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ORIGINAL RESEARCH ARTICLE

EVALUATION OF DIFFERENT SWEET SORGHUM CULTIVARS FOR SUGAR CHARACTERIZATION AND THEORETICAL BIOETHANOL YIELD IN A SEMI-ARID SUB-SAHARAN ENVIRONMENT

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ABSTRACT

Growing demand for sustainable energy has increased attention toward non-food feedstocks for bioethanol production that places pressure on food resources. Sweet sorghum (Sorghum bicolor (L.) Moench) is increasingly considered as an alternative bioethanol feedstock due to its favourable agronomic and sugar-yield characteristics, such as its short growing cycle, high sugar content, drought resistance, and adaptability to marginal lands, as well as its ability to drastically reduce the 'food versus fuel' crisis. Despite global advances and although Nigeria ranks among the world's leading sorghum-producing countries, the use of sweet sorghum for bioenergy applications remains limited. This study evaluated thirteen sweet sorghum cultivars grown under rainfed conditions in Kano, Nigeria, a semi-arid environment in sub-Saharan Africa during the rainy season between June and October 2023. A randomized block design (RBD) consisting of three replications were used. Sugar characterization parameters such as °Brix content, sugar content, and fermentable sugar concentration were determined. Theoretical bioethanol yield was calculated using a glucose-to-ethanol conversion factor. Results revealed significant varietal differences in the sugar characterization parameters as well as theoretical bioethanol yield. Among the cultivars, SAMSORG 50 SW and Sugar Drip recorded the highest theoretical bioethanol yield values of 98.1 g/L and 95.0 g/L, respectively, indicating their strong potential for bioethanol production in Nigeria's dryland zones. The findings demonstrated the prospects of utilizing sweet sorghum for bioethanol production in semi-arid Nigerian environment and provided a basis for selecting cultivars for subsequent field-scale evaluation.

1.0 Introduction

The global community is grappling with a cascade of interrelated challenges that threaten both energy security and environmental sustainability. Climate change, primarily fueled by excessive fossil fuel consumption (Naudé, 2025), has intensified the occurrence and severity of extremely harsh weather events such as droughts, deforestation, and hurricanes with far-reaching policy consequences at macroeconomic, sectoral, and individual levels (Nobanee and Nghiem, 2024). Projections indicated that human population could increase to over 9.5 billion by 2050 and 10.4 billion by the end of the 21st century (Hebishima and Inage, 2025). These projections were sure to drive up energy demand, further accelerating fossil fuel exploitation and depletion, and thereby exacerbating sustainability concerns (Awan *et al*., 2025). Another dimension to this challenge lies in the continued industrial expansions required to satisfy the needs of a growing population which also contributes substantially to greenhouse gas emissions and other forms of environmental pressure (Babatunde and Afolabi, 2024). In light of these concerns, the urgency to transition from fossil fuels to cleaner energy sources has fueled a global surge in demand for renewable energy within the international markets (Hu *et al*., 2024).

The scientific and industrial communities globally accept biofuels as environmentally sustainable energy alternatives to fossil fuels. Among available biofuels, bioethanol has achieved particularly broad use and acceptance (Madi *et al*., 2024). Its suitability as a transportation fuel is associated with properties such as a high octane rating, substantial oxygen content, compatibility with petrol blending, biodegradability, and comparatively low toxicity (Marwaha and Subramanian, 2024). Universally, bioethanol is regarded as the most predominantly important biofuel, accounting for over 78% of all biofuel usage. (Fu *et al*., 2024). Bioethanol can be produced by microbial fermentation of carbohydrates obtained from three broad feedstock groups: sugar-rich materials, starch-containing crops, and lignocellulosic biomass (Jain and Kumar, 2024). Examples include sugarcane, sugar beet, molasses, and sweet sorghum juice; maize, wheat, barley and rye; as well as agricultural wastes such as rice straw, wheat straw and corn cobs. During anaerobic fermentation, microorganisms metabolize fermentable sugars and convert them into bioethanol (Chen *et al*., 2024). A key limitation of many conventional bioethanol feedstocks is their direct competition with food and feed uses, which intensifies the food-versus-fuel debate (Pender *et al*., 2024). The concern arises when edible crops or feed resources are redirected toward fuel production, creating additional pressure on food availability and affordability, particularly in regions already affected by food insecurity (Purnama *et al*., 2025). Furthermore, supplying food crops for fuel production is a stark contradiction of the Sustainable Development Goals (SDGs) # 2 and #7 (Okoro *et al*., 2024). Among all the potential biofuel feedstocks available, sweet sorghum is regarded as a strong bioethanol feedstock because it combines favourable agronomic traits with high fermentable-sugar potential (Feng *et al*., 2024). Relevant advantages include tolerance to drought, heat and salinity, high biomass productivity, high stalk sugar content, a shorter production cycle than sugarcane, and the ability to be grown on marginal land (Mathias *et al*., 2023). These characteristics strengthen the case for sweet sorghum to be used as a comparatively sustainable bioenergy crop, particularly where reducing competition with conventional food crops is a priority (Chauhan *et al*., 2025).

Historically, utilizing sweet sorghum as a an alternative bioethanol feedstock was first documented by Polack (1980). Since then, sweet sorghum cultivars and genotypes had been evaluated for bioethanol production across a wide range of agro-climatic regions, including tropical, subtropical, temperate, and semi-arid environments (Appiah-Nkansah *et al*., 2019). Additionally, a lot of research on sweet sorghum had been carried out to confirm it as a promising multipurpose crop due to its unique agronomic characteristics. A common objective across many of those sweet sorghum research works had been to assess the suitability of different cultivars for bioethanol production based on agronomic traits and fermentation performance. The studies employed a wide range of experimental designs and analytical techniques. Key parameters measured included juice volume, °Brix values, total soluble solids (TSS), reducing sugar concentration, nutrient content, and fiber composition of bagasse.

Despite the vast literature information about sweet sorghum, the crop remained underutilized and understudied in Nigeria with respect to its bioethanol potential. Notably, it was not until 2020 that the Institute of Agricultural Research, Zaria, Nigeria officially released two sweet sorghum cultivars-SAMSORG 50 SW and SAMSORG 51 SW-developed specifically for sugar juice extraction and potential bioethanol production. These two cultivars, as well as many local and international sweet sorghum cultivars had not been academically assessed for their suitability as bioethanol feedstocks within the Nigerian context. This gap highlighted the need for focused research on cultivar performance under local agro-climatic conditions, particularly in relation to sugar yield, fermentability, and overall bioethanol productivity. Addressing this gap will bridge the disparity between global sweet sorghum advancements and the limited national progress toward its industrial application for bioethanol production in Nigeria. Therefore, the objective of the present study was to assess and compare sugar characterization parameters and theoretical bioethanol yield of thirteen sweet sorghum cultivars in Kano, a semi-arid sub-Saharan environment in Nigeria.

2. Materials and Method

2.1 Site Description and Weather Conditions

The experiment was carried out between June and October of 2023 under rainfed cultivation. The study was conducted at the Centre for Dryland Agriculture (CDA) Farm, Bayero University, Kano, Nigeria. The CDA Farm is located at latitude 11.9827 °N and longitude 8.4186 °E, and 458 m above sea level (Bashir *et al*., 2023).

The weather conditions at the CDA were marked by high temperatures exceeding 40 °C, relatively low humidity dropping well below 50%, and zero rainfall, particularly in the months of March-May. Notably, the period between June and September experienced elevated rainfall and humidity levels. In 2023 and 2024, total annual rainfall reached 833 mm and 1,050 mm, respectively, with relative humidity exceeding 70% during this peak period.

2.2 Plant Materials

Two of the sweet sorghum cultivars-SAMSORG 50 SW and SAMSORG 51 SW-were provided by the Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria. Other sweet sorghum cultivars-Sumac, Dale, Kansas Orange, Texas Seeded Ribbon, Mennonite, Sugar Drip, Black Amber, Iowa Sweet, M81E, Honey Drip, and Topper 76-6-were purchased from two international seed companies-Thresh Seed Company LLC, Iowa, USA and Seedville Company, Ohio, USA.

2.3 Experimental Design

The experimental design for planting the 13 sweet sorghum cultivars was carried out using the method adopted by Alade *et al.* (2022). The field experiment was arranged out using a randomized block design (RBD) having three replications. Thirteen sweet sorghum cultivars were evaluated, resulting in a total of 39 experimental plots (13 plots per block). Each plot comprised of four rows, each 5 meters long, with an inter-row spacing of 75 cm. The area of every plot was 11.25 m^2. All cultivars were randomly assigned within each block to minimize environmental bias, and identical agronomic practices were maintained across all plots to ensure uniformity of treatment conditions.

Table 1: RBD layout for 13 Sweet Sorghum Cultivars

Block	Replication I	Replication II	Replication III
1	C1	C11	C10
2	C5	C7	C2
3	C9	C3	C11
4	C4	C2	C5
5	C10	C13	C6
6	C6	C8	C3
7	C2	C4	C1
8	C8	C10	C7
9	C13	C9	C12
10	C7	C12	C4
11	C11	C5	C13
12	C3	C6	C9
13	C12	C1	C8

C1: SAMSORG 50 SW, C2: SAMSORG 51 SW, C3: Sumac, C4: Dale C5: Kansas Orange, C6: Texas Seeded Orange, C7: Mennonite, C8: Sugar Drip, C9: Black Amber, C10: Iowa Sweet Sorghum, C11: M81E, C12: Honey Drip, C13: Topper 76-6

2.4 Crop Management

The agronomic practices for growing sweet sorghum were done using the method carried out by Ajeigbe *et al.* (2020). All seeds were chemically dressed for plant protection against soil-borne, disease-causing pathogens. Land clearing was carried out using manual labor. Land was prepared for planting by ploughing with a disc to loosen the soil, followed by a single pass disc harrowing to create a suitable seedbed. Planting rows were made manually. After ploughing and harrowing, planting was carried out at the beginning of the rainy season. The sweet sorghum seeds were planted at a depth of 30-40 mm with an inter-plant spacing of 25 cm. At planting time, a blanket of 50 kg per hectare of NPK (15:15:15) was applied to each plot, followed by 50 kg per hectare of N in the form of Urea just before flowering (at about 30-40 cm in height). Both weeding and harvesting were carried out manually. Harvesting of the sweet sorghum crop was carried out using the method adopted by Yücel *et al.* (2022) where the crops were harvested at the beginning of the dough stage of the grains. From each plot, two rows were randomly selected from the middle, and a sample of 10 plants per cultivar was randomly taken from these rows for further analysis and computations. Side rows and the top and bottom 0.5 meters of each plot were excluded to avoid border effects. For each harvest exercise, the leaves, leaf sheaths, and panicles of the plants were removed, grain heads cut, and bagged, while stalks were bundled and transported to a work area where the sugar juice extraction from the stalks was done.

2.5 Data Collection

Data collection involved extraction and treatment of the extracted sweet sorghum juice. For all the thirteen sweet sorghum cultivars, juice was extracted by pressing in a 4-roller press mill (Bakers Choice Industries). The muddy juice was then passed through a 0.25 mm sieve for filtration to remove any form of dirt and plant residue. The main treatment process that was done to preserve the various sugar juice samples was thermal treatment. For the thermal treatment, the filtrate was sterilized by heating up to 100 °C for a period of 30 minutes to destroy any enzymes and microorganisms. This was important to reduce the rate of decaying of the sugar juice samples. After cooling the filtered and treated sugar juice sample to room temperature, the °Brix content of the sweet sorghum stalk juice for each cultivar was determined using a handheld digital refractometer (NOHAWK Brix Meter).

The °Brix value is a unit of measurement that indicates the percentage of soluble solids-in a liquid solution, commonly used to estimate sugar content in a sample, and is typically measured using a refractometer (Oktem and Oktem, 2024). The °Brix value was determined using a hand-held digital refractometer (NOHAWK Model). Prior to use, the digital refractometer was calibrated with distilled water to ensure accuracy by adding 1-2 drops of the extracted sweet sorghum juice sample on the refractometer prism and obtaining the °Brix value directly from the refractometer reading. All measurements were taken at room temperature to maintain consistency.

2.6 Determination of Sugar Characterization Parameters of selected Sweet Sorghum Cultivars

The various sugar characterization parameters of the sweet sorghum cultivars were determined during the hard dough stage and based on the approach of Endalamaw *et al.* (2026), followed by two sequential approaches below. First, and in accordance with the method described by Nazli and Polat (2024), the °Brix values were converted to sugar content. Specifically, sugar content was calculated at 75% of the measured °Brix value. Therefore, Equation 1 was used for sugar content determination.

$$Sugar\ Content\ (SC)\ (\%) = \ °Brix\ x\ 0.75 \qquad 1$$

Sugar content refers to the combined amount of various sugars (monosaccharides, disaccharides, and polyols) present in a sample product (Thuy *et al*., 2024). The sugar content (SC) was assumed to be equal to 75% of the °Brix content and therefore calculated by multiplying it with the °Brix content as in Equation 1.

Second, and based on the conversion relationship described by Habtegiorgis *et al.* (2025), sugar content was converted into sugar concentration. Specifically, sugar concentration was expressed in g/L using the relationship 1 °Brix = 10 g/L. Therefore, Equation 2 was used for sugar concentration determination:

$$Fermentable\ Sugar\ Concentration\ (FSC)\ (g/L) = \ SC\ (\%) x\ 10 g/L \qquad 2$$

2.7 Determination of theoretical bioethanol yield of selected sweet sorghum cultivars

The theoretical bioethanol yield is the ratio of the bioethanol produced (g) to the total sugars consumed (g) after fermentation (Zabed *et al*., 2024). The overall stoichiometry of the ethanolic fermentation of hexose sugars to bioethanol and carbon dioxide, which provided the fundamental basis for the entire fermentation process is given by Equation 3:

$$C_6H_{12}O_6 \xrightarrow{yeast} 2C_2H_5OH + 2CO_2 \qquad 3$$

where $C_6H_{12}O_6$ is glucose, C_2H_5OH is bioethanol, and CO_2 is carbon dioxide (Jameel *et al*., 2024). Based on stoichiometric conversion of glucose to bioethanol, the theoretical bioethanol yield was calculated according to Cabaroğlu *et al.* (2026), using a conversion factor of 0.511 g bioethanol per gram of fermentable sugar. Accordingly, the theoretical bioethanol yield was determined using Equation 4:

$$Theoretical\ bioethanol\ yield\ (g/L) = FSC\ (g/L)\ x\ 0.511 \qquad 4$$

2.8 Statistical Analysis

For statistical analysis, the data collected for sugar parameters were subjected to analysis of variance (ANOVA) suitable for a randomized block design (RBD) by having three replications and thirteen treatments (cultivars), as was adopted by Wang *et al.* (2023). Thereafter, the means of the various treatments were separated by using the Least Significant Difference (LSD) test at a 5% probability level, as similarly adopted by Gidey *et al.* (2024), and the cultivars were ranked based on their mean Brix values. The statistical model used for the randomized block design (RBD) was adopted from the standard RBD linear model described by Ozturk *et al.* (2024), as in Equation 5:

$$Y_{ij} = \mu + \tau_i + \beta_j + \varepsilon^{ij} \quad (5)$$

where Y_{ij} is the observed °Brix value of the *i-th cultivar* in the *j-th replication*, μ is the overall mean (grand mean of all observations), τ_i is the effect of the *i-th cultivar* (treatment effect), β_j is effect of the *j-th* replication (block effect), and ε^{ij} is the random error associated with each observation.

3. Results and Discussion

3.1 °Brix Content of Sweet Sorghum Cultivars

Based on the raw experimental data for determination of various sugar characterization parameters, the °Brix values of the 13 sweet sorghum cultivars across the three replications are presented in Table 2. The results showed °Brix values varied among the cultivars and across replications with SAMSORG 50 SW (C1) consistently recording the highest °Brix values across the three replications, with an average 25.6%, followed closely by Sugar Drip (C8), Dale (C4), and Mennonite with 24.8%, 23.8%, and 23.4% respectively. In contrast, Black Amber (C9) recorded the lowest °Brix value with an average 8.4%, followed by Kansas Orange (C5), Texas Seeded Orange (C6), and Honey Drip, with averages of 10.2%, 15.0%, and 17.4%, respectively. Most other cultivars showed typical values varying by only 0.2% to 0.6%. These values form the basis of all the calculation of other sugar characterization parameters, mainly sugar content (SC) and fermentable sugar concentration. The detailed raw materials recording the dough stage week, and °Brix value are presented in Table 2.

Table 2: Brix (%) Values of 13 Sweet Sorghum Cultivars for Three Replications

Cultivar Code	Name of Cultivar	Rep I	Rep II	Rep III	Average
C1	SAMSORG 50 SW	25.2	26.0	25.6	25.60
C2	SAMSORG 51 SW	22.2	22.5	23.1	22.60
C3	Sumac	21.5	22.0	21.9	21.80
C4	Dale	23.4	23.8	24.2	23.80
C5	Kansas Orange	9.8	10.2	10.6	10.20
C6	Texas Seeded Orange	14.6	15.0	15.4	15.00
C7	Mennonite	23.0	23.5	23.8	23.43
C8	Sugar Drip	24.4	24.6	25.4	24.80
C9	Black Amber	8.2	8.3	8.6	8.37
C10	Iowa Sweet Sorghum	20.4	20.9	21.1	20.80
C11	M81E	21.2	21.8	22.3	21.77
C12	Honey Drip	17.0	17.5	17.7	17.40
C13	Topper 76-6	20.9	21.2	21.4	21.17

3.2 Statistical Analysis

Analysis of variance (ANOVA) conducted on the °Brix results and as displayed on Table 3 is a one-way ANOVA (i.e. treatments = cultivars). The ANOVA revealed that both replication and cultivar effects were statistically significant ($p < 0.05$). The replication effect exhibited a mean square value of 1.68. With an error mean square of 0.03, a high F-value of 56 was calculated, which is significantly higher than the typical F-critical value of 2.18 at 5% level. This showed that that the differences between the three replications were not due to random chance, but rather they were real variations of environmental conditions such as soil conditions, moisture, climate etc.

Equally important, the cultivar effect showed an extremely large mean square value of 89.52 relative to the error mean square (0.03), resulting in a very high F-value (2984). This clearly demonstrated highly significant differences between the sweet sorghum cultivars evaluated. In other words, there were truly significant differences in terms of °Brix content between the 13 sweet sorghum cultivars. This indicated that some cultivars have a higher total soluble solid (TSS) value more than others. Consequently, the null hypothesis of no difference among cultivars was rejected, confirming that genetic variation among the cultivars had a pronounced influence on the measured trait. In conclusion, the data in Table 4.2 did not show random results. Rather, the data showed real differences across both blocks and cultivars of both environmental conditions and the TSS content of the 13 sweet sorghum cultivars.

Table 3: Analysis of Variance (ANOVA) for Brix (%)

Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	MS (=SS/df)	F
Replications (a)	3.364	2	1.682	56**
Treatment (Cultivars) (b)	1074.191	12	89.516	2984**
(a) x (b)/Error	0.703	24	0.029	
Total	1078.257	38	91.23	

3.3 Ranking of Sweet Sorghum Cultivars for °Brix Content (%)

The error mean square (MSE) used for the least significant difference (LSD) calculation was obtained from the Replication x Treatment variation as shown:

$$MSE = \frac{SS}{df} = \frac{0.703}{24} = 0.0293$$

Then, the LSD at 5% probability level was calculated as:

$$LSD_{0.05} = 2.064\ x\ \sqrt{\frac{2\ x\ (0.0293)}{3}} = 0.29$$

Where 2.064 is the t-value at 5% probability level with 24 error degrees of freedom, 0.0293 is the MSE, 3 is the number of replications, 0.29 is the LSD value. Therefore, any two cultivars are significantly different when their mean °Brix values differ by more than 0.29. Following this, the results showed that Treatment 1 recorded the highest °Brix value of 25.60 °Brix and was significantly different from the other treatments. This was followed by Treatment 8, Treatment 4, and Treatment 7, with mean °Brix values of 24.80, 23.80, and 23.43 °Brix, respectively. Treatments 3 and 11 were statistically similar, as their mean values were not separated by the LSD value. Treatment 9 recorded the lowest °Brix value of 8.37 °Brix. Therefore, in terms of °Brix value, Treatment 1 is the most promising cultivar for bioethanol production based.

Table 4: Ranking of °Brix (%) Values Using Least Square Difference (LSD)

Rank	Treatment	Cultivar	Mean Brix (%)	LSD Group
1	1	SAMSORG 50 SW	25.60	A
2	8	Sugar Drip	24.80	B
3	4	Dale	23.80	C
4	7	Mennonite	23.43	D
5	2	SAMSORG 51 SW	22.60	E
6	3	Sumac	21.80	F
7	11	M81E	21.77	F
8	13	Topper 76-6	21.17	G
9	10	Iowa Sweet Sorghum	20.80	H
10	12	Honey Drip	17.40	I
11	6	Texas Seeded Orange	15.00	J
12	5	Kansas Orange	10.20	K
13	9	Black Amber	8.37	L

3.4 Results of Sugar Characterization Parameters

The evaluated sugar characterization parameters of the sweet sorghum cultivars were °Brix content (BC), sugar content (SC), and fermentable sugar concentration (FSC) and are presented in Table 5. The results reveal substantial variation among the cultivars and the most suitable cultivar with the highest sugar characterization parameters. Among the cultivars evaluated, SAMSORG 50 SW recorded the highest values for °Brix content (25.6%), sugar content (19.2 g/L), and sugar concentration (192 g/L), indicating its superior performance. Sugar Drip and Dale also exhibited relatively high sugar characterization parameters of °Brix content (24.8%), sugar content (18.6 g/L), and sugar concentration (186 g/L) and °Brix content (23.8%), sugar content (17.9 g/L), and sugar concentration (179 g/L), respectively. These statistical facts make them promising alternatives, although their performances were slightly lower than that of SAMSORG 50 SW. In contrast, cultivars such as Black Amber, Kansas Orange, and Texas Seeded Ribbon recorded comparatively low °Brix content, sugar content, and fermentable sugar concentration. These low values indicated poor sugar accumulation and therefore less suitable for bioethanol production potential.

Table 5: Sugar Characterization Parameters of Juices of Sweet Sorghum Cultivars

S/No	Varieties	BC (%)	SC (%)	FSC (g/L)
1	SAMSORG 50 SW	25.6	19.2	192
2	Sugar Drip	24.8	18.6	186
3	Dale	23.8	17.9	179
4	Mennonite	23.4	17.6	176
5	SAMSORG 51 SW	22.6	17.0	170
6	Sumac	21.8	16.4	164
7	M81E	21.8	16.4	164
8	Top 76-6	21.2	15.9	159
9	Iowa Sweet Sorghum	20.8	15.6	156
10	Honey Drip	17.4	13.1	131
11	Texas Seeded Ribbon	15.0	11.3	113
12	Kansas Orange	10.2	7.7	77
13	Black Amber	8.4	6.3	63

BC: °Brix Content, SC: Sugar Content, FSC: Fermentable Sugar Concentration.

3.5 Comparison of SAMSORG 50 SW with other Sweet Sorghum Cultivars

The results revealed the highest fermentable sugar concentration to be from SAMSORG 50 SW with 192 g/L. Although directly comparable systematic cultivar evaluations are limited in Nigeria, internationally, values of X-Y have been reported for sweet sorghum cultivars grown under similar conditions (). The differences between these studies and the present investigation may be attributable to genotypes, environmental conditions, maturity stage and crop management. The scarcity of comparable Nigerian field data highlights the need for multi-location evaluation of promising cultivars such as SAMSORG 50 SW.

3.6 Results of Theoretical Bioethanol Yield Assessment

The theoretical bioethanol yield of the 13 sweet sorghum cultivars, as influenced by °Brix content (BC) and sugar content (SC), is presented in Table 6. The results revealed substantial variation among the cultivars, thereby providing a basis for identifying the most suitable cultivar for bioethanol production. Among the cultivars evaluated, SAMSORG 50 SW recorded the highest values for °Brix content (25.6%), sugar content (192.0 g/L), and theoretical bioethanol yield (98.1 g/L), indicating its superior performance. This suggests that SAMSORG 50 SW possesses the greatest potential for bioethanol production and can be considered the best-performing cultivar under the conditions of this study. Sugar Drip and Dale also exhibited relatively high °Brix, sugar content, and bioethanol yield values, making them promising alternatives, although their performances were slightly lower than that of SAMSORG 50 SW.

Table 6: Sugar Characterization Parameters of Juices of Sweet Sorghum Cultivars

S/No	Varieties	FSC (g/L)	Theoretical Bioethanol Yield (g/L
1	SAMSORG 50 SW	192	98.1
2	Sugar Drip	186	95.0
3	Dale	179	91.5
4	Mennonite	176	89.9
5	SAMSORG 51 SW	170	86.9
6	Sumac	164	83.8
7	M81E	164	83.8
8	Top 76-6	159	81.2
9	Iowa Sweet Sorghum	156	79.7
10	Honey Drip	131	66.9
11	Texas Seeded Ribbon	113	57.7
12	Kansas Orange	77	39.3
13	Black Amber	63	32.2

In contrast, cultivars such as Black Amber, Kansas Orange, and Texas Seeded Ribbon recorded comparatively low °Brix content, sugar content, and theoretical bioethanol yield. These low values indicate poor sugar accumulation and reduced bioethanol production potential, making them less suitable for bioethanol production. The results further demonstrated a strong positive relationship between °Brix value, sugar content, and theoretical bioethanol yield, confirming that cultivars with higher sugar concentrations tend to produce higher bioethanol yields. Based on these findings, SAMSORG 50 SW is identified as the most suitable cultivar for bioethanol production, followed by Sugar Drip and Dale, while cultivars with low sugar content are not recommended for this purpose.

4. Conclusion

The environmental, economic, and political consequences of utilization of fossil fuels have generated a growing search for alternative sources of energy. Biofuels have emerged as the most promising alternative, with bioethanol occupying a unique position among the various available biofuels. Almost 100 % of global bioethanol production comes from food sources (mainly corn and sugarcane) thereby creating a ‘food versus fuel’ crisis. Sweet sorghum stands out as a unique and promising alternative biofuel feedstock due to its various agronomic advantages such as its high sugar content, adaptability, and tolerance as well as its ability to mitigate the ‘food versus fuel’ crisis. In view of its biofuel potential, sweet sorghum research has been taking place in various parts of the world since 1980. Nigeria, being the second largest global producer of sorghum has not been part of this research effort. Therefore, thirteen (13) cultivars were selected and tested in a semi-arid sub-Saharan environment in Nigeria.

The cultivars with the highest potential as feedstocks for bioethanol production in the selected semi-arid sub-Saharan environment are SAMSORG 50 SW, Sugar Drip, Dale, Mennonite, and SAMSORG 51 SW varieties. However, among these selected cultivars, SAMSORG 50 SW was the highest sugar-yielding cultivar with °Brix content of 25.6%, sugar content of 19.2%, fermentable sugar concentration of 192 g/L, and theoretical bioethanol yield of 98.1 g/L. The results indicated that the cultivars with the lowest potential for bioethanol production were Black Amber, Kansas Orange, Texas Seeded Ribbon, Honey Drip, and Iowa Sweet Sorghum. The various parameters for Black Amber were a °Brix content of 8.4%, sugar content of 6.3%, fermentable sugar concentration of 63 g/L, and theoretical bioethanol yield of 32.2 g/L.

One important limitation of the present study is that although SAMSORG 50 SW exhibited the highest juice sugar concentration among the evaluated cultivars, this result should not be interpreted as demonstrating the highest bioethanol yield per unit land area. Overall, bioethanol productivity also depends on other sources of bioethanol on the sweet sorghum crop-such as sorghum grains and lignocellulosic biomass. Since this study was limited to the stalk juice alone, further field-scale evaluation is required before the cultivar can be recommended for industrial-scale bioethanol production.

In view of the prospects of this potential area of research work, future research on sweet sorghum should focus on evaluating other sweet sorghum cultivars since it had been estimated that there are as many as 4000 different sweet sorghum cultivars distributed across different geographical regions (Bakari *et al*., 2023). This will be important to determine the various cultivars that can be grown in different parts of Nigeria. Also, to obtain the complete bioethanol yield of any cultivar, further field-level evaluation of stalk biomass yield, juice extractability and juice yield per hectare is required to establish its full agronomic performance and suitability for industrial-scale bioethanol production. Additionally, research should focus on Techno-economic analyses (TEAs) and Life Cycle Analyses (LEAs) to determine the economic viability of producing sweet sorghum for commercial purposes and environmental impact assessment, respectively.

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