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GRAIN PROXIMATE COMPOSITIONS OF TWO SORGHUM (*Sorghum bicolor* (L.) Moench) VARIETIES AS AFFECTED BY COW DUNG AND INORGANIC NITROGEN FERTILIZER IN NORTHERN GUINEA SAVANNA ECOLOGICAL ZONE.

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Abstract

Proximate compositions of two sorghum varieties were determined in 2019 and 2020. The grain used were harvested and stored for seven years under ambient temperature conditions. The field experiments were conducted at the Research Farm of the Institute for Agricultural Research, Samaru and Kaduna State Agricultural Project, Maigana to study the growth, yield and malting physical quality of two sorghum varieties as affected by cow dung and inorganic nitrogen fertilizer during the 2013 and 2014 rainy seasons. The treatments consisted of four rates of nitrogen fertilizer (0, 30, 60 and 90 kg N ha⁻¹) and cow dung (0, 5, 10 and 15 tonnes ha⁻¹) and two sorghum varieties (SAMSORG-17, and SAMSORG 44). Treatments were laid out in a split plot design and replicated three times with nitrogen and cow dung rates assigned in the main plot while the varieties were assigned in the sub-plots. The result showed that N-application was found to significantly affect the grain proximate concentrations by every increase of 30 kg ha⁻¹ in the rate up to the highest rate of 90 kg N ha⁻¹ in both years and locations. The application of cow dung significantly affected the grain proximate composition by every 5 t ha⁻¹ up to 15 t ha⁻¹, however the increase was not consistent among the parameters. Sorghum variety SAMSORGH 17 consistently gave higher mean values of the proximate compositions except carbohydrate in both years and locations. Application of 60 kg N and 10 tons of cow dung on variety SAMSORGH-17 is adequate and can be recommended for better grain quality to farmers in the northern Guinea savanna ecological zone of Nigeria.

Keywords: variety, cow dung and nitrogen.

Introduction

The yield and quality of sorghum produced worldwide are affected by a wide array of biotic and abiotic constraints (Huang et al., 2022; Zhao et al., 2024). Some of these constraints are low soil fertility, adverse rainfall, insect pests and diseases as well as poor responsiveness to improved agronomic practices. These factors account for its low grain yield. Proximate compositions are determined when the cereal grain is steeped, milled and distilled. It has been shown that increase in the application of nitrogen rate increases the grain protein content which signifies nitrogen content of the grain (Labe, 2000). How this agronomic practice

affects the proximate compositions of Sorghum is not known even though the crop is produced in Nigeria by a majority of farmers using a combination of organic manure with inorganic fertilizers.

Adequate fertilization through a complementary application of organic and inorganic fertilizer is essential for the attainment of optimum yield and grain quality of sorghum. However, information on the rate and fate of N uptake and its effect on grain malting quality of sorghum from the combine application of organic and inorganic fertilizer in Nigeria are very scanty.

The varieties of Sorghum which are popular for malting and brewing are SAMSORG-17 and SAMSORG-44 otherwise known as short Kaura varieties. As has been stated earlier, the effect of soil nutritional management on the grain qualities of the two varieties has not been determined. Therefore, the nitrogen requirements of the two varieties from the combined organic and inorganic sources of nitrogen as they affect the crop growth, grain yield and grain malting qualities in the northern Guinea savannah of Nigeria are not known empirically and it deserve an empirical research studies.

It was in view of this that this research work was carried out to investigate the following aspects under these objectives:

- 1 to determine the effect of cow dung on proximate compositions of two sorghum varieties.
- 2 to determine the effect of inorganic nitrogen fertilizer on proximate compositions of two sorghum varieties.

Methodology

An experiment was carried out to determine the proximate composition using grain of two sorghum varieties harvested and stored under ambient temperature conditions for seven years (2019 and 2020) respectively. The grains were harvested from field experiments conducted for two consecutive rainy seasons (2013 and 2014) at the Institute for Agricultural Research (IAR) Farm, Samaru (11°11'N, 7°38'E and 686 m above sea level), and the Kaduna Agricultural Development Project (KADP) experimental site at Maigana (11°39'N, 8°02'E and 500 m above sea level), Soba Local Government Area, along the Zaria–Jos Road. Both locations lie within the northern Guinea savanna ecological zone of Nigeria.

The treatments comprised two sorghum varieties (SAMSORG-17 and SAMSORG-44), four nitrogen fertilizer rates (0, 30, 60 and 90 kg N ha⁻¹), and four cow dung rates (0, 5, 10 and 15 t ha⁻¹). The experiment was arranged in a split-plot design with three replications. Nitrogen and cow dung rates were assigned to the main plots, while the sorghum varieties were allocated to the subplots.

Each subplot measured 6.0 m × 4.5 m and consisted of six ridges, each 6 m long. The two central ridges formed the net plot, giving a harvest area of 4.0 m × 1.5 m. All the agronomic practices were dully observed.

The chemical compositions of sorghum grains, including moisture, total carbohydrates, and protein contents, was determined using standard proximate analysis procedures of the Association of Official Analytical Chemists. Total carbohydrate content was estimated by

difference after determining the other proximate components. Nitrogen content of the samples was measured using the Kjeldahl digestion–distillation method, and crude protein was calculated by multiplying total nitrogen by an appropriate conversion factor. Moisture content was determined as weight loss after oven drying of the samples at high temperature until constant weight.

Recent studies on sorghum and cereal grains similarly reported the use of AOAC standard procedures for proximate analysis, where protein is determined by the Kjeldahl method and expressed as nitrogen multiplied by a conversion factor, while carbohydrates are calculated by difference. Moisture content is commonly obtained by oven drying at about 105 °C until constant weight (Tian et al., 2024; Hein et al., 2025; Adebisi et al., 2024).

Results

Grain protein content (%).

The protein content of the grain of the two sorghum varieties as affected by nitrogen and cow dung rates at Samaru and Maigana during 2013, 2014 and combined rainy seasons is shown in Table 1. It was generally observed that each increase of 30 kg ha⁻¹ in nitrogen rate significantly led to a corresponding increase in protein content up to the highest rate of 90 kg N ha⁻¹. Each increase of 5 t ha⁻¹ cow dung had significantly increased grain protein content except in 2013, combined at Samaru and in the combined only at Maigana. Cow dung rate of 5, 10 and 15 t ha⁻¹ at both locations had resulted in statistically similar and higher values of percent grain protein content. The plots left without cow dung had the least values of grain protein content except at Samaru when it was comparable to 5 t ha⁻¹.

Table 1 Effects of Nitrogen and Cowdung rates on grain proximate compositions (%) (Protein & Carbohydrate) of two sorghum varieties at Samaru and Maigana during 2013, 2014 and combined rainy seasons.

Treatment	Grain proximate compositions (%)											
	Samaru						Maigana					
	Protein			Carbohydrate			Protein			Carbohydrate		
	2013	2014	combined	2013	2014	combined	2013	2014	combined	2013	2014	combined
Nitrogen (N) rate(kg ha⁻¹)												
0	7.28d	6.48d	6.88d	76.44a	73.96b	75.20b	8.93d	5.53d	7.23c	82.58b	81.89a	82.24ab
30	8.08c	7.44c	7.76c	76.46a	76.47a	76.47a	9.32c	6.46c	7.89c	85.11a	82.72a	83.92a
60	9.07b	8.30b	8.69b	76.16b	76.16a	76.16a	10.38b	8.73b	9.56b	84.64a	82.77a	83.71a
90	11.27a	12.92a	12.10a	74.08c	70.53c	72.31c	12.74a	11.78a	12.26a	81.66c	75.83b	78.75c
SE±	0.034	0.087	0.205	0.102	0.129	0.337	0.078	0.042	0.332	1.206	0.035	0.578
Cowdung (C) rate (t ha⁻¹)												
0	8.25b	7.50d	7.88c	76.34b	76.29a	76.32a	9.74d	7.28d	8.51ab	83.29	81.37a	82.33
5	8.51ab	7.76c	8.14c	76.65a	75.30b	75.98a	9.97c	7.85c	8.91ab	83.85	81.34a	82.60
10	9.14a	8.94b	9.04b	75.11c	73.64c	74.38b	10.41b	8.44b	9.43a	83.77	80.72b	82.25
15	9.80a	10.94a	10.37a	75.04c	71.89d	73.47b	11.25a	8.93a	10.09a	83.08	79.78c	81.43
SE±	0.034	0.087	0.205	0.103	0.129	0.337	0.078	0.042	0.332	1.206	0.035	0.578
Variety (V)												
SAMSORG-17	9.08	9.25a	9.17a	75.43	73.32b	74.38b	10.51a	8.24a	9.38a	83.49	80.71b	82.10
SAMSORG-44	8.77	8.32b	8.55b	76.14	75.24a	76.69a	10.17b	8.10b	9.14b	83.51	80.81a	82.16
SE±	0.024	0.061	0.145	0.073	0.091	0.238	0.055	0.029	0.101	0.006	0.016	0.409
Interaction												
N x V	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
N x C	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
C x V	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
N x C x V	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of probability, using Duncan Multiple Range Test (DMRT at $p \leq 0.05$)

ns: Not significant.

Variety SAMSORG-17 consistently had significantly higher grain protein content values than SAMSORG-44 variety at both locations, years and combined except at Samaru in 2013 when no significant difference in grain protein content between the two sorghum varieties was observed. There were no significant treatments factor interactions on grain protein content observed.

Grain carbohydrate content.

The grain carbohydrate content of the two sorghum varieties as affected by nitrogen and cow dung rates at Samaru and Maigana during 2013, 2014 and combined rainy seasons is shown in Table 1. Generally, the highest carbohydrate content of the two sorghum varieties was recorded at either 0 or 30 kg N ha⁻¹ except in 2014 and combined at Samaru and in 2013 at Maigana when significant difference was observed between the two rates. However, further increase to 60 kg N ha⁻¹ had no significant effect on carbohydrate content in both years locations and the combined. The plots that received the highest rate of 90 kg N ha⁻¹ had the least carbohydrate content.

The increase in grain carbohydrate content by every increase of 5 t ha⁻¹ cow dung was not consistent among the years and locations. The highest percent carbohydrate content was recorded on the controlled plots at Samaru except in 2013 when 5 t ha⁻¹ was significantly higher than the controlled plots. The plots that were fertilized with 90 kg N ha⁻¹ had the least grain carbohydrate content. Similarly, at Maigana the highest grain carbohydrate content was observed in the unfertilized plots and the least was in the plots fertilized at 90 kg N ha⁻¹ except in 2013 and combined where no significant difference was recorded between the rates.

Variety had no significant difference in both years and locations except in 2014 at both locations when SAMSORG-44 consistently proves superior to SAMSORG-17. There were no significant treatments factor interactions on grain carbohydrate content.

Grain moisture content (%).

The moisture content of the two sorghum varieties as affected by nitrogen rate and cow dung rates at Samaru and Maigana during 2013, 2014 and combined seasons is shown in Table 2. The highest grain moisture content was observed at 90 kg N ha⁻¹ in both years, locations and combined. The plots left without nitrogen fertilizer had the least values of grain moisture content except in 2013 at Samaru when 30 kg N ha⁻¹ had the least values of grain moisture content but comparable with 60 kg N ha⁻¹.

Cow dung application also significantly influenced grain moisture content in both years, locations and combined. All the plots with the highest rate of 15 t ha⁻¹ had the highest grain moisture content. The plots left without cow dung had the least grain moisture content except the combined at Samaru when no significant difference was observed between the rates. However, at Maigana the increase in grain moisture content was only up to 5 t ha⁻¹ beyond which no significant difference was observed.

SAMSORG-17 had more grain moisture content than SAMSORG-44 at Samaru in both years and combined while no significant difference was observed between them at Maigana in both years and combined. There were no significant treatments factor interactions on grain moisture content in both years and combined.

Grain Ash content (%).

The grain ash content of the two sorghum varieties as affected by nitrogen and cow dung rates at Samaru and Maigana during 2013, 2014 and combined seasons is shown in Table 2.

Table 2 Effects of Nitrogen and Cowdung rates on grain proximate compositions (%) (Moisture & Ash) of two sorghum varieties at Samaru and Maigana during 2013, 2014 and combined rainy seasons.

Treatment	Grain proximate compositions (%)											
	Samaru						Maigana					
	Moisture			Ash			Moisture			Ash		
	2013	2019	combined	2013	2014	combined	2013	2014	combined	2013	2014	combined
Nitrogen (N) rate(kg ha⁻¹)												
0	1.16b	0.94d	1.05c	1.43b	0.76d	1.10d	0.46b	0.69c	0.58bc	0.41d	0.56d	0.49c
30	1.03c	1.89c	1.46b	1.35b	1.58c	1.47c	0.77b	1.16b	0.97b	0.48c	0.62c	0.55c
60	1.09c	2.05b	1.57b	1.40b	1.72b	1.56b	0.84b	1.26b	1.05b	0.79b	1.11b	0.95b
90	1.27a	2.43a	1.85a	1.66a	1.76a	1.71a	0.97a	1.45a	1.21a	0.91a	1.24a	1.08a
SE±	0.003	0.006	0.065	0.002	0.002	0.008	0.026	0.039	0.039	0.004	0.002	0.022
Cowdung (C) rate (t ha⁻¹)												
0	1.09d	1.68d	1.39	1.41b	1.30d	1.36b	0.66b	0.99b	0.83b	0.59d	0.81d	0.70b
5	1.11c	1.82c	1.47	1.53a	1.49c	1.51a	0.77a	1.15a	0.96a	0.64c	0.89c	0.77a
10	1.14b	1.88b	1.51	1.50a	1.51b	1.51a	0.81a	1.22a	1.02a	0.67b	0.91b	0.79a
15	1.21a	1.93a	1.57	1.40b	1.52a	1.46b	0.80a	1.20a	1.00a	0.69a	0.92a	0.81a
SE±	0.003	0.006	0.065	0.002	0.002	0.008	0.026	0.039	0.039	0.004	0.002	0.022
Variety (V)												
SAMSORG-17	1.15a	1.88a	1.52a	1.48a	1.50a	1.49a	0.75	1.15	0.95	0.66a	0.90a	0.78a
SAMSORG-44	1.12b	1.78b	1.45b	1.44b	1.41b	1.43b	0.77	1.13	0.95	0.63b	0.86b	0.75b
SE±	0.002	0.004	0.01	0.001	0.001	0.002	0.018	0.027	0.027	0.003	0.001	0.010
Interaction												
N x V	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
N x C	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
C x V	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
N x C x V	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Means followed by the same letter(s) within a treatment group are not statistically different at 5% level of probability, using Duncan Multiple Range Test (DMRT at $p \leq 0.05$)

ns: Not significant.

The grain ash content of the two sorghum varieties as affected by nitrogen and cow dung rates at Samaru and Maigana during 2013, 2014 and combined seasons is shown in Table 2. Generally, every increase of 30 kg N ha⁻¹ had led to a significant increase in grain ash content in both years, locations and combined. The highest grain ash content was observed at 90 kg N ha⁻¹. The plots left without had least values of grain ash content except at Samaru in 2013 where it was statistically similar with 30 and 60 kg N ha⁻¹.

Each increase of 5 t ha⁻¹ cow dung had significant increase in grain ash content except in 2013 and combined at Samaru and combined at Maigana. The highest grain ash content value was recorded at 15 t ha⁻¹ but the year combined at both locations when the increase was significant only up to 10 t ha⁻¹ at Samaru while at Maigana the increase was only up to 5 t ha⁻¹ beyond which no significant increase was observed.

SAMSORG-17 consistently had significantly higher grain ash content than SAMSORG-44 variety at both locations years and combined. There were no significant factor interactions on grain ash content.

Grain fibre content (%).

The grain fibre content of the two sorghum varieties as affected by nitrogen and cow dung rates at Samaru and Maigana during 2013, 2014 and combined rainy seasons is shown in Table 3. In both years, locations and combined, the highest grain fibre content was observed at the controlled plots except Samaru in 2013 where it was statistically similar with 30 kg N ha⁻¹. The plots that were fertilized with 90 kg N ha⁻¹ of fertilizer had least values of grain fibre content except in 2014 and combined at Maigana where 60 kg N ha⁻¹ had the least.

Table 3. Effects of Nitrogen and Cowdung rates on grain proximate compositions (%) (Fibre & Lipids) of two sorghum varieties at Samaru and Maigana during 2013, 2014 and combined rainy seasons.

Treatment	Grain proximate compositions (%)											
	Samaru						Maigana					
	Fiber			Lipids			Fiber			Lipids		
	2013	2014	combined	2013	2014	combined	2013	2014	combined	2013	2014	combined
Nitrogen (N) rate(kg ha⁻¹)												
0	10.30a	16.16a	13.23a	3.39a	1.70d	2.55bc	7.19a	8.23a	7.71a	0.43d	3.10b	1.77a
30	10.17a	8.70b	9.44b	2.91b	3.92b	3.42b	3.48b	5.17c	4.33b	0.84c	3.87a	2.36a
60	9.58b	8.65b	9.12b	2.70b	3.12c	2.91b	2.01c	3.68d	2.85c	1.34b	1.45d	1.40ab
90	8.20c	5.06c	6.63c	3.52a	7.30a	5.41a	2.00c	7.98b	4.99b	1.72a	1.72c	1.72a
SE±	0.057	0.057	0.540	0.099	0.085	0.304	2.080	0.081	0.278	0.012	0.089	0.260
Cowdung (C) rate (t ha⁻¹)												
0	9.63b	8.98b	9.31a	3.28a	4.25c	3.77a	4.79a	6.79b	5.79a	0.93d	2.76b	1.85a
5	9.15d	8.89b	9.02ab	2.95b	4.74b	3.85a	3.74b	7.07a	5.41a	1.03c	1.70d	1.37ab
10	10.04a	8.78b	9.41a	3.07a	5.25a	4.16a	3.19c	5.39c	4.29b	1.15b	2.32c	1.74a
15	9.43c	11.92a	10.68a	3.22a	1.80d	2.51b	2.96c	5.81d	4.39b	1.22a	3.36a	2.29a
SE±	0.057	0.057	0.540	0.099	0.085	0.304	2.080	0.081	0.278	0.012	0.089	0.260
Variety (V)												
SAMSORG-17	9.78a	9.84a	9.81a	3.08	4.21a	3.65	3.48b	6.24b	4.86b	1.11a	2.76a	1.94a
SAMSORG-44	9.35b	9.44b	9.40b	3.18	3.81b	3.50	3.86a	6.79a	5.33a	1.06b	2.31b	1.69b
SE±	0.040	0.040	0.182	0.070	0.060	0.215	0.005	0.057	0.046	0.008	0.063	0.030
Interaction												
N x V	ns	Ns	ns	ns	ns	ns	ns	ns	ns	Ns	ns	ns
N x C	ns	Ns	ns	ns	ns	ns	ns	ns	ns	Ns	ns	ns
C x V	ns	Ns	ns	ns	ns	ns	ns	ns	ns	Ns	ns	ns
N x C x V	ns	Ns	ns	ns	ns	ns	ns	ns	ns	Ns	ns	ns

Means followed by the same letter(s) within a treatment group are not statistically different at 5% level of probability, using Duncan Multiple Range Test (DMRT at $p \leq 0.05$)

ns: Not significant.

The increase in grain fibre content by each increase of 5 t ha⁻¹ cowdung rate was not consistent in both years, locations and combined. The highest grain fibre content value was recorded when 10 t ha⁻¹ of cow dung was applied in 2013 and 15 t ha⁻¹ in 2014 at Samaru. However, no significant difference was observed between the rates in the combined. The increase in grain fibre content at Maigana shows that the highest grain fibre content was obtained in the controlled plots except in 2014 when 5 t ha⁻¹ had the highest value of grain fibre content. The plots that were fertilized at 15 t ha⁻¹ had the least grain fibre.

SAMSORG-17 had significantly higher grain fibre content than SAMSORG-44 variety at Samaru while at Maigana it was SAMSORG-44. Significant difference in grain fiber content of the two varieties was observed in the combined years at both locations. SAMSORG-17 was superior at Samaru while at Maigana it was SAMSORG-44. There were no significant treatment factor interactions on grain fibre content observed.

Grain lipid content (%).

The grain lipid content of the two sorghum varieties as affected by nitrogen and cow dung rates at Samaru and Maigana during 2013, 2014 and combined rainy seasons is shown in Table 3. Generally, application of 90 kg N ha⁻¹ had the highest grain lipid content in both years, locations and combined except in 2013 at Samaru when it was statistically similar with the control. The controlled plots gave the least lipid content except in 2013 at Samaru and combined at Maigana where they were statistically similar with 90 kg N ha⁻¹ however, in 2014 at Maigana 60 kg N ha⁻¹ had the least lipid content.

Cow dung rate had significantly influenced grain lipid content. The highest grain lipid content was observed at 15 t ha⁻¹ but statistically the same with 0,10 t ha⁻¹ in 2013 and 10 t ha⁻¹ in 2014 at Samaru, while the increase was significant only up to 10 t ha⁻¹ in the combined years further increase to 15 t ha⁻¹ had no significant difference. At Maigana, cow dung rate of 15 t ha⁻¹ had the highest grain lipid content but statistically at par with 10 and 5 t ha⁻¹ in the combined only. The plots that were left without fertilizer had the least except in 2014 when 5 t ha⁻¹ had the least.

Variety SAMSORG-17 consistently had significantly higher grain lipid content than SAMSORG-44 variety at both locations except in 2013 and combined at Samaru. There were no significant factor interactions on grain lipid content.

Discussions

The grain proximate composition is one of the major factors responsible for the attainment of high quality malt and to the greater extent depends on N supplied. Grain protein and carbohydrate which are the major grain proximate components determining malt quality were greatly affected by N availability in the soil, and closely related to the rate and timing of N fertilizer application (Kumar *et al.*, 2022) These grain proximate qualities have been reported elsewhere among other parameters used to test the quality of grain for malting (Maleke *et al.*, 2024). Other studies have also shown that the use of grain sorghum for malt as well as *dolo* (burukutu or otika) production requires a high quality grain produced through increased crop fertilization practices (Adebo *et al.*, 2023).

The increase in grain quality parameter such as grain weight and protein content by every increase of 30 kg N ha⁻¹ in this study could be due to the influence of N on these parameters. Grain protein content of malting barley was reported to increase due to increase N rate (Cammarano *et al.*, 2024).

The response of sorghum to organic manure fertilization in the form of cow dung was similarly favourable for a number of the crop parameters assessed. The grain proximate composition of the grain exemplified the assertion. The proximate compositions such as protein, moisture, ash, lipid, crude fibre, carbohydrate and water absorption efficiency based on the standardized unit of 100 grains were some of the parameters used for testing proximate compositions in this study. The significant increases recorded on the aforementioned parameters due to the applied cow dung could be linked to its role in supplying nutrients which enhances the growth of crop's photosynthetic apparatus that are responsible for assimilate production, translocation and partitioning thus increased dry matter which eventually translated to yield that was depicted by the responses of these parameters to cow dung rate. This was further proved by the significant and positive correlation between 100 grains weight and those parameters.

The response of sorghum to organic manure fertilization in the form of cow dung was similarly favourable for a number of the crop parameters assessed. The grain proximate composition of the grain exemplified the assertion. The proximate compositions such as protein, moisture, ash, lipid, crude fibre, carbohydrate and water absorption efficiency based on the standardized unit of 100 grains were some of the parameters used for testing proximate compositions in this study. The significant increases recorded on the aforementioned parameters due to the applied cow dung could be linked to its role in supplying nutrients which enhances the growth of crop's photosynthetic apparatus that are responsible for assimilate production, translocation and partitioning thus increased dry matter which eventually translated to yield that was depicted by the responses of these parameters to cow dung rate. This was further proved by the significant and positive correlation between 100 grains weight and those parameters.

Apparently, the low crude protein could have resulted in lower enzymatic activity during germination as earlier reported by (Maleke *et al.*, 2024) Both low and high grain protein content that are not within the recommended levels of 9.5 to 11.5 % is undesirable for malting because it increases steeping time during malting (Gastl *et al.*, 2025). Thus this could be the reason for the lower mean values of water absorption efficiency recorded by grains that were harvested from plots that received higher rates of N than the control in this study. High grain protein contents that exceeded the recommended levels increases steeping time, uneven water uptake during steeping, uneven germination during malting.

The negative relationship between protein and carbohydrate content indicate that as the former increased the later increased. This might not be unconnected with respiration of grain under storage where most of the carbohydrate is converted to other compounds. Protein and starch (carbohydrate) are the major components of the sorghum grain comprising 75 to 90% of the grain (Zhang *et al.*, 2025), and thus their concentrations are often inversely related (Zahid *et al.*, 2024).

Starch (carbohydrate), being an important biochemical component for sorghum processing (Food Chemistry review, 2024), is the most abundant component of the grain carbohydrates and the

main source of energy during germination (Zhang *et al.*, 2025). Starch concentration often is positively correlated to grain yield (Kamal *et al.*, 2023) and protein concentration often is negatively correlated (Cao *et al.*, 2024) to grain yield.

The increase in grain protein content by every increase of 30 kg N ha⁻¹ in this study could be due to the influence of N on these parameters. Grain protein content and 1000-kernel weights of malting barley were reported to increase due to increase N rate (Cammarano *et al.*, 2024).

The consistently higher mean values of the proximate compositions recorded except carbohydrate in both years and locations on sorghum variety SAMSORGH-17 could be attributed to varietal differences and its high responsiveness to fertilization compared to SAMSORGH-44. Utilization of the applied nitrogen among sorghum genotypes differs, nitrogen influences grain biochemical composition such as protein and other proximate constituents (Huang *et al.*, 2022; Zhou *et al.*, 2024). The higher proximate compositions values exhibited by SAMSORGH-17 in this study could be due its genetic make-up and better nutrient utilization than SAMSORGH-44.

Conclusions

Nitrogen application was found to significantly affect the grain proximate concentrations by every increase in the rate up to the highest rate of 90 kg N ha⁻¹ in both years and locations. The application of cow dung significantly affected the grain proximate compositions by every 5 t ha⁻¹ up to 15 t ha⁻¹, however the increase was not consistent among the parameters. Sorghum variety SAMSORGH-17 consistently gave higher mean values of the proximate composition except carbohydrate in both years and locations.

Recommendations

From the present study, application of 60 kg N and 10 tons of cow dung on SAMSORGH-17 is adequate and can be recommended for better grain quality (protein and carbohydrate) to farmers in the northern Guinea savanna ecological zone of Nigeria.

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