from wood and alfafa feedstaock against *Bactrocera oleaebirch* revealed that 100% of the LS from both materials greatly repelled the insects. The results were similar for LS produced at both 300 and 500 °C. Reppelence effect from individual chemical components like furfural, syringol, acetic acid, and methanol is short span compared to their combined effect. In another study by Urrutia *et al.* [24] which used LS from sunflower seed hulls against L. serricorne and *T.castaneum*, LS applied at 1 mg cm $^{-2}$ was found to cause a repellence effect on both insects. They added that LS also triggered taxi responses, thus causing the insect to move further away from the LS site. Butanoic acid (Allyl N-Butanoate) and Hydrazine, 1,1-dimethyl from the results of the GCMS analysis in Table 1 were found to be very volatile with a strong odor that can repel insects.

C. Percentage Bean Damage, Weightloss, Moisture Content, and FDI of treatments

From the results in Table 3, the beans treated with 100% LS recorded the most negligible amounts of damage, although this was not significantly different ($P > 0.05$) from beans treated with other levels of LS (10- 50%). The percentage of beans weight loss also reduced significantly ($P < 0.05$) as the level of treatment was increased from 0% to 100%. The feeding deterrence effect also increased steadily as the concentration of LS treatment was increased. Treatment with 100% LS recorded the highest antifeedant effect of approximately 90%. Although the moisture content of beans before treatment was 6.7 %, it decreased slightly (insignificantly) after two weeks of treatment. This implies the individual treatments did not contribute to any significant change in the bean's moisture content. The data also suggest that the weight loss recorded can be largely attributed to the activity of insects rather than a loss in moisture content. Another measure to make sure weight loss observed is basically due to damage from insects was the use of the count and weigh method for calculating weight loss[23].

TABLE III
DATA ± STANDARD ERROR (SE) OF DAMAGE, WEIGHTLOSS, FDI, AND MOISTURE CONTENT OF COCOA BEANS

Trmt (%)	Damaged beans (%)	Weight loss (%)	FDI (%)	Moisture Content (%)
Cont	21.99±3.11^{a}	2.13 ± 0.25^{a}	0.00±0.00 ^{e}	6.44±0.41^{a}
10	9.57 ±1.47^{b}	1.35 ± 0.47 ^{b}	24.43±15.07^{d}	6.69± 0.30^{a}
20	10.50 ± 2.60 ^{b}	0.85 ±0.34^{bc}	44.30±16.06^{bc}	6.59± 0.23^{a}
50	9.54 ±2.08 ^{b}	0.39± 0.28^{cd}	70.15±17.81^{ab}	6.47 ± 0.00^{a}
100	7.65 ±1.10^{b}	0.11± 0.02^{d}	90.06 ±2.66^{a}	6.56 ± 0.25 ^{a}
StDev	1.889	0.3142	12.72	0.2717

Different superscript letters within a column represent a significant difference in observation within the column (P < 0.05)

Feeding deterrence is usually targeted at the taste receptors of the insect pest. Aromatic compounds in the LS cause deterrent receptors in the insects to be stimulated to send signals to the central nervous system, blocking or interrupting the insect's perception of feeding. According to Arivoli and Tennyson [33], other antifeedant mechanisms can cause an eruption of electrical impulses that make insects unable to acquire accurate taste information to put up a suitable feeding approach. In another trial, Sapindal *et al.* [34] treated 3rd instar larvae of diamondback moth with LS from *Azadirachta excelsa*, 1% LS treatment caused about 50% reduction in the feeding of the insects. They concluded that LS from *A. excelsa* functioned as a chemoreceptor that disrupted and choked receptor cells, preventing the larva's feeding stimulus. In a review article on how volatile compounds can protect agriculture commodities in storage against insect pest attack, Singh *et al.* [11] mentioned that volatile compounds' repellence and antifeedant properties make the commodities look offensive, unpalatable, and unappealing. The antifeedants, in particular, induce either temporal or permanent cessation of feeding. The activities ultimately keep the item intact from damage and losses. Another outstanding benefit of using volatiles for pest control is the maintenance of ecological balance by not eliminating the natural enemies of insect pests. In a system where there is zero-tolerance for both dead and live insects in produces, volatiles substances like LS can be very useful in controlling the pest. Recent technological developments in the field have seen the blending of lignin fractions of biomass with high-density polyethylene (HDPE) to build insect repellent packaging and storage materials for food commodities [35].

D. FFA and PH of Cocoa Beans

The data in Table 4 shows that the cocoa bean samples' free fatty acids (FFA) remained the same regardless of LS concentration changes (treatments). The pH values showed some significant changes, but the changes did not follow any particular trend nor correlate with the various LS concentration treatments.

TABLE IV
DATA ± STANDARD ERROR (SE) OF PERCENTAGE FFA AND PH OF COCOA BEANS

Treatment (%)	FFA (%)	pH
Control	1.2833±0.1576 ^{a}	6.6650±0.0129 ^{a}
10	1.0511±0.1455 ^{a}	6.6125±0.0050 ^{b}
20	1.1741±0.1941 ^{a}	6.5800±0.0141^{c}
50	1.2194±0.1056 ^{a}	6.5925±0.0126^{bc}
100	1.3143±0.1781 ^{a}	6.5950±0.0058^{bc}
St Dev	0.1591	0.0108

Different superscript letters within a column represent a significant difference in observation within the column (P < 0.05)

According to Mounjouenpou *et al.*[25] FFA value of beans reflect the level of triglycerides degradation in cocoa butter. The high FFA content of a cocoa bean often results from poor postharvest handling, which triggers microbial lipase to facilitate the release of fatty acids from the triglyceride in cocoa butter.

Some of the known causes of high FFA (> 1.75) include beans from diseased pods, slow drying of the bean, broken beans, extended storage in damp environments, storing beans with high moisture content (> 8%), an infestation of insect pest and general physical integrity loss of the cocoa beans [36]. In another FFA study of cocoa beans, Oyewo and Amo [37] reported that beans damaged by insects recorded higher FFA beyond acceptable limits in contrast to intact beans, but Servent *et al.* [38] attributed FFA change to genotype and origin of the cocoa.

The cocoa bean used in the present study was guarded against all the above risks that could increase FFA content except for insect infestation. That notwithstanding, the figures recorded still fell within the acceptable limit (<1.75). The possible reason for the observation could be because the storage period (2 weeks) was not long enough to allow damage caused by the insect to transform into FFA increase. This assertion is also backed by the control samples, which suffered significant insect damage yet recorded the same FFA as the treated samples. The fermentation process primarily influences the pH of cocoa beans. This occurs from the production of acetic and lactic acid. Proper drying, however, has been reported to serve as a remedy for acidic (pH<5) beans resulting from faulty fermentation [38].

From both FFA and pH data, it can be inferred that treatment with LS did not cause any significant change in both quality parameters.

E. Taste and Aroma Preference Test

The preference test on the taste and aroma of beans showed that most panelists were indifferent about the acceptability of the taste of the cocoa beans (Table 5). For aroma, panelists slightly accepted the control (0%) and 10% concentration sample. They were indifferent about the aroma of the remaining samples' (20%, 50%, and 100%). The choices made by the panelist did not correlate with the concentration levels of treatment. Therefore, the sheer absence of dislike among the responses proves that LS treatment did not cause any significant deterioration in the taste and aroma properties of the beans.

According to Lemarcq *et al.* [39], heat treatment at 150°C during roasting eliminates some undesirable volatiles compounds and reduces the moisture content to about 1 %. It also triggers a Maillard reaction in which flavor compounds are formed, giving roasted beans a new flavor (roasty & sweet) that is different from that of the unroasted one. LS usage as biopesticide has been primarily restricted to field crop protection and other non-food uses due to concerns over safety and the smoky smell it can produce in food. According to this study, treatment of stored cocoa beans can be an exception due to the thermal treatment process that helps evaporate the aroma residue.

TABLE V
DATA ± STANDARD ERROR (SE) OF TASTE AND AROMA ACCEPTABILITY OF COCOA BEANS

Treatment	**Taste**	**Aroma**
Control	3.83[a]	5.08[a]
10%	3.75[a]	4.88[a]
20%	3.70[a]	4.00[b]
50%	3.68[a]	3.83[b]
100%	3.60[a]	4.43[ab]
St Dev.	0.569	0.116

*Different superscript letters within a column represent a significant difference in observation within the column ($P < 0.05$) . **Key** 1. strongly dislike 2. Moderately dislike 3. Slightly dislike 4. Indifferent 5. Slightly liked 6. Moderately liked 7. Strongly liked.*

F. Identification of Flavour Attributes

According to Quelal-vásconez and Pérez-esteve [36], flavor attributes in cocoa beans are formed from a combination of physical and chemical parameters. While the physical is mostly about the integrity of the beans, the chemical encompasses the volatile and nonvolatile compound constituents. The saccharides (Monosaccharides, disaccharides, oligosaccharides) contribute a sweet taste, while fatty acids result in acidic flavors.

As shown in Figure 3, the test for identifying some basic flavor attributes revealed that all samples, regardless of the LS concentration treatment, shared similar flavor attributes.

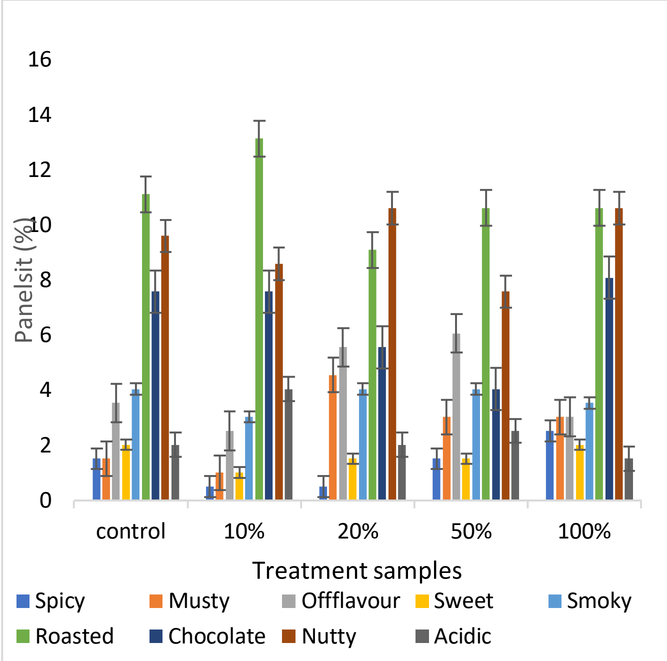

Fig. 3 Results of panelist perception of flavor attributes of various samples

Most panelists, regardless of treatments, choose roasty and musty as the detected flavors across the board. The smoky flavor was also detected by a similar number of panelists across all treatment samples, including control (without LS treatment). This infers that the LS treatment did not induce the smoky flavor perceived by the panelist. According to Urbańska and Kowalska [40]**,** acidity, Woody, Spicy, bitter, astringency, Sweet, fruity (Fresh Fruit), floral, nutty, and roasted flavors are the standard flavor attributes used in the flavor test.

It is important to note that the present test is not a standard test to build a cocoa flavor profile but rather to identify whether the LS treatment left any noticeable level of smoky flavor in the roasted beans. Therefore, the present results seek to point out that LS treatment of stored cocoa beans does not produce a smoky flavor in roasted beans.

IV. CONCLUSION

GCMS analysis of the liquid smoke detected 20 compounds represented in different concentrations. Allyl N-butanoate and Hydrazine, 1,1-dimethyl compounds, possessed a strong odor, with a high potential for insect repellent. LS at 100% concentration showed a powerful repellence effect, repelling almost 90% of the insect population. The repellence effect of 10, 20, and 50% LS similarly repelled about 50% of the larval population.

The feeding deterrence index (FDI) effect was also highest, with the 100% LS treatment repelling almost 90% of the larval population. This was, however, not significantly different from the performance of the LS with 50% concentration. The antifeedant effect caused a reduction in bean damage from 22% in control to 7.65% for 100% LS-treated beans. Weight loss was also reduced from 2.13% in control to 0.11 % in 100% LS.

Further quality checks on the beans show that LS treatment at all concentration levels did not cause any significant change in the FFA and pH content of the beans. The organoleptic test also proved that LS treatment caused no significant change in the flavor and overall acceptance of beans taste and aroma.

In conclusion, spraying the outer surface of jute sacks containing cocoa beans with LS can considerably protect the beans against attack by storage pests (Corcyra) and preserve quality. Liquid smoke, therefore, has the potential to be developed into an effective and sustainable biopesticide.

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