Determinants of profitability of black soldier fly farming enterprise in Kenya

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Abstract

Black soldier fly (BSF) farming is emerging as a new farm enterprise in Kenya poised to provide high-quality and affordable alternative protein sources for animal feed production. Consequently, commercialisation and adoption require farmers to understand if the enterprise is economically viable. This study sought to assess the determinants of profitability of the BSF farm enterprise. A census survey was conducted whereby 34 well-established smallholder BSF farmers were interviewed. A double log regression analysis on the determinants of profitability of the BSF farm enterprise was done. The results revealed that 93.6% of the variation in enterprise gross margin was explained by the independent variables. Feed and household size contributed positively and significantly to the enterprise gross margin. Labour was significantly and negatively correlated to the enterprise gross margin. Farm size, gender, level of education, and age of the farmer did not significantly influence the gross margin of the enterprise. Furthermore, the survey showed that a 1% increase in man-hours spent in the BSF farming enterprise would result in a 0.34% reduction in the gross margin while a 1% increase in the usage of the rearing substrate would lead to a 1.38% increase in the gross margin. There is a need for farmers to reduce the man-hours spent in the BSF farms but at the same time increase significantly the utilisation of more rearing substrate to improve their profitability. However, a long-term socio-economic impact assessment on the BSF farming enterprise would be valuable to attract investors and interest in the insect production sector for animal feed.

Keywords: black soldier fly, gross margin, enterprise, profitability

1. Introduction

According to UNDESA (2019), 9.8 billion people are envisaged to be inhabiting the continent by the year 2050. To sustain this fast-growing population, food production must increase (Alexandratos and Bruinsma, 2012). Foley *et al.* (2011) noted that this increased demand for food raises concerns over the environmental impact of the expansion of land under agriculture on a global scale. Sachs (2015) further highlighted that conventional agricultural production has been a significant contributor to greenhouse gases and this has been linked to climate change on a global scale with evident impacts. Consequently, alternative sources of food which are cognisant of the environmental impact must be identified.

Edible insects production is environmentally friendly and cost-effective than either keeping livestock or growing crops, which is becoming unsustainable due to dwindling land and water scarcity imposed by climate change (Bosch *et al.*, 2019; Van Huis, 2015; Wang and Shelomi, 2017). Edible insects production enterprise is a low-cost technology with a reduced ecological footprint (limited greenhouse gas emission), and less water and land requirement for production (Lensvelt and Steenbekkers, 2014). Notably, edible insects have emerged as sustainable alternative sources of high-quality animal proteins and fat that can be used by humans or for livestock feeding (Purschke *et al.*, 2017). They have been incorporated as alternative ingredients in the making of animal feeds. This has had a positive contribution to farmers by reducing the costs of feeding and thus increasing their profitability levels (Anankware *et al.*, 2018). Despite these advantages, insect

production has its delimitations. For instance, the quality of output is highly dependent on the quality of the inputs. Further, many countries, especially developing countries are lacking a fully equipped regulatory framework that can solve any issues that may arise when enabling these innovations in the market (Siripan, 2019).

Black soldier fly (BSF), *Hermetia illucens* larva, has received a lot of research attention as an alternative protein ingredient in animal feed (Dabbou *et al.*, 2018; Nyakeri *et al.*, 2017; Schiavone *et al.*, 2018; Wang and Shelomi, 2017). BSF continues to gain popularity because of its ability to grow effectively on a large variety of waste streams (Hoc *et al.*, 2019; Van Huis *et al.*, 2020). The larvae are outstanding candidates for various applications ranging from organic material and waste management, integration in fish, poultry, and pigs' feeds (Bosch *et al.*, 2019; Nyakeri *et al.*, 2017; Vernooij *et al.*, 2019).

Developing countries, Kenya included have a dire need for animal protein. Consequently, the few available animal proteins are not available to the reach of many due to the high prices (Nyakeri *et al.*, 2017). As a result, insufficient protein consumption is a persistent problem. However, there is potential to increase the economic status of populations across Africa since the rearing and harvesting of edible insects can be a source of livelihood to the poorer segment of the society (Diener *et al.*, 2009). This will increase availability and access to highly nutritious protein while being conscious of environmental preservation through biodiversity promotion (Schönfeldt and Hall, 2012).

Evidently, in this dilemma, Hoc *et al.* (2019) noted that BSF could be a remedy. BSF is advantageous over other insects due to its significant role in converting waste to food while at the same time reducing pollution and costs (Bosch *et al.*, 2019; Salomone *et al.*, 2017; Surendra *et al.*, 2016; Wang and Shelomi, 2017). On the same note, there is a very attractive market for dry BSF larvae which has been growing globally (Diener *et al.*, 2009). This baseline informs the promotion of BSF as a farm enterprise in Kenya. There is massive interest in farming BSF in the country. However, to produce BSF sufficiently to meet the demand of the animal feed industries, uptake needs to be increased drastically. Farmers have to be encouraged to adopt this new enterprise, through the dissemination of information on economic viability and determinants of its profitability. To realise this, there is a need to explore its production as a commercial farm enterprise. Thus the objective of this study was to assess the determinants of profitability of the BSF farm enterprise.

2. Materials and methods

Description of the study area

This study was conducted in the counties of Nairobi, Kiambu, Murang'a, Kajiado, Machakos, and Nakuru in Kenya (Figure 1). These counties were purposively selected using the existing platform of farmers trained and supported by the International Centre of Insect Physiology and Ecology (*icipe*). Additionally, these counties experience climatic conditions that are favorable for BSF farming. These regions experience a temperature range of 14 to 28 °C (Alternative, 2021). In cases where the conditions were averse, for instance in the counties of Kiambu, Murang'a, and Nairobi where temperatures go below 23 °C during the cold season, farmers made improvements using light-emitting diodes light sources. This helped improve the temperatures to optimal conditions and maintaining light intensity in times when there is not enough sunlight since the flies are attracted to light and prefer mating under the light. The farmers in the study area were smallholder farmers and their production activities were undertaken manually.

BSF farmers are still relatively few in the country. The sample frame (34) for this study was composed of a census of active smallholder BSF farmers in the respective survey sites. A census approach was more appropriate, particularly due to the small population involved, to minimise errors and provide data on all possible individuals in the population (Chia *et al.*, 2020; Israel, 1992). This allows us to study every unit in the population, to ensure accuracy. In this study, in-depth interviews were conducted since the respondents were few. Though this type of data collection is time-consuming, the respondents were informed in advance and given a schedule on a day that was appropriate or convenient for them, to allow for sufficient timing before the interviews. Further, the interviews provided an opportunity to generate more insightful responses. The respondents were also allowed to validate the data they had provided to avoid bias.

Statistical analysis

All statistical analyses were performed using SPSS software version 20 (IBM, Armonk, NY, USA). Pearson correlation was done to measure the strength and direction between the independent and dependent variables. Multicollinearity was checked through the use of variance inflation factor values. Descriptive characteristics such as percentages were used to analyse BSF farmers' socio-economic characteristics. The determinants of profitability of the BSF farm enterprise were analysed using a double log regression model. The model enabled the transformation of variables that were highly skewed to more appropriately normal variables making them fit for analysis. It further enabled the handling of the non-linear relationship between gender and the gross

Figure 1. Map illustrating the distribution of black soldier farm enterprises in the study sites according to the year of establishment.

margin. Furthermore, the study assumes that the error term is normally distributed thus the choice of the model. Notably, for gender that is a dummy variable, during data collection it was coded as 0 (male) and 1 (female). However, to enable analysis using the double log regression model, this was recoded into 1 (male) and 2 (female).

The model used several explanatory variables to predict the outcome of the response variable i.e. BSF enterprise gross margin. The double log function was specified as:

$$\text{Log } Y = \beta_0 + \beta_1 \text{Log } X_1 + \beta_2 \text{Log } X_2 + \beta_3 \text{Log } X_3 + \beta_4 \text{Log } X_4 + \beta_5 \text{Log } X_5 + \beta_6 \text{Log } X_6 + \beta_7 \text{Log } X_7 + \beta_8 \text{Log } X_8 + \varepsilon$$

where:

Y = Gross margin per acre of the BSF enterprise (KES)

X_1 = Substrate purchased per acre

X_2 = Cost of labor in man-hours per acre

X_3 = Farm size (total area under BSF production in acres)

X_4 = Household size

X_5 = Level of education

X_6 = Age of the farmer

X_7 = Experience

X_8 = Gender

ε = Error term

β_0 = Constant term (the intercept)

β_{is} = Slope parameters

log = Common logarithm

3. Results

Demographic characteristics of the black soldier fly farmers

The demographic characteristics of BSF farmers are shown in Table 1. Over 70.6% of the farmers interviewed were males and 29.4% females. Among these farmers, 79.4% had either college or university education. Households with 3-5 members were the majority representing 67.6%. It was observed that 64.7% of the respondents had been practicing BSF farming for less than 2 years. 97.1% of the farmers had farm sizes below 1 acre.

Determinants of black soldier fly farm enterprise profitability

The model results indicate that 93.6% of the variance in BSF enterprise gross margin was explained by the predictor variables (Table 2). There was a strong positive correlation between the dependent (BSF farm enterprise gross margin) and the independent variables (substrate; labor; farm size;

household size; level of education; the age of the farmer; experience; gender) ($F=57.316$, $df=31$, $P\leq0.0001$).

Substrate and household size had a significantly positive relationship with the gross margin. Labor had a significantly negative relationship with the gross margin. Farm size, the

level of education, age, experience, and gender did not vary significantly. There was a significant relationship between BSF enterprise gross margin and the independent variables.

The Empirical model is:

$$\text{Log } Y = 1.124 + 1.376 \text{ Log } X_1 - 0.338 \text{ Log } X_2 - 0.074 \text{ Log } X_3 + 0.061 \text{ Log } X_4 - 0.640 \text{ Log } X_5 - 0.018 \text{ Log } X_6 + 0.171 \text{ Log } X_7 - 0.031 \text{ Log } X_8 + 0.824$$

Table 1. Demographic characteristics of the black soldier fly farmers.

Characteristics	Number of farmers	Percentage (%)
Gender		
Male	24	70.6
Female	10	29.4
Age		
18-35	17	50
36-60	17	50
Level of education		
Primary	1	2.9
Secondary	6	17.6
College/university	27	79.4
Household size		
0-2	1	2.9
3-5	23	67.6
6-8	9	26.5
Above 9	1	2.9
Farming years		
Below 2	22	64.7
3-5	12	35.3
Farm size		
0-1 acres	33	97.1
1-2 acres	1	2.9

4. Discussion

The amount of rearing substrate had a significantly positive relationship with the enterprise gross margin. The positive coefficient of substrate implies that an additional kilogram of the substrate in the production system would result in increased marginal returns at an increasing rate. These findings contravene reports by various authors (Altahat *et al.*, 2012; Esiobu *et al.*, 2014; Siyaya and Masuku, 2013; Ukwuaba and Inoni, 2012), who demonstrated that the input used for feeding had a significant but negative relationship to the profit margin of farmers. They attributed this to the high cost of feeds which was not the case in the current study. In BSF farming, the quantity and quality of substrate have been shown to significantly affect larvae growth performance and quality (Vuong, 2020). As per the findings of this study, a 1% increase in the usage of the rearing substrate resulted in a 1.38% increase in the gross margin. It was observed that the cost of the substrate was very minimal, in some instances, the farmers obtained the substrate for free with the only cost associated with it being labor and transportation which were consequentially minimal. This probably explains why an extra shilling spent by farmers on the substrate as an input resulted in

Table 2. Double log regression estimates for determinants of profitability of the black soldier fly farm enterprise.¹

Model		Unstandardised coefficients		t-value	P-value
		β	SE		
1	(Constant)	1.124	0.824	1.364	0.186
	Log X_1 (substrate)	1.376	0.099	13.849	0.000***
	Log X_2 (labour)	-0.338	0.095	-3.557	0.002**
	Log X_3 (farm size)	-0.074	0.067	-1.106	0.280 ^{NS}
	Log X_4 (household size)	0.061	0.024	2.537	0.018*
	Log X_5 (level of education)	-0.640	0.521	-1.227	0.232 ^{NS}
	Log X_6 (age of the farmer)	-0.018	0.358	-0.051	0.960 ^{NS}
	Log X_7 (experience)	0.171	0.168	1.018	0.319 ^{NS}
	Log X_8 (gender)	-0.031	0.086	-0.364	0.719 ^{NS}
	R ²	0.952		F-statistic	57.316
	Adjusted R ²	0.936		Prob (F-statistic)	0.000

¹ NS = not significant; * = $P\leq0.05$; ** = $P\leq0.01$; *** = $P\leq0.001$; β = regression coefficient; SE = standard error; dependent variable = gross margin; Predictors = (constant), substrate, labour, farm size, household size, level of education, age of the farmer, experience and gender.

increasingly marginal returns. The findings further highlight that the optimal capacity utilisation for the substrate hasn't been reached and that there is still potential for farmers to increase the output and consequentially their marginal profit by increasing its usage in the production system.

Labor had a significantly negative relationship with the enterprise gross margin. These results are in consonance with (Altahat *et al.*, 2012; Ehinmowo *et al.*, 2015; Ezeano and Ohaemesi, 2019; Itam *et al.*, 2014), who observed a significantly negative relationship between labor and gross profit. These findings contradict Ogisi *et al.* (2013) who demonstrated that labor had a significantly positive effect on farming output. The negative slope of labor implies that the opportunity cost of input in the enterprise is too high and that more units are being spent without commensurate return. In this study, a 1% increase in man-hours spent in the BSF farming enterprise resulted in a 0.34% reduction in the gross margin. It is presumed that more man-hours put into the enterprise without proper utilisation are resulting in diminishing marginal contribution of labor. This limits output and thus possible consequent reduction in farmers' marginal profit as per Onoja *et al.* (2012). According to the model results, the farmers in the study region were in their third stage of the production function with regards to the use of labor as input (Onoja *et al.*, 2012). However, further studies on long-term effect of labor on the marginal profit of BSF farmers would be crucial.

Household size had a significantly positive effect on the enterprise gross margin. These results are in tandem with those of previous studies (Ehinmowo *et al.*, 2015; Lungu, 2013; Onoja *et al.*, 2012), whereby a positive and significant relationship was observed between household size and output or gross margin. Labor is a very common input in BSF production systems for activities such as larvae feeding, harvesting, sieving, and marketing. Most of which are carried out manually. This probably explains why the coefficient of household size was significant and positive influencing profitability. This is obvious because family size is a significant source of cheap labor in many agricultural production systems as noted by Ehinmowo *et al.* (2015) and Onoja *et al.* (2012). This implies that more family members involved in production provide cheap labor, thus a more profitable farming system. This is because more family members are allocating their time in production thus reducing the need for hired labor (Onoja *et al.*, 2012), such was the case in this study.

Farm size, gender, level of education, age, and the farming experience did not significantly influence the gross margin of the enterprise. The authors acknowledge that the sample size of this study was small, which is a shortcoming but this was due to the Covid 19 pandemic restrictions that hindered movement as a result of frequent lockdowns. Given that this is an emerging enterprise in the country,

further studies are highly recommended with larger sample sizes of farmers.

5. Conclusions and recommendations

The findings demonstrated that the substrate, labor, and household size were the main determinants of profitability of the BSF enterprise. As such, there is still potential for farmers to increase the output and consequentially their marginal profit by increasing the amount and quality of substrate used in their production facilities. The family was the primary source of labor thus household size was significant. It was further noted that there was a generous allocation of labor to the enterprise due to its availability. This leads to higher opportunity costs of labor without commensurate return thus a subsequent decline in marginal returns. Farm size, gender, level of education, and age of the farmer did not significantly influence the gross margin of the enterprise. This study recommends long-term socio-economic impact assessment studies on the BSF farming enterprise to strengthen and promote uptake through the support of investors in the insect production sector.

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Conflict of interest

The authors declare no conflict of interest.

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