Profitability of Biopesticide formulations from Piper Guineense for the control of Storage Pests

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Abstract
Storage pests attack food crops kept in storage for future use leading to food loss, food shortage, health hazard, loss of income for the farmers and other stakeholders involved in agricultural supply chain and value chain. The long known method of controlling storage pests with synthetic pesticide is now being abandoned in favour of plant-origin pesticide as a result of the advantages the latter is said to have over the former. The study assessed the profitability of formulating biopesticide from Piper guineense for the control of storage pests using the budgetary analysis involving total costs incurred and the expected revenue. The total variable cost incurred in the production is ₦2900, total fixed cost is ₦400, making the total cost of production to be₦3300. Revenue from the production/sale of the formulated biopesticide stands at ₦5320. The profitability of formulating the biopesticide was estimated by calculating several values such as profit or net margin, gross margin, rate of return, cost benefit ratio. The results gave a rate of return of 0.61 and a cost benefit ratio of 1.61 indicating that formulating biopesticide with Piper guineense is profitable, efficient, worthy of investment and expansion for the use of farmers and others in the business of stored produce. A large scale production of the biopesticide will help to reduce the cost of production, price of the biopesticide and increase the producer's revenue and profit.
Keywords: profitability, biopesticide, *Piper guineense,* excipients, storage pests

Introduction

Storage pests are organisms which attack agricultural produce in storage, either in the silo, crib, barn, stall, storage bags and even in buckets and other forms of containers where agricultural produce are kept for preservation and future use. Keeping agricultural produce in storage will ensure having a continuous supply of the produce at stable price especially during the off season (Chatterjee & Chakraborty, 2022). Storage pests cause a lot of qualitative and quantitative damage to such stored produce by feeding on it and or excreting on the stored produce leaving the produce with an undesirable smell and taste thereby reducing the economic value of the produce (Deshwal*et al*, 2020; Dawodu*et al*., 2021; Nihal, 2022).The loss in value of stored produce due to depreciation resulting from pest infestation or other foreign products is known as dockage (Nihal, 2022). Besides, this makes way for bio-deterioration as a result of secondary pathogens and fungal growth on the stored produce (Pandey*et al*., 2023). Furthermore, the agricultural produce becomes unsuitable for human consumption and often initiate allergic reactions and poisoning in man (Ogunkoya& Dawodu, 2014).

Similarly, storage pests attack stored produce for food and habitat and destroy storage containers as well thus causing various kinds of losses to the storage (Babarinde*et al*, 2021; Dawodu*et al*. 2022a). The ease of causing damage to stored produce by storage pestsdepends on factors such as the moisture content of the stored produce, quality of the stored produce, length of storage time, storage containers and climatic conditions (Belay *et al.*, 2017; Fufa*et al.*, 2020). The quantitative losses caused by storage pests include loss of weight in kernels, pulses, cerealwhile the qualitative losses are reflective in the quantity of aminoacid present in grains like rice, loss of seed viability, biochemical degradation, loss of calorific value and loss of the sweet taste

(Deepak and Prasanta, 2017; Fufa*et al* 2020).

According to Fufa*et al*., (2020), the introduction of pests into storage often starts from the field, although other sources of pest invasion ranges from storage under poor condition, when infested produce are stored with healthy produce, when a 'carrier' of the pest visits the store and unknowingly deposits the pests into the store or perhaps when infested storage is used without cleaning and disinfecting (Azam*et al*., 2017). According to Nihal (2022); Islam *et al*.(2024), the possibility of pest infestation also has a relationship with the storability of farm produce as it affects the moisture content, biological condition of the environment such as the relative humidity, temperature, morpho-chemical properties of the stored produce (such as the texture, thickness, hardness, amylase and protein content of the stored produce), the type of storage facility used, period of storage, state of the stored produce, the ability of the stored produce to either loose or gain moisture.

The infestation of storage pests on stored agricultural produce account for a huge percentage of post-harvest losses leading to the loss of huge amount of money year in year out. According to Nihal (2022), storage pest account for 10% of post-harvest losses worldwide due to their attack on stored agricultural produce. Deshwal*et al* (2020), storage pest infestation account for 10% of post-harvest losses in India. The sources of storage pest include old container, storage structure, old bag, cross over infestation, transfer of pathogen from the field to the store, infested harvesting and processing machines, opening in the wall of the storage room, spread of infestation from stored grains, through wind-blown in from the surrounding, nests and burrows of pathogens such as rodents and birds (Deshwal*et al*., 2020; Chartterjee& Chakraborty, 2022). It is therefore of great economic importance to control the establishment and spread of storage pest.

The presence and destructive activities of pests in stored produce can go unnoticed for a long period of time since the produce is not required for immediate but future use (Ogunkoya& Dawodu, 2014). However, the signs of the presence of pests' infestation can be

made known when large quantities of pests are seen walking on the wall of the storage room or there are noticeable large holes on the grains or when the powdery form of the stored product is noticed below the product in the storage bowl/container or by the presence of cobweb in the storage area or container (Goma, *et al*., 2022). Pests also destroy stored produce by making holes on the grains thereby reducing the grains to shell and reducing the market value of the produce, can also cause the rotting away of the tuber and or a reduction in the viability of the produce. Pests also destroy the sweet smell and taste of the produce by excreting on the produce (Nihal, 2022).

Storage pests include vertebrates such as rodents and birds, arthropods such as insects and mites, microorganism such as bacteria and fungi (Deshwal et al, 2020; Dawodu*et al*, 2022) insects pest include beetles, moths etc. non-insect pest include mites. Storage pests can further be classified into primary and secondary pests (Deshwal, 2020; Nihal, 2022). Primary pests attack the healthy, uninfected crop produce while the secondary pests attack the already infested, damaged crops in the store (Chartterjee and Chakraborty, 2022). Examples of primary pests include pulse beetle, rice weevil, sweet potato weevil, lesser grain borer, grain moth, etc., while the examples of secondary pests are saw toothed grain moth, rice moth.

According to Deshwal et al (2020), there are almost 10,000 species of storage insects globally which infest agricultural produce in storage including the orders Lepidoptera and Coleoptera. Other scholars agreed that some pests of the order Psocoptera also attack stored produce (Kawasaki, 2018; Chartterjee& Chakraborty, 2022; Nihal, 2022). Deshwal*et al* (2020), identified specific examples of storage pests to include rice weevil (*Sitophilusoryzae*), lesser grain borer (*Rhyzoperthadominaca*), red flour beetle (*Troboliumcastaneuum*), pulse beetle (*Callosbruchusmaculatus*), angoumois grain moth (*Sitotrogacereallela*), rice moth (*Corcyra cephalonica*), almond moth (*Cadracautella*). Mites also attack stored produce. Other storage pests include wheat grain psocid (*Liposcelisspp*), Mediterranean flour moth (*Ephestiakuehniella*,),Yellow mealworm (*Tenebriomolitor*), Saw-toothed grain beetle (*Oryzaephilussurinamensis*,), Cabinet beetle (*Trogodermagranarium*), Hide beetle (*Demestes maculates*) (Olowo &Dawodu, 2014; Babarinde *et al*., 2016; Dawodu*et al.,* 2022)

Losses recorded from stored products as a result of pest infestation has been a challenge to farmers, middlemen, processors, consumers and all others involved in the trade and use of agricultural produce in store (Idoko &Ileke, 2020; Ileke&Ojomo, 2024). As a result of these losses, researchers are challenged to look for ways of preventing and controlling pest infestation in storage in order to minimise food losses and to improve the keeping quality of stored produce (Rammal & Elhajj, 2023). There are several ways of controlling storage pests. According to Charttejee& Chakraborty (2022), pests in storage can be managed or controlled by employing two broad terms which are both preventive and curative methods. Ileke&Ojomo, (2024) suggested preventive methods such as sweeping and washing the storage, and emptying out the dirt before storing the farm produce therein, closing and plastering the opening in the wall, washing the store with white repellent, storing the produce at the right moisture content in ventilated areas, fortifying the storage to be rat and or moisture proof. Similarly, preventive measures include stacking storage bags to allow for ventilation and ease of movement for intermittent inspection, using pesticide to treat the farm produce, storage bags, room or container before using such for storage (Islam *et al*., 2024). Applying preventive measures to prevent the attack and infestation of storage pests is preferred to using curative method. However, where the preventive method is not sufficient or efficient, curative method must be used.

Curative methods involve the use of ecological control measures such as control of the moisture content of the grain, temperature and available oxygen in the environment of the grain(Tyagi*et al*, 2015; Chartterjee& Chakraborty, 2022). It also involved the use of mechanical control method which encompasses the use of traps to catch the pests in the store.

Furthermore, curative method could be enhanced by using chemical control methods such as the prophylactic treatments, fumigation and treatment of seeds with novel insecticides. Similarly, biological control measures such as the use of semiochemicals, botanicals and biopesticides are also curative in nature (Rajasri & Kavitha, 2015).

Though the use of the synthetic pesticide has been noted for its quick action in fumigating the storage, the attending negative effects have also been noted to include high cost of purchase, development of resistance of the crop pests to the pesticide, toxicity of the pesticide to man, his crop, animal and environment (Idoko &Ileke, 2020; Dawodu*et al*, 2022;Charttejee& Chakraborty, 2022). Therefore, lots of researches are being carried out to find alternative means of controlling storage pest with a substance that is friendly to man and his environment. This has led to the discovery and development of materials of plant origin, with natural pungent smell which can control pests of agricultural produce which are referred to as biopesticides (Olaifa&Erhun, 1988). The use of natural compounds of plant-origin which are used as pesticide to control storage pests have been reported to have several advantages over synthetic pesticides. The advantages have been identified to include abundance, readily available and accessibility to the plant, non-toxicity to man and his environment, rapid degradation of the biopesticides and its zero negative effect on the stored plant, prolonged protection (Abd El-Aziz, 2011; Chatterjee & Chakraborty, 2022).

According to several authors, (Onuh et al, 2008; Abd El Aziz, 2011; Effiong &Ochagu, 2019; Chatterjee & Chakraborty, 2022; Alagbe*et al*, 2021; Dawodu*et al*, 2022b), many naturally occurring plants have the potentials of being used to formulate dusts, oil or powders which can be used to control storage pests. These plants include *Dennettiatripetala*, *Azadirachtaindica*, *Ocimumviridis*, *O. gratissimum*, *Piper guineense*, *Rosemarinusofficinalis*.

In Nigeria, *Piper guineense* is commonly called ‘iyere’, ‘uziza’, ‘masoro’ by (Yoruba, Igbo and Hausa speaking tribes) respectively, while it is referred to as ‘sorowisa’ by the Ghanaians. In other parts of the world, it is called other different common names including West African black pepper, Ashanti pepper, Benin pepper, false cubeb, Guinea pepper (Alagbe*et al*, 2021). It is commonly found in Nigeria, Ghana, Guinea, Uganda and other countries within the wet forest fringe. *P. guineense* is a perennial, flowering woody climbing plant. It can climb up to a height of 12m on trees with the aid of its adventitious rootlets. The plant has greenish yellow flowers and oval-shaped fruits which is about 5mm in diameter and red in colour when ripe but black when dried (Effiong &Ochagu, 2019; Alagbe*et al*, 2021).

P. guineense is said to have some verified pharmacological and therapeutic properties such as spice, anti-oxidant, anti-inflammatory, anti-convulsant, anti-aphrodisiac, anti-microbial, anti-nutrients, anti-parasitic, anti-insecticidal, pesticides properties (Chinwendu *etal*, 2016; Effiong &Ochagu, 2019; Alagbe*et al*, 2021). The usefulness of *P.guineense* as a pesticide has been reported by several authors. For example, the use of aqueous extract of *P.guineense*has been reported to be effective in the control of the larvae of *Plutellaxylostella*in beans, egg viability of *Marucavitrata*and *Clavigrallatomentosicollis* in banana and plantain crops, pulverised leaves inhibits the hatching of eggs and emergence of adult of *Dermestesmaculatus* in stored smoked catfish, essential oil from the seeds of *P. guineense* is also said to be efficacious against *Triboliumcastanuem* of stored millet seeds, the odour of the plant has also been confirmed to repel *Sitophiluszeamais*adult weevil of maize, powders from the seeds have also been reported to control mould fungus in maize (Lale & Yusuf, 2001; Onuh et al, 2008; Olowo & Dawodu, 2014; Benson *et al*, 2019; Alagbe*et al*, 2021).

The advantages of using *P. guineense* in controlling storage pests have been listed to include zero alteration of the colour, texture, taste and or the nutritional composition of the agricultural produce after being protected with the oil, extract, and powders of *P. guineense*(Onuh et al 2008; Asawalam et al, 2012; Benson *et al*, 2019, Dawodu, 2022).

Furthermore, the method employed in controlling pest must be one that is effective, economical and prioritize prevention of food contamination and safe for man consumption.

In a study conducted by Onuh *et al* (2008), to test the efficacy of *P.guineense* in the control of mould fungus in stored maize seeds, the results showed that the powder extract of *P.guineense* had significant effect ($P < 0.05$) in the mean number of live weevils recorded in the different levels of the powder extract and the control experiment. The study confirmed that the level of significance of the powder of *P.guineense* in the control of mould fungus increased with increase in the concentration of the powder.

Benson *et al* (2019), evaluated the effect of *P.guineense* in the control of cowpea storage weevils and its implication for sustainable credit advancement. The study observed the contact toxicity of *P. guineense* at 0.2, 0.4, 0.6, 0.8 and 1 g per 20 g of cowpea seeds in test tubes including a control. It was observed that the treatment materials exhibited significant efficacy from 24 hours after infestation. The study showed that*P. guineense* at 1g concentration significantly reduced the oviposition potential, egg hatching rate, holes and emergence of adult *Callosobruchusmaculatus* on treated seeds. The study concluded that the powders caused chronic toxicity and inhibited development of cowpea weevil. Also, the increase in the rates of *P. guineense* increases its effectiveness of the control.

Given the advocacy to use *Piper guineense* as a biopesticide in controlling and combating storage pests of agricultural produce, there is a need to assess its profitability. This study therefore aims to estimate the cost of producing biopesticide with *P.guineense*; estimate the expected revenue from the sale of *P.guineense*biopesticide powder; and determine the profitability of producing biopesticide using the powder of *P.guineense.*

Profitability is the difference between the cost incurred in the production activities and the revenue realised from the sale of the outputfrom the production activities. Profitability shows the costs incurred in the production process and the expected revenue from the sale of the produce and the difference between the cost and the revenue (Bumbescu, 2015). Profitability can thus be said to be a measure of the results of production activities (Aturamu*et al*., 2021). The resultant effect of profitability is shown by the profit such as the net profit (Bumbescu, 2015).

According to Isfanescu*et al*, (2002) in Bumbescu(2015), profit and rate of return are means of expressing the profitability of a production activity. While the rate of return shows the ratio at which the used resources generate profit, profit shows the absolute gain/profitability. Therefore, when the values of rate of return and profit for a firm/farm is positive such a farm/firm is said to be profitable.

Materials and Methods

Materials

The study was carried out in the laboratory. *Piper guineense* seeds were obtained from Forest Research Institute of Nigeria, Ibadan (FRIN) after due authentication. The seeds were dried in the oven for 72hours to a constant weightat a temperature of 40^{o}C. The plant seeds along with excipients such as maize husk, rice husk, cowpea pod was then ground into powder to prepare the biopesticide. This was sieved with an Engineer standard sieve of sizes 212µm, 300µm, 500µm and 1000µm. The different sized and sieved powder were kept in tightly fitted lid plastic containers and labelled accordingly. They were stored on the shelf under ambient conditions until being used to protect stored seeds of cowpea from infestation, damage and destruction by *C. maculatus*.

Budgetary analysis of costs and revenue:

To carry out the budgetary analysis, the total cost of producing the biopesticide was calculated and the expected revenue was estimated using the current market price. Thus, the

variables include costs, revenue and profit. Both fixed costs and variable costs were incurred on inputs to produce the biopesticide.

Variable Costs of the material used (VC): these are the costs of the variable inputs used in the production of the biopesticide. The variable costs included costs of excipient materials, cost of active ingredients, cost of milling, cost of labour and miscellaneous costs such as costs of transportation and maintenance. **Total Variable Cost of the materials used (TVC)** is the sum of the costs of all the variable inputs used in production.

Fixed Costs of the materials used (FC): these are the costs of the fixed inputs used in production such as the depreciated cost of sieve, cost of containers/packaging materials, cost of kitchen mill, cost of oven. **Total Fixed Cost of the materials used (TFC)** is the sum of the costs of all the fixed inputs used in production.

Total Cost of Production (TC): is the sum of the total fixed cost and total variable cost

TC = TFC + TVC

Revenue: The multiplication of the quantity of the biopesticide produced by its current market price gave the total revenue or the gross receipt.

Total Revenue (TR) or Gross receipt (GR)

= unit price of the output x quantity produced = PQ

Where P = price, Q = quantity

Profitability: Profitability can be measured as profit, which is the absolute size of the profitability or as rates of return, which is the degree to which the inputs generate profit. Indicators of rate of return include net profit, gross margin (Bumbescu, 2015).Profit is used to justify the production activities while rates of returns show the return on cost incurred and how the costs can be minimised for profit maximization (Kirill *et al*., 2020). To estimate the profitability of producing biopesticide using *P.guineense*, rice bran, maize husk and cowpea pod, manual computation was done using different budgetary analysis formulas like profit, gross margin (GM), total revenue (TR), rate of return (ROR), benefit-cost ratio (BCR).

Profit (π) or net margin (NM) or net profit: According to Aturamu*et al*, (2021), net profit or net margin (NM) or profit (π) is calculated by taking into account all the cost incurred in production and the revenue accrued from the sale of the output. Thus, profit shows how profitable a production activity is and ascertains the efficiency of the business.

Profit (π) or net margin (NM) or net profit= TR – TCOr = TR – TVC – TFC

Recall that gross margin (GM) = TR – TVC

Therefore, Profit (π) or net margin (NM) or net profit = GM – TFC

Rate of return per naira (Ret/₦): To further determine the profitability of producing biopesticide with *Piper guineense* and the excipients, the rate of return per naira was also estimated. The rate of return is a relative measure which shows the rate at which capital generates profit i.e. the amount of money earned for each additional cost incurred (Bumbescu, 2015; Abdullahi*et al*., 2020). Rate of return is a measurement tool for determining the performance and making decisions on investment or production (Bacon et al, 2018). It aids proficiency. It is the ratio of the profit made from production activities to the total cost incurred.

Rate of return, Ret/₦ $= \frac{\text{profit}}{totalcost} or \frac{netmargin}{totalcost} = \frac{\Pi}{TC} or \frac{NM}{TC}$

Benefit Cost Analysis (BCA) or Benefit Cost Ratio (BCR): This is the process of quantifying the benefits and costs of a production activity. The benefits include the monetary, social and environmental benefits gained from a business, which can be expressed in qualitative or quantitative form. It is used for estimating 'value addition' among alternative enterprises/ trade-offs in order to make informed decision (ELD Initiative, 2019).

Benefit Cost Analysis (BCA) or Benefit Cost Ratio (BCR) $= \frac{\text{TR}}{TC}$

Gross Margin (GM) = total revenue – total cost =TR – TVC

Results and Discussion

Cost of formulating biopesticides from the excipient materials (maize husk, rice bran, cowpea pod) and active ingredient (*Piper* guineense).

Table 1 shows the cost of producing biopesticide using maize husk, cowpea pod, rice bran and *P. guineense.* The results showed that the total variable cost (TVC) was ₦2900 which represented about 93%of the total cost of production, while the total fixed cost (TFC) was ₦400 representing about 7% of the total cost. The total cost (TC) of production was ₦3300.

Table 1: cost of formulating biopesticides from maize husk, rice bran, cowpea pod and *P. guineense*

Item	Unit	Quantity	Price (₦)	Total (₦)
Variable costs (VC):				
Maize husk	Kg	2.5	40	100
Rice bran	Kg	2.5	80	200
Cowpea pod	Kg	2.5	160	400
Piper guineense	Kg	2.5	400	1000
Milling of the biopesticide materials	Kg	10.0		250
Miscellaneous				950
Total variable cost (TVC)	**Kg**	**10.0**		**2900**
Fixed cost (FC):				
Depreciated cost of materials				400
Total fixed cost (TFC)				**400**
Total cost (TC) = TFC + TVC				**3300**

Source: Authors' computation, 2024

Revenue earned from producing formulated biopesticides using active ingredients of *P.guineense* with the excipient materials of maize husk, rice bran and cowpea pod

The finding on the expected total revenue (TR) from the sale of the produced biopesticide was estimated to be ₦5320 as shown in table 2 below. This shows that the expected revenue is greater than the costs incurred in producing the biopesticide.

Table 2: Revenue earned from producing biopesticides using maize husk, rice bran, cowpea pod and *P. guineense*

Item	Unit	Quantity	Price (₦)	Total (₦)
Revenue (unit price x quantity produced)	Kg	10	532	5320
Total revenue (TR)				**5320**

Source: Authors' computation, 2024

Profitability of producing biopesticide using maize husk, rice bran, cowpea pod and *P. guineense*

Table 3 below shows the profitability of producing biopesticide using maize husk, rice bran, cowpea pod and *P. guineense.* Profitability was calculated manually using various formulas such as profit, gross margin, rate of return, etc. The profit (π) or net margin (NM) and gross margin (GM) were ₦2020 and ₦2420 respectively. A profit of ₦2020 on an investment of ₦3300 shows that the total revenue is greater than the total cost. Therefore, the business was very profitable and efficient (Aturamu*et al*, 2021). The gross ratio was estimated to be 0.62 indicating that on every ₦1 spent, a return on the production of each formulated pesticide was about 62kobo. The expense structure ratio estimate was 0.12, which indicated that about 12% of the total cost of production was made up of the fixed cost. The value of the cost benefit ratio (BCR) is greater than 1. This shows that the production of the formulated biopesticide is profitable. Furthermore, the value of the estimated rate of return (ROR) was 0.61. This shows that for every ₦1 spent on producing the formulated biopesticide, about 61kobo was gained as profit. The findings shown in table 3 indicate that formulating biopesticide with maize husk, rice bran, cowpea pod and *P. guineense* is a profitable venture and worthy of investment and expansion which is in line with the works of (Amoabeng et al, 2014; Abdullahi et al, 2020; Koopmans &Mouter, 2021).

Table 3: Profitability of producing biopesticides using maize husk, rice bran, cowpea pod and *P. guineense*

Description	Total (₦)
Total fixed cost (TFC)	400
Total variable cost (TVC)	2900
Total cost (TC) = TFC + TVC	3300
Total revenue (TR)	5320
Profit (π) or Net margin (NM) = TR – TC	2020
Rate of return = π / TC or NM / TC	0.61
Gross margin (GM) = TR – TVC	2420
Gross ratio = TC / TR	0.62
Expense structure ratio = TFC / TC	0.12
Benefit Cost Ratio (BCR) = TR / TC	1.61

Source: Authors' computation, 2024

Conclusion and Recommendation

The world is moving from the use of synthetic pesticide to the use of pesticides which is friendly to man, his health, crops, animals and environment. Pesticides formulated with naturally occurring plants compounds are friendly to man and his environment. An example is biopesticide formulated with the active ingredients of *P.* guineense and excipients including maize husk, rice bran and cowpea pod. The ingredients abound and can be cheaply and easily obtained resulting in a low total cost of production. The biopesticide has a great demand due to the advantages it has over synthetic pesticides resulting in high efficiency and

profitability. Therefore, producers should produce the pesticide in large quantity so as to enjoy economies of scale and reduce the cost of production and price. The price of the pesticide should thus be reduced so as to encourage the consumers to buy more of it leading to higher revenue and profit for the producer.

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