DETERMINATION OF EFFICACY OF NSPRIDUST® AS MAIZE PROTECTANT IN SILO

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ABSTRACT
The use of conventional silos for grain storage involves application of synthetic pesticides that produce harmful residue after use. This study was aimed at investigating the efficacy of NSPRIDUST® as a protectant for maize stored in silo with respect to insect control and quality maintenance. Maize treated with NSPRIDUST® in ratio 1:1000 (NSPRIDUST®: Maize) by mass was stored in 2 experimental silos of 500 kg loaded to 80% of its capacity. The NSPRIDUST® was applied to the maize using NSPRIDUST® applicator. Another set of 2 experimental silos were loaded with untreated maize to capacity to create hermetic condition (control). Five hundred (500) newly emerged unsexed adults of Sitophilus zeamais (primary insect pest of stored maize) were introduced into each silo in batches of one hundred (100) insects to ensure proper distribution of the as the grains were loaded. The maize was stored for 12 months and samples were drawn from the silos monthly to determine insect count, germinability and moisture content, while microbial loads and proximate composition were determined before and after the storage using standard laboratory methods. The result shows that the NSPRIDUST® treated maize had no live insect and suppressed F1 generation throughout the storage period depicting a 100% insect mortality, while insect mortality in the control were 75, 83.33 and 100% for the first, second and subsequent sampling months respectively. The effects of NSPRIDUST® on the live insect count, F1 emergence and moisture content of maize grains were statistically significant ($p < 0.05$). NSPRIDUST® caused reduction in bacteria load and fungal count by 80 and 73% respectively, and both were within the acceptable limit ($<0.3 \times 10^3$ cfu/g). It is an effective protectant for maize in silo storage as it maintained grain quality and suppressed proliferation of microbial loads during the storage. Therefore, the application of NSPRIDUST® as a grain protectant could be extended to silo storage of grain.

KEYWORDS: Conventional silos, NSPRIDUST®:Maize, Grain storage, Insect control, Quality control

1. INTRODUCTION

Maize (*Zea mays*) is a cereal crop that is grown widely throughout the world. It is a member of the grass family (*gramineae*) and it originated from South and Central America (Olaniyi and Adewale, 2012). Maize is produced in larger quantity than other grains in Nigeria (FAO, 2022). Africa produces 6.5% of the annual global tonnage, and the largest African producer is Nigeria with nearly 8 million tonnes per annum, followed by South Africa (Olaniyi and Adewole, 2012). Grain storage is an essential aspect in ensuring food security in the ever-increasing population of the

world. To ensure all year-round availability of grains in good condition, proper and effective storage is required.
Most smallholder farmers store maize grain using bags, cribs, rhombus, calabashes, gourds, underground, and earthenware pots (Adeduntan and Falayi, 2017). These are not efficient enough to keep maize safe from pests, rodents, extreme environmental factors and loss of nutritive value. One of the modern methods for storage of grains especially at commercial and industrial levels is the use of silos (Oyewole *et al.*, 2020). The use of conventional silos only cannot adequately address the issue of insect infestation in grains during storage. As a result, synthetic pesticides are usually used in conjunction with the conventional silo to prolong shelf life of grains. One of the only known silos that do not require the use of synthetic pesticides to keep grain safe over a long period is the improved inert atmosphere silo**®** developed by Nigerian Stored Products Research Institute (Oyebanji *et al.*, 2015; Okonkwo *et al.*, 2018; Oyewole *et al.*, 2020). Majority of West African farmers still protect their stored grain against insect attack mostly by application of synthetic, petroleum-based contact organophosphate (OP) and pyrethroid compounds, which may be applied singly or in combination. Use of phosphine emitting tablets is also widely practiced (Ojiako and Adesiyun, 2008). Regrettably, reckless misuse of these neurotoxic compounds by farmers and grain aggregators in Nigeria has led to accidental poisoning and death of several people (Ikpesu *et al.*, 2013).

Additionally, these chemicals have to be imported, are frequently unavailable, out of date (expired), adulterated or too expensive for smallholder farmers (Denloye *et al.*, 2007). There is a growing public aversion to their use in food grains. Several insect pests have also developed resistance to these conventional insecticides in Nigeria (Odeyemi *et al.*, 2010). Therefore, there is an urgent need for the introduction of cost effective and low-risk alternatives to synthetic insecticides that are compatible with Integrated Pest Management (IPM) approach for stored grain protection in Sub-Saharan Africa. One of the most promising alternatives to synthetic pesticides is the use of diatomaceous earths (DEs). Diatomaceous earth (DE) is a natural product mined from deposits of fossilised skeletal remains of diatoms, which inhabited marine and fresh water bodies (Vayias and Athanassiou, 2004). Diatomaceous earths leave no harmful residues on treated grains and have low mammalian toxicity (Stathers *et al*., 2004). DE absorbs lipids and abrades the epicuticular wax layer of insects, causing loss of body water and death within hours or days (Subramanyam and Roesli, 2000). DEs are potentially an attractive alternative for Nigerian smallholder farmers because they do not require specialized equipment or skills for application, have long term efficacy which arises from their high persistence (Athanassiou *et al.*, 2005). Vast deposits of DE have been discovered in Nigeria (RMRDCN, 2009).

Nigerian Stored Products Research Institute has developed a DE based grain protectant patented as NSPRIDUST® for storage of grain crops. Series of research works have been done at laboratory and pilot scales to establish the efficacy of the major raw material in NSPRIDUST® for stored products pest control (Nwaubani *et al.,* 2014; Otitodun *et al.*, 2015; Nwaubani *et al.*, 2020; Ala *et al.*, 2020; Otitodun *et al*., 2021). All the trials run so far are limited to bag storage. At present, most conventional silos are still being operated with synthetic pesticides. Treating grains to be stored in silos with NSPRIDUST**®** before storage will save people and environment from the challenges associated with synthetic pesticides. Therefore, the study was aimed at investigating the efficacy of NSPRIDUST**®** as a protectant for maize stored in silo with respect to insect control and quality maintenance.

2. MATERIALS AND METHODS

2.1 Storage of Maize

Pesticide free yellow maize variety (2.2 tonnes) was purchased from a local market (8.0537° N, 4.1484° E) in Odo-Oba Community, Nigeria for the experiment. The initial moisture content and microbial loads were determined. The maize was cleaned. Out of the grain, 800 kg was treated with NSPRIDUST® in ratio 1:1000 (NSPRIDUST®:Maize) by mass, and was uniformly mixed using NSPRIDUST® applicator. The applicator is an electrically powered mechanical device developed solely for application of the grain protectant (Figure 1).

Four experimental silos were used for the study. They were airtight metal silos of design capacity of 500 kg each. Two units of the silos (labeled A1 and A2) were loaded with treated maize and the other two units of the silo (labelled B1 and B2) were loaded with untreated maize respectively in an alternate arrangement (Figure 2). 400 kg of the treated maize was loaded into the silos A1 and A2, while B1 and B2 were loaded with 635 kg of untreated maize each to create a hermetic storage condition. 500 pieces of newly emerged unsexed adult live *Sitophilus zeamais* adults (primary pest of maize) were introduced into each of the four silos in batches of one hundred (100) insects when loading to ensure proper distribution of the insects. The maize was stored in the silos for 12 months and a sample spear probe was used to draw samples from the treatment and control monthly from different sides of the silos five (5) times (Figure 3) for insect count, germinability test and moisture content. Microbial loads evaluation and proximate analysis were also carried out on the samples at initial and termination of the storage.

Figure 1: NSPRIDUST® applicator for admixture of grains with NSPRIDUST®

Figure 2: Set-up of the experiment

Figure 3: Sampling of grains from silo

2.2 Determination of Proximate Compositions and Microbial Loads

The moisture content of the maize was determined on monthly basis for twelve months while proximate compositions which covered ash, crude protein, crude fibre, crude fat and carbohydrate were determined at the initial and termination of the storage using standard analysis methods of Association of Analytical Chemist (AOAC) (2000). The microbial loads in samples were determined using Manuals of Food Quality Control (FAO, 1997).

2.3 Insect Count and Germinability Test

Entomological parameters carried out on monthly basis were insect count and germinability for a period of eight months. The method described by Adedire and Akinkurolere (2015) was adopted for the germinability test.

2.4 Statistical Analysis

Data obtained were subjected to mixed model ANOVA to test for significant difference (P<0.05) using SPSS version 25.0.0 software package (IBM Statistics).

3. RESULTS AND DISCUSSION

3.1 Effects of NSPRIDUST® on Insect Population

The effects of NSPRIDUST® on insect population in the silos are shown in Figure 4. After a month of storage, the population of insects in the control (hermetic condition) was 167% more than the population in the treated grain. The maximum number of insects drawn from the control was at the fourth month of storage with an average count of 11 insects. This gave a population increase of 1000%. The highest insect count from the treatment was at the second month with an average count of 4 and was 33% lower than that of the control. There were fewer insects per sample per month in the drawn samples from the maize treated with NSPRIDUST® than the control. NSPRIDUST® did not permit the insects to survive beyond the first month, and that was responsible for the fewer insect population recorded in the sample. Progeny suppression was 100% in the treated grain. This could be as a result of suppression of progeny by NSPRIDUST®, which agrees with submissions of Nwaubani *et al.* (2014) and Otitodun *et al.* (2015), that DE which is the major ingredient in NSPRIDUST® is effective in causing insect mortalities and suppression of progeny. The ANOVA showed that there was no significant difference in number of insects found in the NSPRIDUST® treated maize and the control (P < 0.05).

The result showed that samples of the treated grain had no live insect throughout the sampling period despite the presence of oxygen that enhances ecological succession of insect pests due to the headspace available in silos A1 and A2. This suggests that NSPRIDUST® has a 100% insect mortality. Live insects were found in the control in the first two months of storage despite the hermetic condition, thereafter, no live insect was found (Figure 5). This could be as a result of reduced oxygen and feeding activities of the insects (Murdock *et al.*, 2012 and Navarro, 2012) due to the hermetic condition in the control silos. The difference in number of live insects found in the NSPRIDUST® treated maize and the control was significant (P<0.05).

The higher number of dead insects found in the control is an indication that there was population increase as a result of the progenies from the insects. Statistical analysis showed that the number of dead insects in the treatment and the control over time were not the same (P<0.05). The 100% insect mortality recorded by NSPRIDUST® allowed no F1 generation emergence from samples of the treated maize. However, F1 generation emerged in samples from the untreated maize with highest number of 13 insects after the first month of storage. Progeny suppression was 100% in the treated grain (Figure 6). This indicates that the protection offered by NSPRIDUST® continued even after the removal of the sample from the silos.

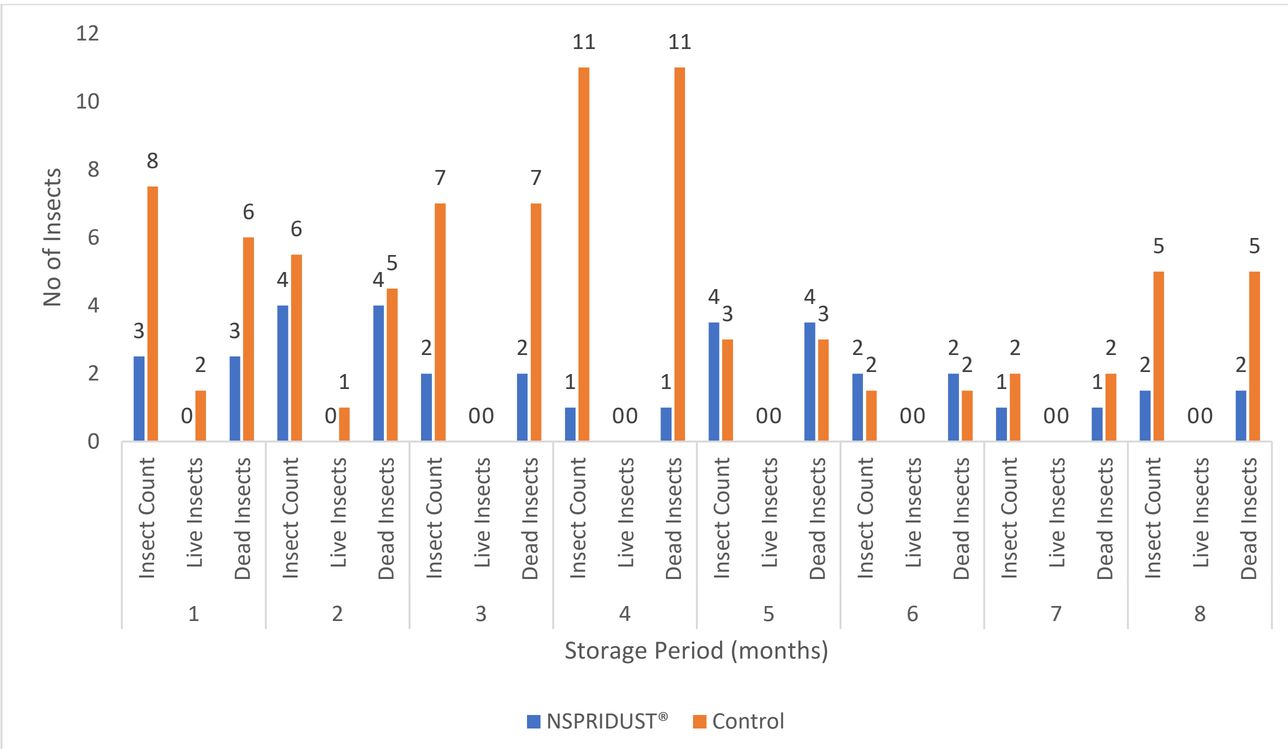

Figure 4: Effect of NSPRIDUST® on insect population in maize stored in silo.

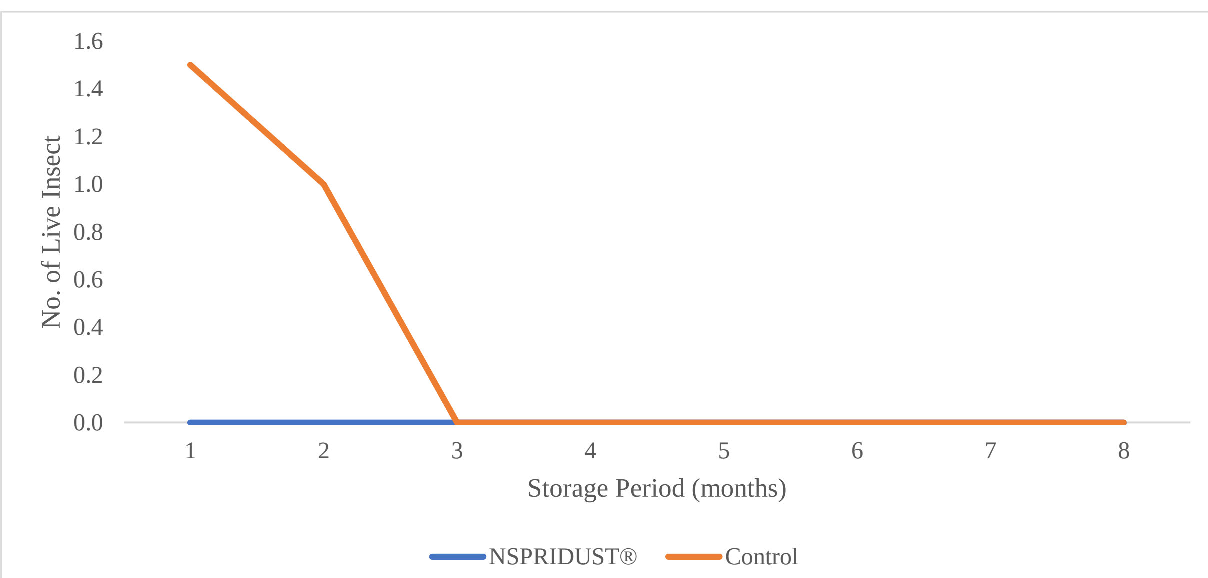

Figure 5: Effect of NSPRIDUST® on live insect population

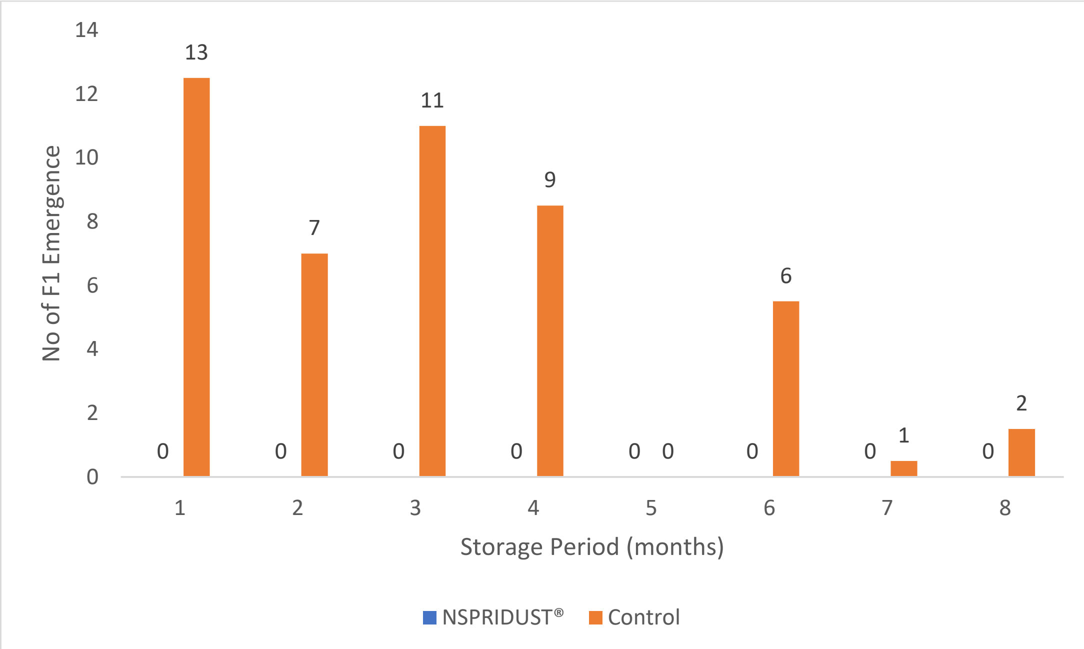

Figure 6: Effect of NSPRIDUST® on F1 emergence in maize stored in silo.

3.2 Effect of NSPRIDUST® on Germinability

There was no significant difference in the means of the germinability of NSPRIDUST® treated maize and the control ($P<0.05$), but samples from both treated and untreated maize gave high germinability of not less than 94% for the eight months considered for this parameter (Table 1). This suggests that NSPRIDUST® and hermetic storage were able to maintain the germinability of the stored maize grains for 8 months.

Table 1: Germinability of stored maize grains

Months	NSPRIDUST® Treated Grain (%)	Control Grain (%)
1	98	97
2	99	96
3	100	95
4	98	94
5	98	97
6	96	96
7	94	96
8	94	95
Average	**97**	**96**

3.3 Effect of NSPRIDUST® on Moisture Content

The initial moisture content of the maize before treatment and storage was 13.40 % (dry basis (db)). Moisture content ranged from 12.64 (3rd month) to 15.44 % (db) (11th month) for the treated grains and 11.59 (2nd month) to 14.95 % (db) (11th month) for the control (Figure 7). The varying increase in moisture content could be attributed to aerobic respiration of stored maize which produces CO_2 and H_2O (Mhiko, 2012). Analysis showed that the differences in moisture content of NSPRIDUST® treated maize and the control were significant ($P < 0.05$). However, the moisture contents for the treated and control grains were not above the safe moisture content of 16% (dry basis) for bulk storage (Huang *et al.*, 2013).

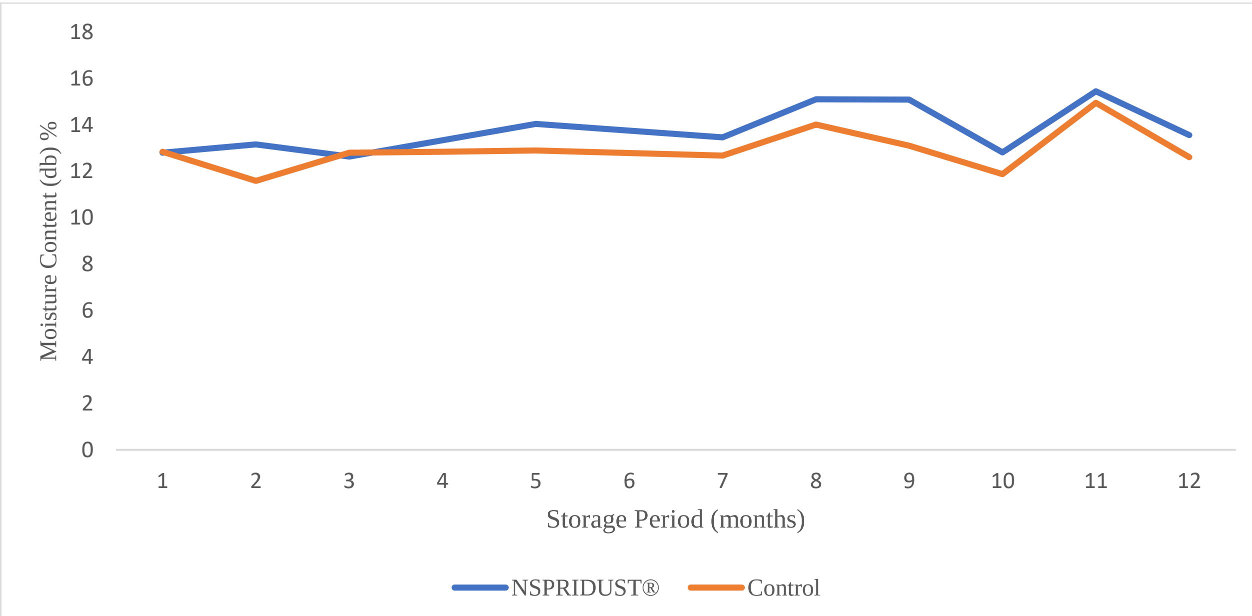

Figure 7: Moisture contents of stored maize

3.4 Effect of NSPRIDUST® on Microbial Loads

The mean viable bacteria count after 12 months of storage was 0.12 x 10^3 cfu/g for treated maize and 0.16 x 10^3 cfu/g for control as compared to the initial bacteria count of 0.6 x 10^3 cfu/g. The mean fungal counts after 12 months of storage were 0.12 x 10^3 cfu/g for treated maize and 0.25 x 10^3 cfu/g for control, while the initial fungal count was 0.5 x 10^3 cfu/g (Table 2). The total viable count and fungal count for both the treatment and the control were below the acceptable standard (<0.3 x 10^3 cfu/g). NSPRIDUST® caused reduction in bacteria load and fungal count by 80 and 73% respectively, while the hermetic condition brought reductions of 76 and 50% in bacteria load and fungal count respectively. It could be deduced from the results that both NSPRIDUST® and hermetic condition (control) significantly reduced the microbial loads from 0.6 x 10^3 cfu/g to values within the acceptable standard (ICMSF, 2002). This result is in conformity with the report of a maize storage in inert atmosphere silo where reduction in microbial load was recorded (Oyewole *et al.*, 2020).

Table 2: Microbial loads of maize samples

Parameter	Treatment	Initial	Final
Bacteria (cfu/g)	**NSPRIDUST®**	0.60×10^3	0.12×10^3
	Control	0.60×10^3	0.12×10^3
Fungi (cfu/g)	**NSPRIDUST®**	0.50×10^3	0.16×10^3
	Control	0.50×10^3	0.25×10^3

3.5 Effect of NSPRIDUST® on Proximate Compositions

The initial proximate compositions were 1.83% (ash), 5.09% (fat), 1.83% (fibre), 7.65% (protein) and 72.97% (carbohydrate). The ash, fat, fibre, protein and carbohydrate contents for the treatment and control after 12 months were 2.02 and 1.43%, 4.24 and 4.83%, 2.26 and 2.33%, 12.7 and 12.12%, and 66.87 and 68.00% respectively (Figure 8). There was decrease in fat and carbohydrate content of the treated and the control grains, compared to the initial values which are in agreement with studies by Polat (2015) and Befikadu *et al.* (2015). Oyewole *et al.* (2020) also reported a drop in crude fat of maize stored inert atmosphere silo for six months.

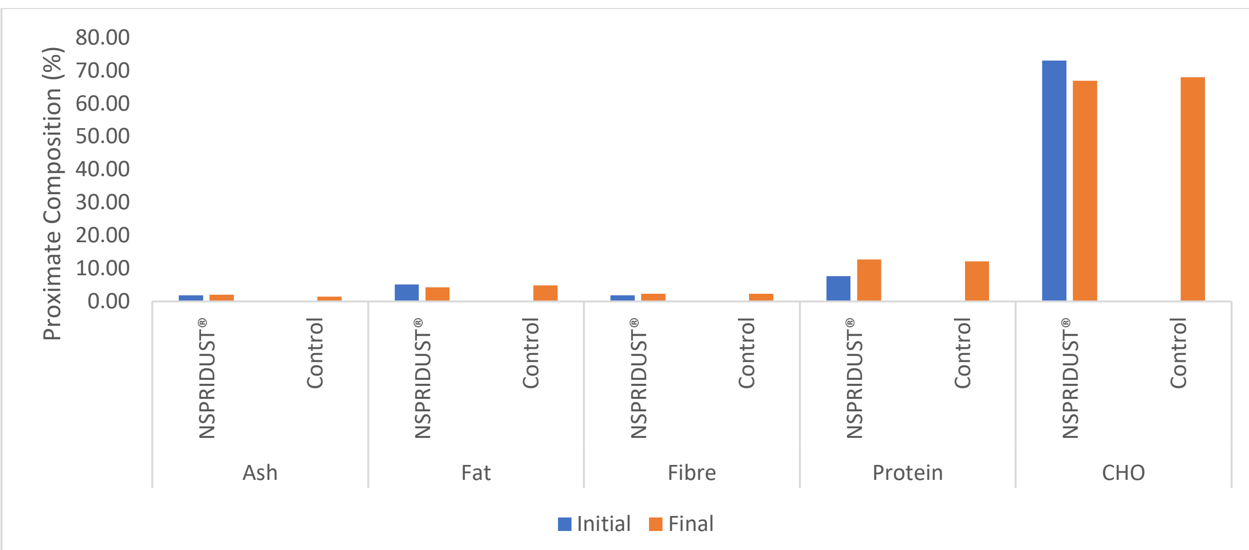

Figure 8: Proximate compositions of the maize at initial and termination of the storage experiment

4. CONCLUSION

There was 100% insect mortality without emergence of progeny throughout the study period in the NSPRIDUST® treated grains. The moisture content and proximate compositions of the maize were not negatively impacted by NSPRIDUST®**.** In addition, it exhibited greater potential in curtailing proliferation of microbial loads during the storage. It could be concluded that NSPRIDUST® could be applied to maize storage in silo. Its application could also be extended to seed storage in silo because the germinability of the maize was not negatively impacted.

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