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REGULAR ARTICLES

Evaluation of silage from maize stover, maize husk and *Andropogon gayanus* in equal level with *Tephrosia bracteolata* as feed for West African Dwarf sheep

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Abstract
The study investigated the nutritive composition as well as acceptability of ensiled roughages comprising *Andropogon gayanus* (AG), maize husk (MH), maize stover (MS) and their mixtures in equal proportion with *Tephrosia bracteolata* (TB) by West African Dwarf (WAD) sheep. Seven treatment diets were formulated comprising AG: 100% *Andropogon gayanus*, MH: 100% maize husk, MS: 100% maize stover, TB: 100% *Tephrosia bracteolata*, AG + TB: 50% *Andropogon gayanus* + 50% *Tephrosia bracteolata*, MS + TB: 50% maize husk + 50% *Tephrosia bracteolata*, MS + TB: 50% maize stover + 50% *Tephrosia bracteolata*. The experiment was completely randomized in design. Significant variations were observed in the chemical composition of the plant materials before and after ensiling. It was revealed that *Tephrosia bracteolata*, prior to ensiling, had the highest crude protein (CP) content, lowest crude fibre (CF), neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL). Similar trend was observed in the chemical composition of *Tephrosia bracteolata* after ensiling. Inclusion of *Tephrosia bracteolata* in the roughages improved their nutritional quality. All the silage treatments presented good physical characteristics. The acceptability of the silage by 12 WAD sheep ranked thus: TB > MS + TB > AG + TB > AG > MS > MH + TB > MH. Silage digestibility was highest (66.60%) in TB, closely followed by MH + TB (62.67%) and least in MS. It was concluded that WAD sheep production could be enhanced by feeding ensiled maize plant residues alone or in combination with *Tephrosia bracteolata* during the lean season.

Keywords *Andropogon gayanus* · Maize husk · Maize stover · *Tephrosia bracteolata* · Silage · WAD sheep

Statement of novelty Nigeria is the largest producer of maize in Africa, with an output of over 33 million tons in 2018 (www.iita.org/cropsnew/maize). This massive output has led to the associated challenge of production of huge quantities of maize by-products such as maize husk and maize stover at every planting season of the year. In Nigeria, maize grain is one of the major staple foods for man and livestock. These by-products portend a serious threat to the environment when left as wastes. These wastes can be converted to useful products that will enhance ruminant productivity and ensure a healthy environment. It was opined that if these wastes are properly harnessed, it can reduce poverty among rural dwellers and improve their standard of living through improved income. Converting maize husk and maize stover in combination with other forages that are abundantly available during raining season to silage is not a common practice in Nigeria and even in the tropical countries as a whole. There is no documented or scanty information on this aspect of unconventional feed production and green agriculture. The outcome of this study will attempt to provide one of the means of ameliorating feed shortage and inadequate feeding in ruminant production.

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Introduction

Improved feeding regime to meet the nutrient requirements of the ruminants in the tropics is highly essential. In most tropical countries, grasses, crop residues and browse trees form the bulk of feeds for ruminants. Babayemi and Bamikole (2006) earlier reported that uncultivated grasses grow fast and mature early, with the resultant implication of low nutrients composition. In the tropics, the weather conditions could support the cultivation of indigenous grasses for high biomass production even on low soil fertility. During the dry period of the year, there is always poor availability of green grasses and those available are highly lignified resulting to feeding imbalanced nutrients to animals.

Andropogon gayanus is native to tropical Africa and well adapted to regions with 400–1400 mm annual rainfall (Akinola 2018). The grass has been extensively used for grazing ruminants in the Guinea Savannah Region of Nigeria. Tropical savannas are characterized by both wet and long

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dry seasonal climate. One management approach to ameliorate shortage of feed during dry period of the year could be ensiling the surplus forage in the rainy season when quality is good. It has been recognized that actively growing grasses have higher nutritional quality than the matured ones, but they contain high moisture content. The high moisture content may pose a challenge in silage production, as they can lead to poor silage in terms of secondary fermentation and mouldiness, among others (McDonald et al. 1991). As the plant reaches maturity, dry matter (DM) yield is higher and the DM concentration (30 to 35% DM) is good for silage production, but at this stage, the high lignin content may reduce the nutritional quality and consequently low consumption by the animal (Van Soest, 1994).

Cereal wastes, such as maize stover, corn cob and maize husks, are equally available during the wet season but they are low in nutrients and as such cannot meet the nutritional requirements of ruminants. During such season, they are usually found in heaps along the farm roads, market places and public places, constituting an environmental pollution challenge to the society. Some of these wastes may even find their way into the rivers and streams thereby altering the aquatic ecosystem negatively (Jonathan et al. 2008). Maize husks are fibrous leafy materials covering the maize ear. They are usually heaped on the streets, farm lands and market areas and even sometimes near homes during the harvesting period. They usually constitute nuisance to the environment and many a times, blocking the drainage. Nevertheless, these materials are occasionally consumed by ruminant animals because of their fibrous nature and low nutritive value. In spite of these deficiencies, maize wastes could be repackaged into a valuable feed resources for ruminant animals if further processed.

Tephrosia bracteolata is a shrub legume species mostly found in the bush part of the Southern Guinea Savanna and middle belt zones of Nigeria. Goats and sheep on range and also in confinement have proved to accept *T. bracteolata* (Babayemi and Bamikole 2006). This leguminous shrub is available in large quantities in the rainy season, being an annual plant that completes its life cycle within a short period.

The inability of the ruminant livestock keepers to supply the animals with quality feed throughout the year has therefore necessitated the need for feed conservation, most especially during the rainy period of the year. In Nigeria, forage conservation is not a usual practice by the small holder livestock farmers. Globally, in the developed countries, different methods have been adopted for this purpose such as hay, silage making and feed blocking technology. Silage is the conservation of moist crops by natural fermentation under anaerobic conditions, where beneficial bacteria convert fermentable energy sources to produce lactic acid (Successful Silage 2020). When sufficient acid is produced to lower the pH of the material, most metabolic actions cease and the forage is preserved. The preservation of excess plant materials in the form of silage is indispensable, and this allows mitigating the feed deficit that could be encountered during the critical period of the year.

Silage making is a technology that could be practiced to conserve green fodder under anaerobic condition to produce lactic acids. Ashbell et al. (2001) indicated the possibility of ensiling forage in small plastic bags (10–20 kg) which can be used by small holder ruminant owners in Africa. It was observed that although such bags are not completely air tight, the volatile fatty acids, such as the acetic acid that results from the fermentation, accumulate in the bags and so inhibit aerobic spoilage. Lane (2000) earlier reported the use of small plastic bags containing 6 kg of silage and Pariyar (2005) also used plastic bags holding 6 and 12 kg of silage. The present study was therefore carried out to investigate the nutrient quality of silage produced from the combination of green maize stover, maize husk and *Andropogon gayanus* with *Tephrosia bracteolata*, as feed for West African Dwarf sheep using polythene bags.

Materials and methods

The experiment was carried out at the Teaching and Research Farm, Kwara State University, Malete, located on Latitude 8.71°N and Longitude 4.44°E in the Southern Guinea Savannah agro-ecological zone of Nigeria. The climate of the study area is characterized by distinct wet and dry seasons. The wet season starts in March or April and ends in October with a dry spell in August.

Preparation of plant materials for silage

Andropogon gayanus, *Tephrosia bracteolata* and maize stover were collected within the premises of the Teaching and Research Farm, while maize husk was collected from local maize sellers in the neighbouring village. The harvested materials were weighed in order to determine the expected amount for the making of silage. Representative samples of known weights were taken for dry matter analysis by placing them in a Gallenkamp oven at 65 °C for 48 h. Samples were harvested during the sunny period in order to reduce their moisture contents. Seven treatments consisting of *Andropogon gayanus* (AG), maize husk (MH), maize stover (MS) solely and their mixtures in equal proportion with *Tephrosia bracteolata* (TB) were made:

AG: 100% *Andropogon gayanus*
MH: 100% maize husk
MS: 100% maize stover
TB: 100% *Tephrosia bracteolata*

AG + TB: 50% *Andropogon gayanus* + 50% *Tephrosia bracteolata*
MS + TB: 50% maize husk + 50% *Tephrosia bracteolata*
MS + TB: 50% maize stover + 50% *Tephrosia bracteolata*

The plant materials were chopped into 2–3-cm lengths for ease of compaction and consolidation for silage. Molasses was added at 2% to each treatment to enhance the fermentation. Each silo weighing 10 kg in four replicates for the different treatments was filled in a plastic bag. The plastic was lined inside with thick and strong nylon sheets. Each layer of the materials was compacted manually to eliminate trapped air until the containers were filled. The final compaction was made in which the inner sheet was wrapped over the material tightly. Big stones and used tyres were placed on the air-tight filled bags and were left to ferment for 60 days in the store free of rodents and rain.

Determination of silage quality

On the 60th day, the fermentation was terminated and the silages were opened to evaluate the silage quality. Colour, smell, texture, pH and temperature were determined according to Falola et al. (2013). Immediately, the silage was opened, and a laboratory thermometer was inserted to measure the temperature. Small samples from different points and depths were taken and oven dried at 65 °C. The dry samples were milled and stored in an air-tight glass bottle for chemical analysis. The pH of the silage samples was done by heating 100 g in a beaker containing 100 ml of distilled water for 5 min at 60 °C. The supernatant liquid was decanted, cooled at room temperature and a pH metre was used to determine the level of the pH. Colour was ascertained using visual observation with the aid of a colour chart (www.RALcolor.com). The odour or smell of the silage was relatively assessed as to whether nice or pleasant or fruity. Structure of the silage was also determined whether it is separable or visible or collapsible when squeezed between the palms.

Silage acceptability study

Twelve growing male sheep on average weight 12 kg of 8–10 months old were obtained from the flock at the Teaching and Research Farm, Kwara State University, Malate, Nigeria. The animals (already adapted to the environment) were taken out of their pens and the individual pens were cleaned and disinfected with Asuntol and allowed to rest for 2 days. The animals were divided into 4 groups and each group with three (3) animals in a completely randomized design (CRD). Two (2) kilograms of each silage was served to the sheep in each group. The silage was fed to the animals for 2 h between 8.00 and 10.00 h every day for 2 weeks. The left-over of the feeds was weighed and recorded separately. Daily silage intake was deduced from the quantity offered and the left over. The relative preference index (PI) was calculated for each species by dividing intake values for each browse species by the amount of feed offered and multiplying the result by 100 in order to express it as a percentage.

$$\text{Preference Index (\%)} = \frac{\text{Forage intake}}{\text{Forage offered}} \times 100$$

The ensiled materials were ranked according to the calculated preference index obtained.

Dry matter digestibility of ensiled materials

The same twelve sheep used for the acceptability study were subjected to digestibility study. They were individually put in a wooden metabolic cage constructed in such a way that urine and faeces could be collected separately. The animals were fed the silage diets made from AG, TB, MH and MS and their mixtures based on 5% of their body weight daily and fresh water were supplied ad libitum. Daily feed intake was calculated from the amount given and the left over the following day. This study lasted 14 days with 7 days of cage adjustment and another 7 days for data collection. The faeces and urine were collected in the morning before feeding and weighed. Ten percent` of the daily faecal samples collected from each animal was oven dried at 60 °C, bulked, milled and stored in air-tight bottle for laboratory analysis.

Chemical and statistical analysis

Crude protein, crude fibre, ether extract and ash contents of the silage were carried out in triplicates as described by AOAC (1990). The fibre components including neutral detergent fibre, acid detergent fibre and acid detergent lignin were also determined according to Van Soest et al. (1991). Data were analysed using analysis of variance by following the procedure of SAS (2002). The significant means were separated by the use of Duncan multiple range of the same package.

Results

Chemical composition of the silage materials before fermentation is given in Table 1. All the plant materials used in this experiment were in their green forms. Significant ($P < 0.05$) differences were observed for all the parameters measured except dry matter (DM). *Tephrosia bracteolata* had the highest crude protein content, lowest crude fibre and fibre fractions when compared to other plants.

The chemical composition of the ensiled plant mixtures is shown in Table 2. Similar trends were observed in the chemical composition of the plant materials before and after ensiling. The inclusion level of *Tephrosia bracteolata* in the silage mixtures influenced the fibre contents of the final silage products. The concentrations of neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin decreased with the addition of the legume in the mixtures. These values were however higher in the materials before ensiling.

The physical characteristics of silages from the plant materials and its mixtures are shown in Table 3. All the silages were of good quality. The colour of the silage was greenish in nature. This was similar to the original plant materials before ensiling. The texture was friable (maize stover and maize husk) to firm and the pH of the silage was within the normal range of a good silage (4.0–5.0). The temperature ranged between 26.5 and 27.5 °C among the silage. The aroma was pleasant and appealing.

The DM intake and the preference index of the silages by WAD sheep were increasing as the day progressed (Table 4). However, there were significant variations in these values but the mixtures were better eaten by the sheep than the silage made from the individual plant materials. This trend

Table 1 Chemical composition of materials used in the preparation of silage (g/mg)

Samples	Nutrient composition							
	DM	CP	EE	CF	ASH	NDF	ADF	ADL
MS	30.43	7.03^{b}	1.30^{a}	31.28^{a}	6.83^{b}	68.57	38.80	5.43^{b}
MH	29.15	4.50^{b}	0.81^{c}	31.31^{a}	2.98^{c}	63.74	41.85	10.53^{a}
TB	29.12	14.88^{a}	3.32^{b}	18.43^{c}	7.06^{b}	54.10	32.87	4.63^{b}
AG	27.79	5.90^{b}	8.7^{a}	27.20^{b}	9.73^{a}	66.13	34.97	5.13^{b}
SEM	2.70	0.98	0.43	1.16	0.77	4.86	3.80	0.93

MS maize stover, *MH* maize husk, *TB Tephrosia bracteolata*, *AG Andropogon gayanus*; ^{a,b,c}Means within column with different superscripts differ significantly ($P < 0.05$)

Table 2 Chemical composition of silage from the combination of *Tephrosia bracteolate* and plant materials

Silage	Nutrient composition							
	DM	CP	EE	CF	ASH	NDF	ADF	ADL
MS	26.15	5.12^{c}	0.46^{c}	27.00^{ab}	5.56^{cd}	59.67^{a}	31.09^{abc}	3.66^{d}
MH	26.13	3.33^{d}	0.28^{c}	28.02^{a}	2.75^{e}	61.40^{a}	39.35^{a}	8.71^{a}
TB	27.08	12.87^{a}	2.00^{b}	17.00^{d}	6.67^{bc}	48.76^{b}	23.69^{c}	4.47^{c}
AG	25.86	5.33^{c}	4.60^{a}	24.18^{c}	8.13^{a}	62.11^{a}	29.65^{bc}	3.65^{d}
MH + TB	27.04	9.5^{b}	2.71^{b}	28.66^{a}	4.85^{d}	50.35^{b}	31.99^{abc}	8.58^{a}
AG + TB	25.73	10.00^{b}	3.82^{a}	24.53^{bc}	8.42^{a}	59.43^{a}	33.37^{ab}	6.68^{b}
MS + TB	26.50	10.33^{b}	1.82^{b}	27.23^{ab}	6.61^{b}	60.96^{a}	29.93^{abc}	8.82^{a}
SEM	1.03	0.33	0.32	0.84	0.30	1.65	2.80	0.16

MS maize stover, *MH* maize husk, *TB Tephrosia bracteolata*, *AG Andropogon gayanus MH + TB* 50% MH and 50% TB, *AG + TB* 50% AG and 50% AG, *MS + TB* 50% MS and 50% TB; ^{a,b,c,d,e}Means within column with different superscripts differ significantly ($P < 0.05$)

Table 3 Silage characteristics of the ensiled maize crop residues

Silage	Colour	Colour code	Aroma	Texture	pH	Temp
MS	May green	6017	Pleasant	Friable	4.3	27.4
MH	May green	6017	Pleasant	Friable	4.2	27.5
TB	Curry yellow	1027	Pleasant	Firm	4.4	27.4
AG	Curry yellow	1027	Pleasant	Firm	4.4	26.7
MH + TB	Curry yellow	1027	Pleasant	Firm	4.6	26.7
AG + TB	Curry yellow	1027	Pleasant	Firm	4.5	26.5
MS + TB	Curry yellow	1027	Pleasant	Firm	4.7	26.8

MS maize stover, *MH* maize husk, *TB Tephrosia bracteolata*, *AG Andropogon gayanus*, *MH + TB* 50% MH and 50% TB, *AG + TB* 50% AG and 50% AG, *MS+TB* 50% MS and 50% TB

Table 4 Mean daily DM intake (kg) and percentage preference of ensiled materials from plant materials

Ensiled materials	Day 1		Day 3		Day 5		Day 7	
	Daily DM intake	% PI	Daily DM intake	%PI	Daily DM intake	% PI	Daily DM intake	% PI
AG + TB	0.63	31.67^{a}	0.77^{a}	40.0^{a}	0.87^{a}	43.34^{a}	1.00^{a}	50.00^{a}
MH + TB	0.47	23.33^{ab}	0.60^{ab}	30.00^{bc}	0.70^{bc}	35.00^{bc}	0.87^{a}	43.33^{a}
MS + TB	0.60	30.00^{a}	0.70^{a}	35.00^{ab}	0.77^{ab}	38.43^{ab}	1.03^{a}	51.67^{a}
TB	0.33	16.67^{b}	0.40^{c}	20.00^{d}	0.47^{d}	23.52^{d}	1.20^{a}	51.87^{a}
MH	0.33	18.33^{b}	0.50^{bc}	25.00^{cd}	0.56^{cd}	28.33^{cd}	0.60^{b}	30.00^{b}
MS	0.43	21.67^{ab}	0.60^{ab}	23.33^{bcd}	0.63^{bc}	31.67^{b}c	0.90^{a}	45.00^{a}
AG	0.46	23.33^{ab}	0.60^{ab}	30.00^{bc}	0.70^{bc}	35.00^{bc}	0.97^{a}	46.33^{a}
SEM	0.06	3.12	0.05	2.96	0.05	2.26	0.07	3.42

MS maize stover, *MH* maize husk, *TB Tephrosia bracteolata*, AG: *Andropogon gayanus*, *MH + TB* 50% MH and 50% TB, *AG + TB* 50% AG and 50% AG, *MS + TB* 50% MS and 50% TB; [a,b,c,d]Means within column with different superscripts differ significantly ($P < 0.05$)

was observed from the first day of the acceptability study till the last day of the experiment.

The apparent dry matter (DM) digestibility of the different ensiled plant materials was significantly different (Fig. 1). The highest value ($P < 0.05$) for digestibility was recorded for the sole *Tephrosia bracteolata* silage, followed by its mixtures with the other plant materials. Meanwhile, maize husk (MH) and *Andropogon gayanus* (AG) had the lowest ($P < 0.05$) digestibility among the silage treatments.

Discussion

The crude protein contents of the silages produced from maize stover, maize husk and *Andropogon gayanus* were lower than the minimum (7%) required by ruminant rations for normal, healthy rumen functions (Minson 1990; McDonald et al. 2010) but higher in the silages produced when combined with *Tephrosia bracteolata* in equal proportions. The crude protein content obtained for ensiled *Andropogon gayanus* in this study is lower than the value of 9.44% reported by Amuda et al. (2020) but the values obtained for maize stover and maize husk compare with other reports (Li et al. 2014). The increased protein concentration in the *Tephrosia* silage mixtures may be due to the fact that it is a leguminous plant with higher protein value before ensiling. Thus, its inclusion in the mixtures had a positive effect ($P < 0.05$) on all the parameters measured in this study. The findings underscored the importance of incorporating leguminous plant in the diets of ruminants, most especially in silage production, to ameliorate dry season low quality feed and shortage.

It was generally observed that the fibre contents obtained for the silages in this study were high. The high values obtained

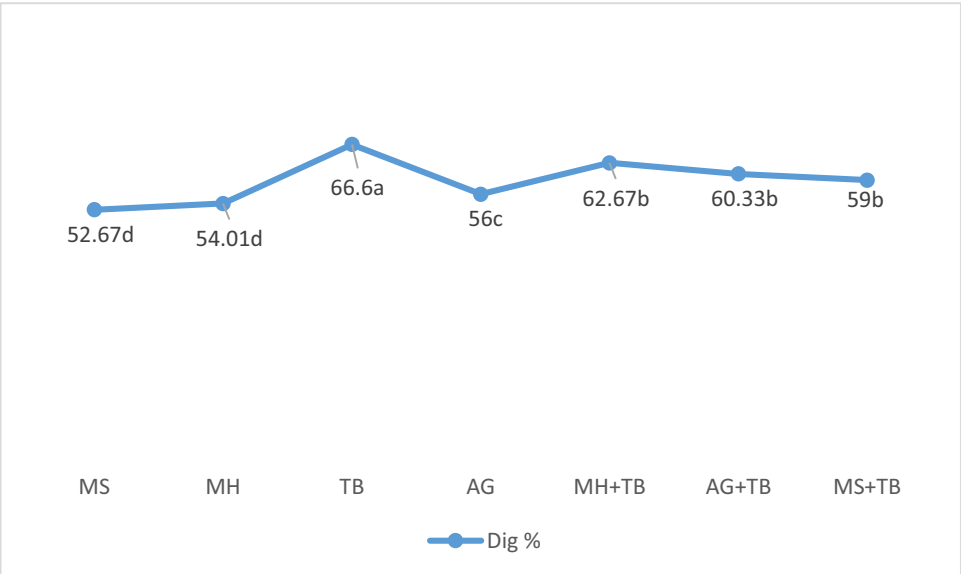


Fig. 1 % Dry matter digestibility of silage from various plant materials in combination with *Tephrosia bracteolate*

can be correlated with the quality of the plant materials used as is typical of many tropical forages (Ngamsaeng et al. 2006).

The physical qualities showed that the silage treatments were good to feed ruminant animals. It has been reported that good silage usually preserves the original colour of the pasture or forage (t'Mannetje 1999) and silage that is closer to the original green coloration of the pasture is considered good, well preserved and well fermented (Babayemi 2009), although silage with yellowish colour from green grass has also been classified as a well-made silage (Kung and Shaver 2002). The temperature of all the silages presented was below 28 °C which indicated they were well preserved. Temperature is one of the essential factors affecting silage colour. The lower the temperature during ensilage, the less will be the colour change. Temperature values from 30 °C and greater have been reported to be responsible for dark yellow or close to brown caramelization of sugars. (Jianxin 2002).

Very pleasant and pleasant smell recorded in this study was also an indication of good silage. Kung and Shaver (2002) reported that pleasant smell is accepted for a good or well-made silage. The texture of the present silages was firm, which is a further indication of a good silage.

Preference study is a short-term feed evaluation trial in which animals are given the free choice to select the most preferred feed or test diet. Most preference studies usually run for an average of 7 days (Bamikole et al. 2004; Figueroa et al. 2020). The better acceptance of the forage mixtures could be due to the high nutritive values of these silages. The high concentration of crude protein in the silage is a major factor that contributed to their acceptance while poor acceptance of others could be attributed to phenolic compounds that could be found in some of the plant materials used for silage production (Silanikove et al. 1996).

The trend observed in the DM apparent digestibility could be as a result of the high percentage of crude protein inherent in these silages which make it more relished and utilized by the animals. The high nutritive value of *Tephrosia bracteolata* and its mixtures helped to improve dry matter digestibility by the animals. The result was in agreement with Hussain and Cheeke (1996) and Hynes et al. (2016). The higher the crude protein content of the feed, the better is the digestibility. The results obtained in this study may also be ascribed to the fact that the silages contain soluble carbohydrate which could increase microbial proliferation, thereby creating healthy rumen environment (Mekasha et al. (2003).

Conclusion

It was concluded that some wastes and pasture of poor quality can be ensiled successfully with a leguminous plant such as *Tephrosia bracteolata* to improve rumen efficiency and overall performance of West African Dwarf sheep. The inclusion of *Tephrosia bracteolata* into the ensiled materials improved their nutritive value, acceptability and digestibility. This approach can be embarked upon during period of forage surplus, in the year, to mitigate feed shortage at the dry season and to enhance animal productivity.

Author contribution DOO designed and initiated the conduct of the research. She was involved in the data analysis and result interpretation and participated in the manuscript write-up while JAO was involved in the data interpretation and the manuscript write up, including the graphical abstract.

Data availability All the data collected during the study is available and is hereby attached.

Code availability Not applicable.

Declarations

Ethics approval Ethical permission to undertake the research was requested from and approved by the Centre For Research, Innovation and Training of the Kwara State University, Malete (Ref: KWASU/CRIT/REA/2020/002).

Consent to participate The co-author gave his full consent to participate in the study.

Consent for publicatiob The co-author gave his consent for the publication of the research findings.

Conflict of interest The authors declare no competing interests.

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