Production of sweet sorghum liquid sugar in the first ratoon harvest

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Abstract. Sorghum is a multipurpose food crop commodity. One of the benefits is by utilizing the stalks which contain sweet juice which can be processed into liquid sugar. This processed product in the form of liquid sugar from the sweet sorghum plant has the potential to meet the needs of the healthy sugar industry in the future. This study aims to determine the production of sweet sorghum plant liquid sugar in the first ratoon harvest. The research was arranged in the form of a completely randomized factorial design. The first factor consisted of two levels, namely Numbu Varieties and Super 1 Varieties. The second factor consisted of three levels, namely the storage time of sorghum stalks for 0, 3, and 6 days. The results showed that the best treatment was found in the treatment of sorghum stalks of the Numbu variety which were stored for 3 days with 35.4% yield of juice, liquid sugar with 44.01% reduced sugar content, 77.25% liquid sugar Brix content, and 3 flavor organoleptic results, taste 3.81 (like), aroma 3.50 (like), and color 3.72 (like).

1. Introduction
Sorghum is a multipurpose food crop commodity. One of the benefits is by utilizing the stalks which contain sweet juice which can be processed into liquid sugar. This processed product in the form of liquid sugar from the sweet sorghum plant has the potential to meet the needs of the healthy sugar industry in the future. The juice is obtained from the stalks of the sorghum plant, by squeezing it or crushing the stalks. Sorghum stalks are rich in sugars that are easy to consume [1,2]. The by-product of sorghum stalks is around 15 tons/ha, which so far is still considered waste and has not been fully utilized [3].

A study conducted by Noerhartati and Rahayuningsih [3] the content of sugar Brix from sorghum stalk juice of KD4 white stalk varieties with Brix degrees of 14.7%. In addition, the Brix levels of sorghum stalk juice of the NTJ 2 variety were 16.7% and even 21.1% for the ICSR variety [4], the Brix levels of sorghum stalk juice ranged from 15% - 21% [5]. The potential of the juice with high sugar Brix degrees can be turned into liquid sugar, but this opportunity is not sustainable because it is still constrained by the availability of raw materials. Therefore, it is necessary to accelerate the dissemination regarding the benefits of sorghum as a functional food and healthy food as well as economically beneficial. Sorghum plants can grow on marginal lands, have wide adaptability, require less water and lower agricultural production inputs, and are suitable for planting on dry and hot land [6,7]. In addition, according to Pabendon [8], another advantage of the sorghum crop can be harvested again after the main crop is harvested, by regrowing ratoon after harvesting the main crop, although each harvest has decreased yields.

Based on the above, it is necessary to study the potential of liquid sugar from sweet sorghum stalk juice in the production of the first ratoon harvest, by examining the yield of juice from sorghum stalk
extract, the resulting Brix sugar content, and reducing sugar levels from sorghum liquid sugar. This will be in line with support for the national sugar self-sufficiency program, by providing an alternative to the consumption of sugar derived from the stalks of the sorghum plant. The research objective was to determine the production of sweet sorghum liquid sugar at the first ratoon harvest.

2. Materials and Methode
This research was conducted at IP2TP Gorontalo Assessment Institute for Agricultural Technology (AIAT) from January to July 2020.

2.1. Materials
The material used in this study was sorghum stalks obtained from the IP2TP area of Gorontalo Assessment Institute for Agricultural Technology (AIAT). The sorghum stalks used were Numbu varieties and Super 1 varieties with an average height of ± 200 cm. In addition, the main equipment used in the production process of sweet sorghum stalks liquid sugar includes crusher, analytical scales Brix meter, pH meter, and bottle siller.

2.2. Research Design
The research design used a completely randomized design (CRD) with two factors. The first factor is Sweet Sorghum Variety with 2 experimental levels, namely Numbu Variety (NB) and Super 1 Variety (SP) and the second factor is the storage time for sorghum stalks 0 days (0H), 3 days (3H), and 6 days (6H). The research was conducted with 2 replications. To see the effect of treatment, analysis of variance was carried out. If there is an influence between treatments, then it is followed by Duncan's continued test at the level (α <0.05).

2.3. Sorghum Liquid Sugar Manufacturing Process
Making liquid sugar begins with sorting the sorghum stalks at harvest. Sweet sorghum stalks are harvested using a sickle, harvesting is done at the age of 105 days after planting. Sorghum stalks are cut into pieces ± 2 m in length uniformly. Furthermore, the sorghum stalks are stored for 0 days, 3 days, and 6 days. Before extracting, the sorghum stalks are cut into 45 cm pieces for easy grinding. The sorghum stalks are milled to get the juice, and then the juice is cooked at a temperature of ± 90 ºC for ± 50 minutes until liquid sugar is obtained, which is marked with a brownish cream color and a little thick and the aroma of caramelized sugar.

2.4. Observation Parameters
The parameters measured included yield, stover, Brix degree of sap, Brix degree of liquid sugar, and reducing sugar. Observation of these parameters is carried out using the following methods: Measurement of Brix degrees using a refractometer according to AOAC [9], determination of reducing sugar using the Luff Schoorl method according to SNI [10]. Organoleptic test (color, aroma, and taste) using the Hedonic Scale method (level of preference) according to Setyaningsih [11], involving 25 untrained panelists. The hedonic numbers used include: (1) dislike extremely, (2) dislike, (3) slightly like, (4) like, (5) like extremely. The liquid sugar samples were prepared in small bottles to be assessed by the panelists for color, aroma, and taste parameters. Organoleptic test data analysis used the Friedman test using the SPSS version 23 statistical program.

2.5. Rendement
Yield Calculation The yield of sweet sorghum is calculated based on the ratio between the volume of fresh juice (sap) produced and the weight of the sweet sorghum stalks used.

\[
\text{Rendement (\%) = \frac{\text{Volume Fresh Juice}}{\text{Sweet Sorghum Stalk Weight}}} \times 100\%
\]
2.6. Brix

The steps taken in the Brix measurement are to take ± 5 drops of the juice from each part and put it into the refractometer lens then press the start button and the results will appear on the screen. The brix value obtained is expressed in% (v/w) units.

3. Results and Discussion

3.1. Physicochemical Analysis of Sweet Sorghum Stalk Juice

Physical analysis of the yield of sweet sorghum stalk juice in each treatment was the largest on the SP6H treatment of 44.4% and the lowest was in the NB0H treatment of 34%. The yield of juice from SP6H treatment was higher than that research with sorghum variety of white stalk (KD4) of 40.7% [3], while yields of sweet sorghum juice are around 50% of the initial plant weight (stalk) [12]. For the greatest bagasse value found in NB0H treatment of 66% and for the lowest found in SP6H treatment of 55.6%. The results of the analysis of variance show that the yield of juice is significant at a value of 0.017 <0.05, and a significant bagasse of 0.016 <0.05, this can be stated that the yield of juice and bagasse is significantly different (Table 1). Planting time can have a major effect on the productivity of sweet sorghum [13].

The results of the analysis of variance in the percentage of sweet sorghum juice Brix were significant at 0.015 <0.05. It can be stated that the treatment is significantly different. The results of the study for the percentage levels of Brix juice during storage increased. The highest percentage of sweet sorghum juice Brix was found in the SP3H treatment of 15%, while the lowest percentage of Brix juice was found in the SP0H treatment, namely 13%. The high percentage of juice Brix at 3 days storage in SP3H treatment was due to the reduced water content in sorghum stalks. This is related to harvesting conditions in the rainy season or in the dry season. Sorghum harvest time can affect the percentage of Brix and volume levels of juice [14,15,16], harvesting in the morning is appropriate to get the best volume and percentage of juice Brix, besides that along with the length of storage there will be an increase in the juice sugar Brix until the third day [15]. Meanwhile, according to Putrianti [4] that the longer the sorghum stalks are stored, the percentage of Brix juice will decrease, although on the fourth day it is still around ± 14% for rootstock sorghum. Sweet sorghum typically peaks its sugar yield when it approaches physiological maturity, and then begins to decline as plants begin to reallocate sugars for new vegetative growth [5]. Some research results also show that some nitrogen pressure at maturity can increase the accumulation of sugar in sorghum stalks, although this statement needs further evaluation, besides that the juice Brix is also influenced by the harvest stage [17].

| Table 1. Analysis of yield, bagasse and Brix sugar content juice in the stalks sweet sorghum* |
|----------------------------------------------------------|
| Treatment | Yield of Juice (%) | Bagasse (%) | Brix Sugar Content of Juice (%) |
|-----------|--------------------|-------------|--------------------------------|
| NB0H      | 34,00a             | 59,07d      | 14,50ab                        |
| NB3H      | 35,40ab            | 58,30cd     | 14,50cd                        |
| NB6H      | 36,00bc            | 57,70c      | 14,50de                        |
| SP0H      | 40,00d             | 53,70bc     | 13,00a                         |
| SP3H      | 42,00de            | 51,70b      | 15,00e                         |
| SP6H      | 44,40f             | 49,30a      | 14,00bc                        |

*Notes : Numbers followers by the same letters in same column are not significantly different by Duncan 5%, with treatment NB = numbu varieties, SP = super 1 varieties, 0H = 0 days, 3H = 3 days, 6H = 6 days
3.2. Chemical Analysis of Sweet Sorghum Stalk Liquid Sugar

The results of the chemical analysis of liquid sorghum stalk sugar include observations of reducing sugar levels and liquid sugar Brix levels which are assumed to be sucrose. In the research of Souza [5] regarding the reducing sugars of sorghum juice being considered are glucose and fructose. Reducing sugars are monosaccharides that can be oxidized in the presence of an oxidizer in an alkaline solution because they have free carbonyl and ketone groups. The highest value of reducing sugar levels was found in the NB3H and SP3H treatments, respectively 44.01% and 46.85%, and the lowest were in the SP0H treatment of 28.65%. The same thing for the highest liquid sugar Brix content was found in the NB3H and SP3H treatments of 77.25% and 77.75%, respectively, while the lowest was in the SP0H treatment which was 58.25%. This has been preceded by high levels of sorghum juice sugar, according to Yu [18], sweet sorghum juice mainly consists of sucrose, glucose, and fructose, and the amount of sucrose is higher than glucose or fructose. Sorghum sugar is easily extracted in the form of juice with a concentration of 12.18%, where sucrose accounts for 53.85%, glucose 9.33%, and fructose 6.21% [13].

The results of the analysis of variance showed that the reduced sugar content was significant 0.002 <0.05 and the liquid sugar Brix was significant 0.001 <0.05, this means that the reduced sugar content and the liquid sugar Brix value were significantly different. It can be assumed that the raw material factor, namely sorghum stalks, affects the Brix value of liquid sugar.

Table 2. Analysis of reducing sugar levels and Brix liquid sugar of sweet sorghum stalks

| Treatment | Reducing Sugar (%) | Brix Liquid Sugar(%) |
|-----------|--------------------|---------------------|
| NB0H      | 31.90bc            | 63.50c              |
| NB3H      | 44.01e             | 77.25e              |
| NB6H      | 34.25d             | 65.25d              |
| SP0H      | 28.65a             | 58.25a              |
| SP3H      | 46.85f             | 77.75e              |
| SP6H      | 31.43b             | 61.75b              |

*Notes: Numbers followed by the same letters in same column are not significantly different by Duncan 5%, with treatment NB = Numbu varieties, SP = super 1 varieties, 0H = 0 days, 3H = 3 days, 6H = 6 days*

3.3. Organoleptic Test of Sweet Sorghum Stalks Liquid Sugar

Organoleptic test of sorghum stalk liquid sugar includes color, aroma, and taste. The result of the organoleptic color test showed that the highest level of panelist acceptance was found in the NB3H treatment of 3.72 (like) and the lowest was the panelist acceptance of the color of sweet sorghum liquid sugar by assessing the rather like the NB0H, SP0H, and SP3H treatments (Figure 1). Besides that, the panelists prefer the liquid sugar of the Numbu variety because it is dark brown like honey (Figure 2). Color is an important component in determining food quality, where color is a determinant of consumer attractiveness. Specifically for the aroma of sweet sorghum stalk of liquid sugar, the panelists prefer the NB3H treatment of 3.50 (like), while for all treatments all panelists preferred it slightly like. The organoleptic taste of the sweet sorghum stalk liquid sugar showed that the highest level of panelist acceptance was found in the NB3H treatment of 3.81 (like), while for other treatments the panelists it slightly like. Based on the Friedman test, the Chi-Square value, the effect of the interaction between varieties and the length of storage of the stalks on the organoleptic quality of sweet sorghum, obtained significant results only on taste, while color and aroma were not significant (Table 3). The storage of sweet sorghum stalks and varieties greatly influenced the level of the organoleptic taste of each panelist. It is assumed that the longer it is stored, the sugar conversion will
occur. According to Zao [19], storage of sweet sorghum stalks can increase fructose and glucose due to the enzymatic conversion of sucrose to reducing sugar.

![Figure 1](image1.jpg)

**Figure 1.** The results of the organoleptic test for liquid sugar from sweet sorghum stalks

![Figure 2](image2.jpg)

**(a) Super 1 liquid sugar  (b) Numbu liquid sugar**

**Figure 2.** Super 1 and Numbu varieties of sweet sorghum liquid sugar

| Organoleptic  | Chi-Square and Asyn. Sig.   | Test Result Value |
|---------------|-----------------------------|-------------------|
| Color         | N                           | 25                |
|               | *Chi-Square*                | 10,111            |
|               | *Df*                        | 5                 |
|               | *Asymp. Sig.*               | 0.072             |
| Aroma         | N                           | 25                |
|               | *Chi-Square*                | 6,901             |
|               | *Df*                        | 5                 |
|               | *Asymp. Sig.*               | 0.228             |
| Taste         | N                           | 25                |
4. Conclusion

Sweet sorghum stalk juice to be used as liquid sugar in the first ratoon harvest is very potential by giving the treatment of storing sweet sorghum stalks of the two varieties, namely the Numbu variety and the Super 1 variety. The results showed that the best treatment was found in the treatment of sorghum stalks of the Numbu variety which were stored for 3 days with 35.4% yield of juice, liquid sugar with 44.01% reduced sugar content, 77.25% liquid sugar Brix content. The same was for the panelists assessment of the organoleptic color, aroma, and taste of the average panelists rated the liking for sweet sorghum liquid sugar.

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