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Influence of Some Botanical Powders in Preserving Nutritional Quality of Stored Sorghum Infested by *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae) in Nigeria

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Abstract

Quality deterioration in sorghum grain caused by *S. zeamais* after six months post treatment with some botanicals was determined by proximate and mineral analyses of the grain before and after infestation. Twenty grams of sorghum were treated with leaf powders of *Euphorbia balsamifera* Aiton, *Lawsonia inermis* L., *Mitracarpus hirtus* (L.) DC and *Senna obtusifolia* L. at the concentrations of 2.5 x 10^4, 5.0 x 10^4 and 10.0 x 10^4 ppm along with conventional insecticide (permethrin) at 0.056 x 10^4 ppm. The results showed that moisture content was not significantly different ($p > 0.05$). Ash was higher in treated grains than in untreated ones and vice versa for crude fibre. Percent crude lipid in treated grains ranged from 6.50 ± 0.00 to 7.17 ± 0.17% and increased with increased in concentrations. The amount of crude protein decreased drastically in untreated samples compared to treated grains where it varied between 8.75 ± 0.01 to 8.99 ± 0.41%. Carbohydrate content in the sorghum grains was significantly different ($p < 0.05$) among the botanical treatments. There was a substantial decrease in the minerals content in infested grains.

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Findings of this study have revealed that all the botanical powers have potentials of reducing effect of *S. zeamais* on the nutritional value of sorghum grains with *E. balsamifera* as the most effective.

Introduction

The role of agriculture remains significant in the Nigeria economy despite the strategic importance of the oil sector. Agriculture provides primary means of employment for Nigeria and accounts for more than one third of total gross domestic product (GDP) and labour force [1]. More than 70% of the working adult populations in Nigeria are employed in the agricultural sector directly or indirectly and over 90% of Nigeria's agricultural output comes from peasant farmers who dwell in the rural areas where 60% of the population live [1]. The major cereal crops in Nigeria are rice, maize, sorghum, wheat, and millet. Sorghum is the staple food crop that is economical to grow in dry areas of many regions of Africa where the climatic conditions are unfavourable for the growth of other crops [2].

Sorghum is produced for human nutrition and animal feeds all over the world, and over half (55%) of it is used for human consumption in Asia and Africa [3]. It is the major crop for many poor farmers, especially in Africa, Central America and South Asia [4]. Grain sorghum is used for flours, porridges and side dishes, malted and distilled beverages as well as popped grain. It is the main source of calories and protein in some regions of Africa and Asia [5]. Sorghum is the primary food crop in virtually all parts of northern Nigeria [6].

FAO (2006) reported processed sorghum grains and flour as important sources of calories and proteins to the vast majority of the population as well as for poultry and livestock [7]. Sorghum grain flour has an average energy value of 356 kcal/100 g and protein content which ranges from 7 to 15% [8,9].

Despite its nutritional value, sorghum production has been hindered by biotic and abiotic constraints. Among the biotic constraints, insect pests are the major devastating factors attacking the grains during storage [10]. Once infestation is established, insect pests cause gradual and progressive damage leading to losses in weight, nutritional, organoleptic and aesthetic quality of grains [11]. Goftishu and Belete (2014) emphasized that *S. zeamais* damage leads to quantitative and qualitative deterioration of sorghum grain [12]. These losses could be influenced by the storage time and population of the insects involved in the infestation. The qualitative loss is attributed to change in biochemical components such as carbohydrates, fats and proteins [13]. Damage to sorghum grains in storage in northern Nigeria due to this pest ranges between 4 and 10% [14].

Qualitative loss arises primarily from the alteration of the physical appearance and chemical constituents of the grains with insect frass and debris that could lead to detectable reduction in important nutrients such as sugar, proteins, fats, minerals and vitamins [15]. In order to reduce these losses, some botanicals of various forms have been tested by some researchers against the weevils in maize grains [13].

However, there is limited information on effects of botanicals on nutritional quality of sorghum grains infested by *S. zeamais* or any other insect pest. Considering the economic importance of sorghum and the damage caused to it by *S. zeamais*, the present study was aimed at assessing the qualitative loss in the infested sorghum grains treated with different botanical powders and to determine the effectiveness of the botanicals in protecting the grain quality.

Materials and Methods

Sample Preparation

Twenty grams of sorghum grains of the variety "Farar Kaura" in the plastic bottles was treated with 2.5, 5.0 and 10.0 x 10^4 ppm of *E. balsamifera, L. inermis, M. hirtus* and *S. obtusifolia* along with 0.056 x 10^4 ppm of permethrin powder. Another 20 g of the grains was placed in separate bottle without any treatment. All treatments were arranged in a completely randomised design (CRD) with 3 replicates. Ten adults of *S. zeamais* were introduced into the bottles and allowed them to stay for 14 days in an incubator at 30°C and 70% R.H. after which they were removed. The grains were maintained in the same condition in the incubator for 6 months and then sieved to remove the powders and any other unwanted particles. The sieved samples were then washed with deionised water and ovum dried at 65°CC for 6 hrs [16]. The dried samples were ground into fine powders using laboratory stainless steel mortar and pestle. Clean sorghum grains were earlier obtained and ground into fine powder before infestation (as untreated un-infested). The powders were placed in well-labelled bottles separately and kept in the laboratory for proximate and mineral analyses.

Proximate Analysis of Sorghum Grains Treated with the Botanicals and Infested by *S. zeamais*

To assess the qualitative losses caused to sorghum grains by *S. zeamais,* the ground samples were analyzed for moisture, ash, crude fibre, crude lipid, crude protein and carbohydrate based on the recommendation of the Association of Official Analytical Chemists [17,18]. All analyses were conducted in triplicates.

Determination of Moisture Content

Five grams of the sample powders were weighed into pre-weighed crucible (W_1) and placed into a drying oven at 105°C for 24 hrs. The crucible was removed, cooled in a desiccator and re-weighed. The processes of drying, cooling and re-weighing were repeated until a constant weight (W_2) was obtained. The moisture content was determined as:

$$\%\,Mositure = \frac{W_1 - W_2}{Weight\ of\ sample\,(5\,g)} \times 100$$

Where:
W_1 = Weight (g) of sample
W_2 = Constant weight (g) of crucible + sample after drying

Determination of Ash Content

Five grams of the powdered samples was weighed into pre-weighed crucibles (W_1) and placed into a muffled furnace at 550°C for 8 hrs. The ash was cooled in a desiccator and weighed (W_2). The weight of the ash was determined by the difference between the powdered sample, pre-weighed crucible and the ash in the crucible. Percentage ash was calculated as:

$$\%\, Ash = \frac{W_2 - W_1}{Weight\ of\ sample\,(5\,g)} \times 100$$

Where:
W_1 = Weight (g) of empty crucible
W_2 = Weight (g) of crucible + ash

Determination of Crude Fibre

One gram of the powdered sample was placed in a beaker and boiled in 150 cm^3 of 1.25% H_2SO_4 solution for 30 min. The boiled sample was washed 3 times with 30 cm^3 of hot deionised water and filtered through Whatman No. 1 filter paper. The residue was scrapped back into the beaker with a spatula and boiled again in 150 cm^3 of 1.25% NaOH solution for another 30 min. The boiled sample was washed as in the acid digestion but the last wash was done with cold deionised water, and washed three times with 25 cm^3 of acetone and filtered as above. The residue was carefully transferred into a weighed crucible where it was dried in the oven at 105°C to a constant weight (W_1). It was thereafter burnt to ash in a muffle furnace at 550°C, cooled in a desiccator and weighed (W_2). The percentage crude fibre was calculated as:

$$\%\, Crude\ Fibre = \frac{W_2 - W_1}{Weight\ of\ sample\,(1\,g)} \times 100$$

Where:
W_1 = Weight (g) of crucible + sample after washing and drying
W_2 = Weight (g) of crucible + sample ash

Determination of Crude Lipid

Crude fat was determined by solvent extraction gravimetric method described by Ilodibia *et al.* (2014) [19]. Two gram of the powdered sample was wrapped in a Whatman No. 1 filter paper and put in a thimble. The thimble was put in a soxhlet extractor and extracted into a pre-weighed extraction flask containing 200 cm^3 of petroleum ether.

The upper of the reflux flask was connected to a water condenser. The solvent (petroleum ether) was heated, boiled, vaporised and condensed into the reflux flask filled. Soon the sample in the thimble was covered with the solvent until the reflux flask filled up and siphoned over, carrying its oil extract down to the boiling flask. This process was allowed to go on repeatedly for 4 hrs before the defatted sample was removed, the solvent recovered and the oil extract was left in the flask. The flask (containing the oil extract) was dried in the oven at 60°C for 30 min to remove any residual solvent. It was cooled in the desiccator and weighed. The weight of fat extract was determined by difference and calculated as a percentage of the weight of sample analyzed thus:

$$\%\,Crude\,Fat = \frac{W_2 - W_1}{Weight\ of\ sample\,(2\,g)} \times 100$$

Where:
W_1 = Weight (g) of empty extraction flask
W_2 = Weight (g) of flask + oil (fat) extract

Determination of Crude Protein

Crude protein was determined using the micro-Kjeldahl whereby 2 g of sample was weighed along with 20 cm^3 of distilled water into a micro-Kjeldahl digestion flask [20]. It was shaken and allowed to stand for some time. Fifteen grams of $NaSO_4$ and 1 g of $CuSO_4$ as catalysts were added followed by addition of 20 cm^3 conc. H_2SO_4. Some glass beads were added as anti-bump. The flask was heated under a fume cup board for 4 hrs and then allowed to cool. The content was transferred into a 50 cm^3 volumetric flask and diluted to the mark with water. An aliquot of 10 cm^3 of the digest was transferred into another micro-Kjeldahl flask along with 20 cm^3 distilled water and placed in the distilling outlet of the micro-Kjeldahl distillation unit. A conical flask containing 20 cm^3 of boric acid indicator was placed under the condenser outlet. A 20 cm^3 of 40% NaOH solution was added to the content in the Kjeldahl flask by opening the funnel stop cock. The distillation started and the heat supplied was regulated to avoid sucking back. When all the available distillate was collected in 20 cm^3 boric acid, the distillation stopped.

The nitrogen in the distillate was determined by titrating with 0.01M of H_2SO_4. The nitrogen content of the sample is given by the formula:

$$\%\,N = \frac{TV \times Na \times 0.014 \times V_1}{G \times V_2} \times 100$$

Where:
TV = Titre value of acid (cm^3);

Na = Concentration or normality of acid;
V_1 = Volume of distilled used for distilling the digest (50 cm^3);
V_2 = Volume of aliquot used for distilling the digest (10 cm^3); and
G = Weight of sample (2 g).

The crude protein was calculated as % Crude Protein = % N x 6.25

Determination of Carbohydrate

The carbohydrate content was obtained by subtracting the values of moisture, ash, crude fibre, crude fat and crude protein from 100. Thus;

$$\%\,Carbohydrate = 100\% - (\%\,Moisture + \%\,Ash + \%\,Crude\ fibre + Crude\ fat + Crude\ protein)$$

Mineral Analysis

Acid digestion of the samples was carried out following Antia *et al.* (2006) [21]. Aqua reader was prepared by adding 133 cm^3 of nitric acid to 400 cm^3 of hydrochloric acid in a 2L measuring cylinder. Distilled water was then added to the acid to the mark of 2L to make the aqua reader. In a beaker, 30 cm^3 of the aqua reader was added to 0.5 g of the sample and boiled on hot plate and the sampled was completely digested. The digest was allowed to cool and then filtered into a 50 cm^3 volumetric flask through Whatman No. 1 filter paper. Distilled water was added to the filtrate to make it 50 cm^3 and stored in sampling bottles. The digested samples were used for determination of sodium (Na), potassium (K), calcium (Ca), magnesium (Mg) and phosphorus (P).

Data Analysis

All data were collected in triplicates and subjected to analysis of variance (ANOVA) at 5% level of significance using Graph Pad Prism (version 7.03). Significantly different means were separated by using Bonferroni's multiple comparisons test and Fisher's LSD. All analyses were carried out at $p < 0.05$.

Results

Proximate Composition of Infested Sorghum Grains Treated with Botanical Powders

The moisture level in grains treated with *E. balsamifera* varied between 10.15 ± 0.01 and 10.24 ± 0.01%. In *L. inermis* and *M. hirtus* treatments, it ranged from 10.19 ± 0.00 to 10.20 ± 0.01% and 10.20 ± 0.01 to 10.22 ± 0.01%, respectively. Grains treated with *S. obtusifolia* had the highest moisture level which varied between 10.21 ± 0.01 to 10.25 ± 0.01%. This was closely followed by permethrin with 10.24 ± 0.02% moisture. However, the untreated grains had 10.27 ± 0.07% moisture (Table 1). The difference in moisture content was highly significantly different (F (6, 42) = 5260.00, $p < 0.0001$), while it was not significantly different among concentrations (F (2, 42) = 0.8098, $p = 0.4518$).

Ash content of grains treated with the botanical powders varied with difference in botanical type at the concentrations, 2.5, 5.0 and 10.0 x 10^4 ppm. The ash content was in decreasing order of Permethrin > *E. balsamifera* > *L. inermis* > *M. hirtus* > *S. obtusifolia* > control. A significant difference existed among the botanical powders as well as among the varying concentrations.

Untreated and infested grains (control) had the highest percent crude fibre as 13.67 ± 0.33 followed by 2.33 ± 0.33 to 4.00 ± 0.00% in *S. obtusifolia*. Grains treated with *M. hirtus,* had 2.00 ± 0.00 to 3.67 ± 0.33%, while the crude fibre in *L. inermis* and *E. balsamifera* treatments ranged from 2.00 ± 0.00 to 3.33 ± 0.33% (Table 1). From the two-way ANOVA, the difference in crude fibre was highly significant among grains treated with the botanical powders (F (6, 42) = 932.80, $p < 0.0001$) as well as among the varying concentrations (F (2, 42) = 24.54, $p < 0.0001$).

Table 1: *Proximate composition of sorghum treated with different concentrations of botanical powders and infested by S. zeamais*

Treatments	Conc. (x 10^4 ppm)	% Organic Compounds (Mean ± S. E.)					
		Moisture	Ash	Crude Fibre	Crude Lipid	Crude Protein	Carbohydrate
E. balsamifera	2.5	10.24 ± 0.01^{b}	1.67 ± 0.07^{ab}	3.33 ± 0.33^{b}	6.83 ± 0.17^{ab}	8.81 ± 0.04^{b}	69.12 ± 0.19^{b}
	5.0	10.13 ± 0.01^{b}	1.73 ± 0.07^{ab}	3.00 ± 0.00^{b}	7.00 ± 0.29^{ab}	8.83 ± 0.01^{b}	69.30 ± 0.34^{ab}
	10.0	10.15 ± 0.01^{b}	2.00 ± 0.12^{a}	2.00 ± 0.00^{c}	7.00 ± 0.29^{ab}	8.89 ± 0.01^{a}	69.96 ± 0.26^{ab}
L. inermis	2.5	10.19 ± 0.01^{b}	1.59 ± 0.11^{b}	3.33 ± 0.33^{b}	6.67 ± 0.17^{ab}	8.80 ± 0.03^{b}	69.42 ± 0.54^{ab}
	5.0	10.20 ± 0.01^{b}	1.69 ± 0.05^{ab}	3.00 ± 0.00^{b}	6.83 ± 0.17^{ab}	8.81 ± 0.01^{b}	69.46 ± 0.14^{ab}
	10.0	10.19 ± 0.00^{b}	1.87 ± 0.07^{ab}	2.00 ± 0.00^{c}	7.17 ± 0.17^{a}	8.85 ± 0.01^{b}	69.93 ± 0.24^{ab}
M. hirtus	2.5	10.22 ± 0.01^{b}	1.53 ± 0.07^{b}	3.67 ± 0.33^{b}	6.67 ± 0.17^{ab}	8.78 ± 0.02^{b}	69.14 ± 0.50^{b}
	5.0	10.20 ± 0.01^{b}	1.64 ± 0.02^{b}	3.33 ± 0.33^{b}	6.83 ± 0.17^{ab}	8.80 ± 0.04^{b}	69.19 ± 0.41^{ab}
	10.0	10.20 ± 0.01^{b}	1.73 ± 0.07^{ab}	2.00 ± 0.00^{c}	7.00 ± 0.29^{ab}	8.83 ± 0.12^{b}	70.24 ± 0.28^{a}
S. obtusifolia	2.5	10.25 ± 0.01^{b}	1.53 ± 0.13^{b}	4.00 ± 0.00^{b}	6.50 ± 0.00^{b}	8.75 ± 0.01^{b}	68.97 ± 0.13^{b}
	5.0	10.22 ± 0.01^{b}	1.64 ± 0.04^{b}	3.67 ± 0.33^{b}	6.50 ± 0.00^{b}	8.78 ± 0.02^{b}	69.19 ± 0.29^{ab}
	10.0	10.21 ± 0.01^{b}	1.67 ± 0.07^{ab}	2.33 ± 0.33^{c}	6.83 ±0.17^{ab}	8.80 ± 0.03^{b}	70.16 ± 0.25^{a}
Permethrin	0.056	10.24 ± 0.02^{b}	1.93 ± 0.07^{a}	2.00 ± 0.00^{c}	7.00 ± 0.00^{ab}	8.90 ± 0.06^{a}	69.93 ± 0.11^{ab}
Untreated un-infested	0.0	10.27 ± 0.07^{b}	1.99 ± 0.01^{a}	1.53 ± 0.27^{c}	7.17 ± 0.33^{a}	8.99 ± 0.41^{a}	70.06 ± 0.28^{a}
Control	0.0	13.98 ± 0.01^{a}	0.67 ± 0.07^{c}	13.67 ± 0.33^{a}	6.50 ± 0.29^{b}	5.70 ± 0.07^{b}	59.49 ± 0.71^{c}

Conc. = Concentration.

Means in the same column followed by different letter superscript are significantly different at $p < 0.05$ by the Bonferroni's Multiple Comparisons Test and Fisher's LSD.

Percent crude lipid in sorghum grains treated with the botanical powders ranged as follows: 6.83 ± 0.17 to 7.00 ± 0.29% in *E. balsamifera,* 7.00 ± 0.29 to 7.17 ± 0.17% in *L. inermis,* 6.67 ± 0.17 to 7.00 ± 0.29% in *M. hirtus,* 6.50 ± 0.00 to 6.83 ± 0.17% in *S. obtusifolia* and 7.00 ± 0.00% in permethrin. The untreated un-infested and control had 7.17 ± 0.33 and 6.50 ± 0.29%, respectively. There was a significant difference (F (6, 42) = 3.198, p = 0.0112) in lipid content among the treatments while it was not significant (F (2, 42) = 1.324, p = 0.2769) in the percent crude lipid among the concentrations.

Protein content in grains treated with botanical powders at the varying concentrations differed and recorded in the following order: Permethrin > *E. balsamifera* > *L. inermis* > *M. hirtus* > *S. obtusifolia* > control. The percent protein was significantly different among the treatments. Moreover, there was no significant difference in crude protein among the varying concentrations.

Highest (70.24 ± 0.28%) percent carbohydrate was recorded in 10.0 x 10^4 ppm of *M. hirtus,* while the least (69.12 ± 0.19%) was in 2.5 x 10^4 ppm of *E. balsamifera* (Table 1). The untreated un-infested and control had 70.06 ± 0.28 and 59.49 ± 0.71% carbohydrate, respectively. A highly significant difference existed in the percent carbohydrate among the treatments (F (6, 42) = 310.20, p < 0.0001). Also, there was a significant difference among the varying concentrations.

Mineral Content of Infested Sorghum Grains Treated with Botanical Powders

There was decrease in loss of mineral elements in botanically treated sorghum grains infested by *S. zeamais.* There was highly significant difference in Na (F (6, 42) = 278.80, p < 0.0001) among treatments and between treatments and the control. Highest (26.32 ± 0.04 mg) amount of Na was in 10.0 x 10^4 ppm *E. balsamifera,* while 2.5 x 10^4 ppm of *S. obtusifolia* had the lowest (22.52 ± 0.04 mg). Similar trend was recorded in all the other elements (K, Ca, Mg and P) (Table 2). The amounts of Na (26.06 ± 0.18 mg), K (64.45 ± 0.20 mg) and P (2.80 ± 0.02 mg) in permethrin treatments were significantly the same to the highest concentration of *E. balsamifera* and *L. inermis*. Phosphorus (P) was the least with its highest (3.12 ± 0.01 mg) and lowest (2.22 ± 0.02 mg) contents in untreated uninfested grains and 2.5 x 10^4 ppm of *S. obtusifolia,* respectively. Loss of the Na, K, Ca, and Mg in the control was greater than in the botanical treatments (Table 2).

Table 2: *Mineral content of sorghum treated with different concentrations of various botanical powders and infested by S. zeamais*

Treatments	Conc. (x 10^4 ppm)	Mineral Elements (mg/100 g ± S. E.)				
		Na	K	Ca	Mg	P
E. balsamifera	2.5	24.62 ± 0.12^{d}	61.84 ± 0.10^{c}	131.95 ± 0.08^{e}	154.23 ± 0.09^{d}	2.47 ± 0.04^{d}
	5.0	25.82 ± 0.02^{c}	62.36 ± 0.14^{bc}	132.88 ± 0.02^{e}	155.15 ± 0.05^{d}	2.69 ± 0.01^{c}
	10.0	26.32 ± 0.04^{b}	64.25 ± 0.07^{b}	165.99 ± 0.76^{c}	186.40 ± 1.70^{b}	2.79 ± 0.01^{b}
L. inermis	2.5	24.45 ± 0.18^{d}	61.54 ± 0.15^{c}	124.94 ± 023^{g}	145.78 ± 0.23^{e}	2.34 ± 0.03^{e}
	5.0	25.48 ± 0.10^{c}	62.25 ± 0.13^{bc}	125.57 ± 0.06^{g}	147.93 ± 0.22^{e}	2.63 ± 0.03^{c}
	10.0	26.02 ± 0.12^{b}	63.26 ± 0.03^{b}	137.84 ± 0.26^{d}	163.22 ± 0.18^{c}	2.74 ± 0.00^{b}

M. hirtus	2.5	23.18 ± 0.12^{e}	55.95 ± 0.59^{d}	123.99 ± 0.15^{g}	143.88 ± 0.56^{e}	2.28 ± 0.04^{e}
	5.0	24.67 ± 0.06^{d}	57.07 ± 0.96^{d}	125.63 ± 0.03^{g}	147.14 ± 0.38^{e}	2.55 ± 0.02^{c}
	10.0	25.04 ± 0.08^{d}	60.96 ± 0.04^{c}	132.86 ± 0.04^{e}	153.45 ± 0.14^{d}	2.70 ± 0.01^{b}
S. obtusifolia	2.5	22.52 ± 0.04^{f}	54.55 ± 0.08^{e}	109.00 ± 0.85^{h}	139.98 ± 0.28^{f}	2.22 ± 0.02^{f}
	5.0	23.57 ± 0.05^{e}	56.84 ± 0.20^{d}	110.68 ± 0.23^{h}	145.78 ± 0.23^{e}	2.55 ± 0.02^{c}
	10.0	24.19 ± 0.02^{d}	58.62 ± 0.26^{c}	127.22 ± 0.18^{f}	152.16 ± 0.14^{d}	2.68 ± 0.00^{c}
Permethrin	0.056	26.06 ± 0.18^{b}	64.45 ± 0.20^{b}	745.78 ± 0.17^{b}	444.07 ± 0.12^{a}	2.80 ± 0.02^{b}
Untreated un-infested	0.0	29.07 ± 0.38^{a}	74.33 ± 0.11^{a}	865.27 ± 0.39^{a}	445.38 ± 0.18^{a}	3.12 ± 0.01^{a}
Control	0.0	19.40 ± 0.13^{g}	50.06 ± 0.30^{f}	100.62 ± 0.23^{i}	97.05 ± 3.34^{g}	2.43 ± 0.03^{d}

Conc. = Concentration.

Means in the same column followed by different letter superscript are significantly different at $p < 0.05$ by the Bonferroni's Multiple Comparisons Test.

Discussion

The Role of Botanical Powders in Preserving Proximate Composition of Sorghum Grains Infested by *S. zeamais*

There is paucity of information on the effects of botanicals on nutritional composition of sorghum grains. However, the effectiveness of the selected botanical powders in reducing organic compounds in treated sorghum corroborates Danjumma *et al.* (2009) who reported that powders of *A. indica, A. sativum, N. tabacum, O. basilicum, Z. officinale* applied at 1 and 2 g/50 g (w/w) decreased loss of organic compounds in treated maize grains. Effect of lower concentration of *E. balsamifera* and *L. inermis* on moisture content of stored sorghum grains was significantly the same as permethrin powder which concurs with Danjumma *et al.* (2009) who reported that moisture content of maize grain treated with 2 g/50 g *A. indica* and a chemical insecticide (coopex) was significantly the same.

The high moisture content in the control (damaged rains) corresponds to the findings of Okoroafor and Job (2017) who reported an increase in moisture content of yellow and white local maize varieties after 12 months of storage [22]. This increase in moisture content of damaged grains could be due to the fact that grain is a living organism that respires and emits moisture that moves within the grain mass. Prolonged stay of insects in the control could also increase respiratory activities in the grain and add more moisture content. This phenomenon was explained by USAID (2011) [23] that biological factors such as insects and moulds respire and can add to the moisture being released and migrating through the stack.

Ash content of the infested grains was significantly affected when treated with different botanical powders. Grains treated with permethrin lost little amount of ash, while in the control it was high. Similar results were reported by Danjumma *et al.* (2009) when maize grains were treated with coopex. The loss of ash content in sorghum treated with the selected botanicals was concentration dependent. This shows that the weevil's feeding and reproductive activities might have reduced the mineral content of the grains [14].

It was found that the untreated sorghum grains had more crude fibre than the treated grains, which concurs with Danjumma *et al.* (2009) who reported that maize grain treated with botanical powders of *A. indica, A. sativum, N. tabacum, O. basilicum* and *Z. officinale* had less crude fibre than the untreated grains. The increase in fibre content in untreated infested grains was as a result of feeding activities of the weevils on endosperm hollowing out the grain leaving only the bran, which is largely fibre. This finding agrees with Bamaiyi *et al.* (2006) who noted that insect infestations decreased the nutritional quality of grains and increased the relative level of dietary fibre [14]. Botanical concentration also affected crude fibre level in the stored sorghum. Higher concentration seemed to preserve more nutritional quality as there were low infestations, hence lower level of fibre than grains treated with lower concentration.

Loss in lipid content in sorghum grains was significantly reduced by the selected powders at the various concentrations. This is consistent to Danjumma *et al.* (2009) who found more crude fat in maize grains treated with some botanical powders than in untreated control [13]. There was drastic loss in crude lipid in untreated sorghum compared to the treated grains, supporting Jood *et al.* (1996) [24] that insect infestations resulted in substantial reduction in crude lipid content of stored grains. There was a reduction in crude lipid in white and yellow local maize varieties damaged by *S. zeamais* after 12 months of storage [22]. The reduction in crude lipid of untreated grains might probably be due to mass infestations by *S. zeamais* which were actively feeding on germ and endosperm of the grain. It was observed that loss in crude lipid increased with increased levels of insect infestations [14].

The decrease in total protein content in sorghum grains treated with botanicals of *E. balsamifera, L. inermis, M. hirtus* and *S. obtusifolia* was less than in untreated grains. It was found that higher concentration of *E. balsamifera* and *L. inermis* were the most effective. This was because the botanicals must have killed most of the weevils early before feeding on the grains, and served as antifeedants to the few that survived shortly, while in the control they survived for longer period and fed much on the grains. Therefore, as insect infestations increased, feeding activity increased and probably a decrease in the protein content of grains. Bamaiyi *et al.* (2006) [14] found that the endosperm component of maize grains contains 90% of seed protein, which is readily damaged by insects, and sorghum has protein content ranging from 7 to 15% [9]. Crude protein in white local maize was reduced from 9.65% to 8.86% in undamaged and damaged grains, respectively [22].

Carbohydrate content in sorghum grains was affected by the weevil's infestations and it was found that the selected botanicals reduced its loss. The untreated grains lost more carbohydrate than the treated ones, probably due to the fact that the insects were freely feeding on the untreated grains while the botanicals inhibited feeding and hence reduced feeding activities. Carbohydrates are important components of the diet for most insects as usual respiratory fuels, converted to lipid, provide carbon skeleton for the synthesis of various amino acids and the cuticle characteristically contains the polysaccharide chitin [25]. Consumption of more carbohydrate in the untreated grains was observed by Chapman [26] that insects feeding on stored products can use a wide range of carbohydrates.

Effects of Botanical Powders on Some Mineral Content of Sorghum Grains Infested by *S. zeamais*

There was substantial decrease in mineral content in infested grains compared to the botanical treatments. This could be due insect feeding which was hindered in the botanical treatments as a result of their antifeedant as well as toxicity effects against the weevils. This is in agreement with Jood and Kapoor (1993) [27] and Danjumma *et al.* (2009) who found that feeding by *S. zeamais* reduced the minerals content of maize grains. The minerals content also depended on botanical concentrations that higher amounts of the powders preserved more minerals than lower concentrations. It was found that permethrin powder was the most effective in reducing loss of mineral elements in infested sorghum grains followed by *E. balsamifera, L. inermis, M. hirtus* and *S. obtusifolia.* Similar results were reported by Danjumma *et al.* (2009) that botanical powders of *A. indica, A. sativum, N. tabacum, O. basilicum* and *Z. officinale* at different concentrations preserved more Na, K, Ca, Mg and P in infested maize grains than in untreated infested grains.

Conclusion

Findings of this study have revealed that leaf powders of *E. balsamifera, L. inermis, M. hirtus* and *S. obtusifolia* reduced losses in proximate composition and mineral contents of sorghum grains and hence, could serve as alternative means protecting sorghum from qualitative damage due to *S. zeamais* infestations which may probably contribute in solving cases of malnutrition especially in rural areas.

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