored. This shall further strengthen the sweet sorghum value chain and thus provide additional livelihood opportunities to the farmers involved in its cultivation. Keeping this in view, this paper presents the progress of the work carried out at ICRISAT-Patancheru; Andhra Pradesh, India,

*Corresponding author.
Email: *s.dattamazumdar@cgiar.org*

in identifying a suitable method for clarification of the sweet sorghum juice to obtain food grade syrup and developing sweet sorghum based beverages. The beverages were developed using clarified sweet sorghum juice or juice reconstituted from sweet sorghum syrup, as the major ingredient and adhering to Indian food regulations (FSSA, 2006). The developed beverages were analyzed for their physico-chemical characteristics, microbial stability, shelf life and also consumer acceptability.

Materials and Methods

Materials and chemicals

Sweet sorghum crop variety ICSV 25274, grown in post rainy season during the year 2009 at ICRISAT farm was harvested at physiological maturity stage. Food grade filter aid [Diatomaceous earth (celite)] was supplied by Molychem India Pvt. Ltd. (Mumbai, India). Nature identical red apple flavor (DO907930) was purchased from Mane India Pvt. Ltd. All other chemicals were purchased from Qualigens Fine Chemicals (Mumbai, India) or Molychem India Pvt. Ltd. (Mumbai, India). Microbiology media were obtained from Hi-Media Laboratories (Mumbai, India). Unless otherwise mentioned all chemicals used were of analytical grade. Juice was extracted from sweet sorghum stalks using a horizontal three roller crusher (Jagadish No. 6, Gujarat, India).

Physico-chemical characteristics

Total soluble solids (°Brix) and pH of juice, syrup and the developed beverages were measured with the help of digital pocket refractometer and pH meter, respectively. Acidity was calculated by titrating against 0.1 N NaOH and expressed as percentage of citric acid. Water activity (a_w) was measured using a water activity meter (HygroLab®, bench top indicator version, Rotronic AG, Switzerland).

Nutritional analysis

Crude protein, crude fiber, total ash, ascorbic acid content, reducing sugars and total sugars were determined using approved AOAC methods (2002).

Microbial analysis

Ten gram analytical unit of each food sample [sweet sorghum ready to serve (RTS) beverage, squash and syrup] was homogenized with 90 ml of sterile Ringer's solution for 2 min and then 10 fold serial dilutions were prepared in sterile Ringer's solution (APHA, 2001). Briefly, individual serial decimal dilutions, starting with the prepared sample and each of the subsequent dilutions were prepared in 9 ml volume of sterile Ringer's solution up to 1×10^{-6} dilution, of the original food sample. Triplicate 1 ml inoculums of appropriate dilutions were pour plated, on the following media; for enumeration of total plate counts (TPC) on plate count agar and for enumeration of yeast and moulds on potato dextrose agar. The inoculated petri plates were incubated at 37°C for 48 h for TPC and at 25°C for 48 h for yeast and moulds, respectively. Colonies were counted and expressed as colony forming units (cfu) per gram. Standard enumeration procedures were followed (Speck, 1975).

Sensory analysis

The sensory assessments were conducted at the Research and Development laboratory of NutriPlus Knowledge (NPK) Program, Agribusiness and Innovation Platform (AIP), ICRISAT. A panel of 12 members consisting of staff and intern students of ICRISAT evaluated the products. To ensure that there was no bias towards the products, it was ensured that the panelists chosen were naive to project objectives. Commercially available "Appy" (Apple RTS Fruit beverage, Parle Agro Pvt. Ltd., India) was used as control. The control was compared with the two apple flavored sweet sorghum RTS formulations, having two different levels of acidity (0.3% and 0.4% as citric acid). Prior to sensory evaluation the samples were chilled to 10ºC. Samples were coded using random three-digit numbers and served chilled. 25 ml of each sample was served, with the order of presentation counter balanced. Panelists were provided with a glass of water and, instructed to rinse their palate with water and drink water between samples. They were given written instructions and asked to rate the coded samples on color, sourness, flavor, sweetness and overall acceptability, using a nine-point hedonic scale [1=like extremely to 9 =dislike extremely] (Carr *et al*., 1999). A more accurate evaluation of hedonic ratings is the determination of fiducial limits for the control sample (Merck, 1963). The fiducial limits represent a range of average scores (for each sensory attribute) for the control, within which an average score for a particular sample is not significant. Average scores of samples above and below the fiducial limits of the control sample indicates significant difference from the control sample. Fiducial limits of control sample was calculated by multiplying the standard error of the mean of the control sample with the factor't' (Values of 't' resources for significance at 0.5% level for two tailed hypothesis)

Clarification of sweet sorghum juice

The freshly harvested sweet sorghum stalks were crushed in roller mill to extract the juice from the stalks. The collected juice was pre-heated for about 20 min at 70°C. The juice was cooled down to 40°C. Further, the cooled juice was clarified by using vacuum filtration. Briefly, the filter cloth cut to size, was placed on the Buchner funnel and a uniform bed of celite was prepared on the filter cloth. The juice was then poured on the celite bed and filtered under vacuum. This process resulted in clarified sweet sorghum juice. The clarified juice thus obtained, is either used directly for preparing beverages or it can be converted in to shelf stable sweet sorghum syrup.

Preparation of sweet sorghum syrup

The clarified sweet sorghum juice was used to prepare syrup. The juice was heated and evaporated slowly. Concentration was carried out under uniform heating conditions with continuous stirring. As concentration proceeds, the boiling point increases. It is thus important that heating is carried out under a low flame to avoid charring. During the concentration process frothing occurs as a result of coagulation of any remaining suspended particles resulting in scum. The scum was continuously removed. When the final °Brix of concentrated juice (syrup) was 72° to 76°Brix, heating was completely stopped. The syrup was then cooled and stored in PET bottles under ambient conditions. This syrup is shelf stable and can also be used for making sweet sorghum based beverages.

Beverage product development

Flavored sweet sorghum based squash

Squash was developed from clarified sweet sorghum juice (18.5°Brix). The final TSS of the squash was adjusted to 40°Brix by the addition of sugar, as required by regulations (FSSA, 2006). The ingredients were mixed using a Silverson® mixer. The prepared squash was then pasteurized at 72°C for 15 seconds. The pasteurized juice was then cooled to room temperature (~30ºC). Nature identical Red apple flavor was added to prepare apple flavored sweet sorghum squash. Finally, preservatives potassium metabisulphite (E224, source of sulphur dioxide) and sodium benzoate (E211, source of benzoic acid) were added to the flavored squashes, as per the limits laid down in the FSSA, 2006 specifications.

The squashes thus prepared were filled into sterilized glass bottles, crown corked and stored at ambient conditions. Squash was also developed from syrup (73°Brix). Initial trials were designed to prepare squash by directly diluting the syrup to 40°Brix. However, the squash made by directly diluting the syrup did not have the desired organoleptic attributes. A bitter after taste was perceived by the sensory panel. Therefore a different approach was taken; the TSS of the syrup was decreased to 18°Brix (to match that of the original juice) by dilution with water. This reconstituted juice, thus prepared, was then converted into squash by raising the TSS to 40°Brix by addition of sugar. The squash is diluted 3 times in water before consumption.

Flavoured sweet sorghum based RTS beverage

The sweet sorghum juice or syrup can be used as the raw material for preparation of the RTS beverage. In the first step, equivalent amount of juice or syrup is taken to obtain a solution of 4°Brix. The acidity of this solution was measured in terms of citric acid. The acidity was then further adjusted by the addition of citric acid and maintained within the limits as per the FSSA, 2006 regulations. TSS of the beverage was then adjusted to a minimum of 10% by addition of sugar. The ingredients were blended using a Silverson® mixer. Subsequently pasteurization was carried out at 72°C for 15 sec. The pasteurized RTS beverage was then cooled to room temperature (~30ºC). Nature identical Red apple flavor was added. Finally, preservatives potassium metabisulphite (E224, source of sulphur dioxide) and sodium benzoate (E211, source of benzoic acid) were added to the RTS beverages, as per the requirements (FSSA, 2006). The RTS beverages thus prepared were filled into sterilized glass bottles.

Results and Discussions

The °Brix, pH, acidity and a_w are the physico chemical characteristics which play an important role in the development of any shelf stable beverage. The physico chemical characteristics of clarified raw sweet sorghum juice, syrup and developed beverages were determined using standard methods. The freshly collected clarified juice had a Brix of 18°±0.05°. The juice was clarified according to the method described above using celite as filter aid followed by vacuum filtration. This method of clarification of sweet sorghum juice, to our knowledge, has not been reported in literature. For industrial applications the same process can be replicated using a filter press with celite being used as the filter aid. From this clarified juice, syrup was prepared by open pan concentration. Concentration was stopped at approximately 73° Brix. Squash and RTS beverage were developed from fresh juice and also using the syrup. Based on the sensory data as well as the physico-chemical analysis, optimised formulations of squash and RTS beverage were obtained. As mentioned it is possible to develop the beverages using either juice or syrup as the starting raw material. The optimised formulations for

Table 1. Optimized squash and RTS beverage formulations developed from sweet sorghum juice and syrup

Ingredients	Squash from sweet sorghum juice	Squash from sweet sorghum syrup	RTS beverage from sweet sorghum juice	RTS beverage sweet sorghum syrup
Total soluble solids	40	40	10	10
Minimum quantity of sweet sorghum juice or syrup (%)	25	6.25*	10	2.5*
Acidity (as % citric acid)	1.2	1.2	0.4	0.4
Flavor (%)	0.36	0.36	0.11	0.11
Potassium metabisulphite (E224) as SO_2 (ppm)	175	175	35	35
Sodium benzoate (E211) as benzoic acid (ppm)	300	300	60	60

*Assuming 4 times concentration of the juice to obtain syrup

the sweet sorghum based squash and RTS beverages are presented in Table 1.

The pH of the fresh juice was about 5.17±0.02. The syrup made from juice had a pH of 3.75±0.034. The decrease in pH was due to concentration of acids during syrup preparation. The pH of the squashes prepared from juice and syrup were 2.54±0.052 and 2.58±0.031, respectively. This lowering of pH is one of the critical hurdles, introduced in the formulation, and is responsible for inhibiting microbiological spoilage of the squash, This is achieved by the addition of citric acid. Similarly the pH and acidity was also adjusted in the RTS beverge formulations. The final acidity of the products were within the specified limits as per FSSA, 2006. a_w of juice, syrup, squash and RTS beverages were 0.99±0.01, 0.65±0.02, 0.95±0.02 and 1.0±0.00 respectively.

Thus, from this data it is clearly inferred that the syrup has a_w within the range of intermediate moisture foods, similar to that of honey (a_w=0.75). Thus, the syrup obtained is shelf stable and does not need any preservatives and can be stored under ambient conditions. However, in order to obtain shelf stable squash and RTS beverages it was essential to bring down the pH within a range to prevent microbial growth. Further shelf stability was ensured by addition of permitted preservatives.

The clarified sweet sorghum juice, syrup and RTS beverages developed were analyzed for their nutritional composition namely protein, total ash, reducing sugars, total sugars and ascorbic acid. The results obtained are expressed on dry basis and presented in Table 2. The clarified juice had a protein content of 1.12±0.1%. The syrup, squash and RTS beverages obtained from juice had a protein content of 5.61±0.1%, 1.35±0.06% and 0.30±0.02%, respectively. Thus, the protein content of the juice as well as the developed beverages is well within the range obtained for other fruit juices and beverages. The syrup also qualifies as a protein source.

The total and reducing sugar content of clarified juice was 18.5±0.1% and 2.95±0.02%, respectively. It is well established that in comparison to sugarcane juice there is a lesser amount of non reducing sugars, especially sucrose (50-80%) in sweet sorghum juice. This prevents crystallisation and hence, it is not possible to obtain crystalline sugar from sweet sorghum juice. However, the sugar profile (ratio of total to reducing sugars) of the juice obtained is suitable for preparation of syrup without any issues of crystallisation in the syrup (FAO, 2010). The total and reducing sugars content of syrup obtained was 72.53±0.1% and 18.53±0.6%, respectively. The total and reducing sugar contents of the optimised beverages formulations were also measured and are presented in Table 2.

The ascorbic acid content of freshly crushed and clarified juice was 10.8±0.9 mg/100g. The syrup contained about 28.0±0.5 mg/100g of ascorbic acid (Table 2). The ascorbic acid content of the syrup theoretically should be 43.60 mg/100g (assuming approximately four fold concentration of the juice to syrup). There was about 35% loss in ascorbic acid content during syrup preparation. This is expected as Vitamin C is heat liable. The ascorbic acid content of the squash was 12.12±0.4 mg/100g and the value for the RTS beverage was 0.4±0.02 mg/100g.

Microbiology data showed no growth for the test of total plate count (TPC) and also negative results were obtained for the enumeration of yeast and moulds using samples of sweet sorghum syrup, squash and RTS beverage after 3 months of storage at ambient temperature (27-30ºC). The data obtained for the sensory analysis is presented in Table 3. The data was further analyzed by calculating the fiducial limit of the control sample (0.5% level of significance) using the hedonic rating scores obtained for overall acceptability. The fiducial limit of overall acceptability calculated for the control sample was found to lie between 1.07 and 2.93. Hence, from the data of overall acceptability of the samples it is clear that there is no significant difference between the commercial and the developed RTS beverages samples. However, from the 4 point ranking data (Table 3) it can be inferred that the sample with 0.4% acidity was preferred over the sample with 0.3% acidity. Similar sensory analysis was also carried out for the developed sweet sorghum-based squash formulations and data analysis showed that the developed squash had acceptable organoleptic properties (data not shown).

In summary, different beverages based on sorghum grains are reported in literature. Most of the sorghum

Table 2. Nutritional composition of sweet sorghum juice, syrup, squash and RTS beverage samples

Samples	Protein (%)	Total Ash (%)	Reducing sugars (%)	Total sugars (%)	Ascorbic acid (mg/100g)
Sorghum juice	1.12±0.1	0.92±0.02	2.95±0.02	18.5±0.1	10.8±0.9
Sorghum syrup	5.61±0.1	4.17±0.2	18.53±0.6	72.53±0.1	28.0±0.5
Squash	1.35±0.06	0.97±0.05	3.33±0.4	41.23±0.7	12.12±0.4
RTS beverage	0.30±0.02	0.20±0.01	0.90±0.1	10.6±0.1	1.4±0.3

Table 3. Data of sensory analysis of sweet sorghum based apple flavored RTS beverage samples and a commercial RTS apple beverage sample using a mixed (trained and un trained, 12 panelists) panel on a 9 point hedonic scale (1=like extremely to 9 =dislike extremely) and ranking test

	Hedonic (9-point scale) scores					
Samples#	Colour	Sourness	Flavor	Sweetness	Overall acceptability	Rank*
XYZ	2.5±0.99	2.4±0.90	2.8±0.93	2.5±0.79	2.8±0.83	2.5±0.66
PQR	2.0±0.85	2.1±0.71	2.4±0.66	2.3±0.88	2.5±0.79	1.7±0.62
UVW	2.0±0.95	2.0±0.66	1.5±0.79	1.6±0.77	2.0±0.99	1.5±0.67

#XYZ: Sweet sorghum RTS beverage with 0.3% acidity, PQR: Sweet sorghum RTS with 0.4% acidity
UVW: Commercial sample of RTS apple beverage (Control). *Ranking scale: 1=best, 2=good, 3=moderate, 4=bad, 5 = worst

grain based beverages are fermented beverages and are traditionally used in Africa (Taylor *et al*., 2006; Taylor and Emmambux, 2008). However, there is no literature evidence reporting the use of sweet sorghum juice or sweet sorghum syrup for the development of non-alcoholic beverages, especially squash and RTS beverages. Most of the research involving sweet sorghum juice is focused on production of ethanol and attaining higher ethanol yield and faster fermentation rate for ethanol production (Liu and Shen, 2008). Hence given this background the work presented in this paper brings forth the potential of using sweet sorghum juice in the food industry for the development of quality syrup as well as other value added non alcoholic beverages. However, as the present work is based on one single variety of sweet sorghum, further physico chemical analysis of different sweet sorghum varieties need to be carried out. These physico chemical properties need to be further correlated with the sensory properties of the end products (syrup, squash or RTS beverage) in order to identify varieties of sweet sorghum best suited for use in food applications.

Conclusions

The present work demonstrates a new method of clarification of sweet-sorghum juice in order to obtain food grade syrup with acceptable organoleptic properties. Using this syrup, shelf stable, squash and RTS beverages were developed and their formulations optimised. From this study it can be concluded that sweet sorghum juice and syrup have a potential to be used in development of commercial beverages. The beverages can be further fortified or blended with other fruit juices, fruit concentrates, protein concentrates etc. and marketed as health beverages in the neutraceutical segment. In addition the syrup itself has a good nutritional profile and potential to be sold directly as health syrup. Future work shall focus on exploring packaging options for the developed products, market research, in order to gain consumer insight, to understand the marketability of the developed products, identifying suitable varieties of sweet sorghum for food grade syrup production and exploring the use of sweet sorghum syrup as a sugar alternative in different food product categories.

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