Vol. 18(1), pp. 27-34, January, 2022
DOI: 10.5897/AJAR2021.15882
Article Number: 4F97F6468532
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

ACADEMIC JOURNALS
expand your knowledge

African Journal of Agricultural Research

Full Length Research Paper

A comparative evaluation of nutrient content of fall armyworm (*Spodoptera frugiperda*) larvae to other chicken feeds

Emilly Awuor Okello[1*], Arnold Watako[1], Calleb Olweny Ochia[1] and Ben Muok[2]

[1]Department of Plant, Animal and Food Sciences, Jaramogi Oginga Odinga University of Science and Technology (JOOUST), P. O. Box 210 - 40601, Bondo, Kenya.
[2]Directorate of Research, Innovation and Partnerships (DRIP), Jaramogi Oginga Odinga University of Science and Technology (JOOUST), P. O. Box 210-40601, Bondo, Kenya.

Received 25 November, 2021; Accepted 30 December, 2021

Fall armyworm (FAW) *Spodoptera frugiperda* is a devastating pest of over 350 plant species especially the cereal crops such as, maize, sorghum and rice. The pest is currently posing threats to food security in Africa. FAW could be potential animal feed that can supplement chicken feed. However, there is little information on its nutritional profile as poultry feed. The aim of the study was to compare the nutrient content of FAW larvae to other chicken feeds. Proximate analysis was performed on air-dried samples of fall armyworm larvae in order to determine the crude fibre, crude protein, ash, ether extract and carbohydrate contents. Experimental data was compared to secondary data of other chicken feeds to determine the quality of fall armyworm as poultry feed. The results indicated that FAW had crude protein content of (36.9 - 63.54)%, crude fibre (9.1 - 9.6)%, fat (17.8 - 22.9)%, ash (5.6 - 7.4)% and carbohydrates (1.65 - 3.3)%. From the findings, FAW larvae have nutrients in sufficient quantities to be considered as an alternative source of protein for chicken diets. Therefore, the study recommends use of FAW for chicken feeding.

Key words: Chicken feed, fall armyworm larvae, proximate composition

INTRODUCTION

Fall armyworm (FAW) *Spodoptera frugiperda* is a polyphagous pest which is widely accepted as the most damaging pest in the American continent (Day et al., 2017; Goergen et al., 2016). This troublesome pest has invaded Africa and is now causing significant yield losses to cereals crops especially maize (Day et al., 2017; MOA, 2017). According to Day et al. (2017), the potential impact of FAW on maize in Africa is between 8.3 and 20.6 million tonnes per year of the total expected production of 39 m tonnes per year and with losses ranging between USD 2,481 m and USD 6,187 m per year of total expected value of USD 11,590.5 m per year.

*Corresponding author. E-mail: emokells@yahoo.com Tel: +254 743 501 209.

Despite the losses and damages caused by FAW, it acts as a food source to some birds and grasshoppers which are also sources of food to human beings (SANBI, 2018). Furthermore, materials from the environment (insects, worms, snails, greens, seeds among others) are possible feed sources for indigenous chicken (FAO, 2013). Besides, insects that are considered as pests in agro-ecosystems can also be used as food or feed (Dobermann et al., 2017; van Huis, 2016, van Huis and Oonincx, 2017).Therefore, FAW larvae could be used as an alternative source of protein for indigenous chicken.

Mechanical control is one of the methods of controlling the fall armyworm in crop fields (Prasanna et al., 2018). Consequently, farmers have started to collect the FAW larvae by handpicking and feeding to the chicken C. Midega, (Personal communication, April, 2019) instead of crushing them. Therefore, FAW larvae could be a promising source of protein. However, there is little information on its nutritional profile. Information on the nutrient quality of FAW larvae would enable people know the benefits of the insect for feed, hence increasing their use.

Indigenous chicken are commonly found in the traditional system of poultry production in the developing countries. The chickens are scavengers which require feeds that can provide them with the necessary nutrients for increased production of eggs and meat. This is because they get very low nutrient inputs during scavenging (Atela et al., 2016). Harvesting of FAW larvae from the crops field and feeding to these chickens could possibly boost their nutrition.

Insects are sources of very high-quality feed (Abro et al., 2020; Duinkerken et al., 2012) that can be supplemented in poultry diets. Black soldier fly and the common housefly can be very good sources of protein for poultry. The black soldier fly larvae /BSFL) has been reported to contain 36.6 - 62.7% crude protein and 14.0 - 40.7% fat (Abro et al., 2020; Ebeneezar et al., 2021; Ewald et al., 2020; Duinkerken et al., 2012; Mohammed et al., 2017; Shumo et al., 2019).

The common housefly (*Musca domestica*) which has been utilized mostly as poultry feed is reported to constitute between 43 – 68% crude protein and 4 – 32% fat (Elahi et al., 2020; Fitches et al., 2019; Duinkerken et al., 2012; Hussein et al., 2017; Pieterse and Pretorius, 2014). According to Duinkerken et al. (2012), the crude protein content in common housefly is comparable to soybean meal which is a conventional poultry feed.

Previous studies have shown that fall armyworm fed on artificial diet had crude protein of 59% and fat of 20.6% while those fed on fresh plant materials had a crude protein of 59.3% and fat of 11.7% (Williams et al., 2016). Therefore, FAW from crop fields could act as an alternative source of protein. The aim of the study was to compare the nutritional profile of FAW larvae to other chicken feeds in order to provide information on the quality of FAW larvae as poultry feed. As a result, more people would use FAW larvae as feed, FAW populations will reduce, and maize yields would increase thus a boost to food security.

MATERIALS AND METHODS

Sample collection

The samples were collected from two sites. The first site was at the School of Agricultural and Food Sciences fields (Formerly Farmers Training Centre (FTC)) located in Siaya County at Siaya town in Kenya, East Africa. The county lies approximately between latitude 0º 26´ South to 0º 18´ North and longitude 33º 58´ and 34º 33´ East (Latitude.tob, 2021). The samples were collected during the short rains of 2020.

Since the study could not get enough FAW larvae for three samples during the short rains of 2020, more FAW larvae were collected in the long rains of 2020 from a maize field in Sindo sub county of Homabay County. Homa Bay County lies between Latitude: 0° 31' 38.32" N and Longitude: 34° 27' 25.70" E (Latitude.toc, 2021).

Method of sample collection

S. frugiperda samples were collected by hand picking the larvae from the maize plants in the field (that is collected from the wild). This was done by observing the maize plants with signs of FAW infestations and then the larvae were removed from the whorl of the plant carefully. The larvae were put together as one composite sample once the study was certain it was sufficient to be used for a complete proximate analysis.

The samples were *S. frugiperda* (S1), *S. frugiperda* (S2) and *S. frugiperda* (S3), where S1 (mature larvae 5th instar (L5) or 6th instar (L6)) were collected from maize fields in Siaya Campus – Siaya County during the short rains of 2020. The S2 and S3 were various stages of the larvae ranging from 2nd instar (L2) to 6th instar (L6), which were collected from a maize field in Homa bay County during the long rains of 2021.

Sample preparation

Fresh samples were left for 24 h to degut and then blanched in boiling water (Ayieko et al., 2016) for about 5 min. Thereafter, they were left in the sun to dry for at least 8 h before they were sent to the laboratories for nutritional analysis. *S. frugiperda* S1 was sent to Kenya Agricultural and Livestock Research Organization (KALRO) in Kakamega County Kenya. The other two samples *S. frugiperda* S2 and *S. frugiperda* S3 were analysed at the Animal Sciences Laboratory in Egerton University, Njoro, Kenya. The samples were taken to Egerton University for analysis after the machines in KALRO broke down.

Proximate analysis

The samples at KALRO were analysed in duplicate, where crude protein analysis was done using a standard Kjeldahl method and a neutral detergent fibre analysis (Zaklouta et al., 2011) was performed for crude fiber. At Egerton University Laboratories, air-dried samples were heated in an oven at 60°C for 2 h. The samples were then ground through a 2-mm screen and kept in an air-tight bottle until analysis (Fombong et al., 2017). The analysis for moisture, crude protein, crude fiber and ash were done in triplicate while that for fat was done in duplicate.

Moisture content was determined by oven drying at 105°C for 8 h. The loss in weight was the moisture content and what was left was the dry matter of the sample. Crude ash was obtained through incineration of the sample in a furnace at 550°C for 4 h, while the crude protein was determined by micro Kjeldahl method, where the protein content = N x 6.25 (conversion factor). The crude fats or ether extract (EE) were determined using Soxhlet extractor method (Ayieko et al., 2016; Zaklouta et al., 2011).

The crude fibre was determined as described by Nduko et al. (2018) by weighing about 2.000 g of air-dried sample into a 600-ml glass beaker in triplicate, where 100 ml of hot water was added before adding 2.04 N H_2SO_4 and then the volume was increased to 200 ml. The content of the beaker was boiled for 30 min but the level of the solvent was kept at 200 ml by adding hot water. Thereafter, the beakers were removed and the content filtered using a filter stick packed with glass wool.

The residue was washed 3 times using hot water and then returned into the beakers into which 100 ml of hot water was added followed by 25 ml of 1.78 N KOH, then the volume was increased to 200 ml using hot water in order to keep it constant. This was boiled for 30 min after which it was filtered and washed 3 times using hot water. The residue was transferred into crucibles and then dried in an oven set at 105°C for 2 h, cooled in a desiccator and weighed accurately. The contents were then burnt in a furnace at 550°C to ash for 4 h and then left to cool to about 100°C. After which the sample were transferred to a desiccator for further cooling to room temperature and then their weights taken immediately.

Carbohydrate content (that is, Nitrogen free extracts) of the insects were determined by subtracting the sum of the weights of protein, fiber, lipid and ash from the total dry matter weight (Fombong et al., 2017).

Comparison of the nutrient content of *S. frugiperda* larvae to other chicken feeds

The primary data on proximate analysis of *S. frugiperda* larvae from the current research was compared to secondary data of the Black soldier fly, the common housefly and soya bean. The study chose to make comparison to Black soldier fly (BSF) larvae and the common housefly (HF) larvae because they have been widely accepted as poultry feed. The study only considered BSFL that were fed on food waste namely: Household waste, kitchen waste and departmental canteen waste. Soya bean data was also used in the study because of its high use as feed for many livestock (Abro et al., 2020; Allegretti et al., 2017).

Statistical analysis

The data was visualized and analyzed using R software for statistical analysis R version 4.0.5 (2021-03-31) -- "Shake and Throw". The distribution of the FAW samples data was checked using Shapiro-Wilk normality test while homogeneity of variance was performed using Bartlett’s test for dry matter, moisture, fat, crude fibre and carbohydrates. Levene's Test was used to check crude protein and Ash. Kruskal-Wallis rank sum test was used to analyse the FAW samples data for dry matter, moisture, ash, crude protein and fat; and then Dunn’s Kruskal–Wallis Multiple Comparisons (Dunn’s Test) was used to perform the post hoc test where there was significant difference.

Mann Whitney U Test (Wilcoxon Rank Sum Test) was then used to compare the differences between S2 and S3 FAW samples for crude fibre and carbohydrates. It was also used to test the differences between: FAW larvae and BSF larvae, FAW larvae and HF larvae and finally FAW larvae and Soya bean.

RESULTS

The results are presented in figures and tables showing visualization and analysis of the data for the proximate composition of the fall armyworm samples, black soldier fly, the common house fly and soya bean.

Proximate composition of FAW larvae

Figure 1 shows the proximate composition of the three samples of *S. frugiperda* (S1, S2 and S3). It indicates that the samples had almost similar amounts of ash, crude fibre, ether extract and carbohydrate content except for the crude protein. S1 was different in the crude protein content from S2 at $p = 0.04$ but similar to S3 (Table 1).

Proximate composition of BSF larvae and FAW larvae

The study revealed that FAW larvae has higher amount of crude protein (%) than BSF larvae but low amount of fat compared to BSF larvae (Figure 2). However, there were no statistical differences at $p = 0.05$ between the crude protein (%) of FAW larvae and BSF larvae. The fat content also differed at $p = 0.04$ for FAW larvae and BSF larvae (Table 2).

Proximate composition of housefly (HF) larvae and FAW larvae

The results in Figure 3 depict that FAW larvae and the common housefly (HF) larvae have the same amount of nutrients content and they are rich in crude protein. This can also be seen in Table 3 where there are no significant differences in the nutrient contents of FAW larvae and BSF larvae.

Proximate composition of Soya bean and FAW larvae

Visualization of the proximate composition of FAW larvae and Soya bean (Figure 4) showed that FAW larvae had higher crude protein content than soya bean. Nevertheless, the results of the crude protein were not statistically significantly different from each other (Table 4).

DISCUSSION

In the current study, there was significant difference in the crude protein between *S. frugiperda* (S1) and *S. frugiperda* (S2) at $p = 0.04$ (Table 1). This is consistent with the report by Rumpold and Schl (2013) that there are differences in the results of nutritional composition of

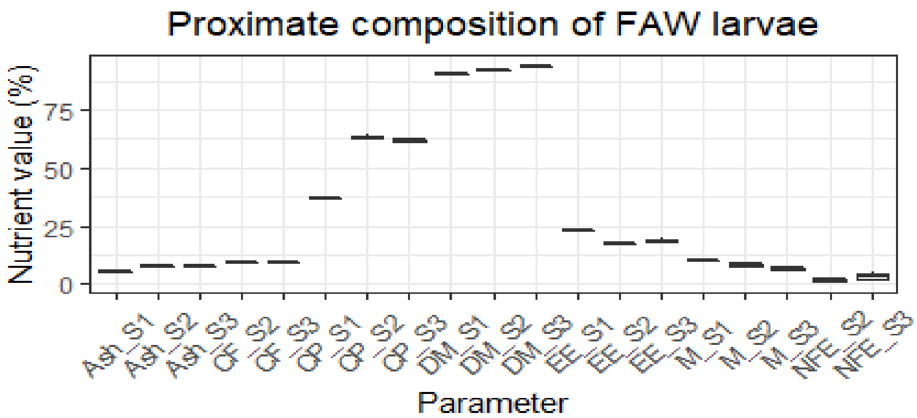

Figure 1. Plot of proximate composition on Dry matter basis (%DM) of the means of *Spodoptera frugiperda* samples (S1, S2 and S3).CF= Crude fibre, CP= Crude protein, DM= Dry matter, EE= Ether extract, M= moisture and NFE=Nitrogen free extract.
Source: Data from current study.

Table 1. Proximate composition of FAW mean n =2 for *S. frugiperda* S1 and mean standard deviation (SD±, n = 3) for *S. frugiperda* S2 and *S. frugiperda* S3 on dry matter basis (% DM).

Sample	*S. frugiperda* S1	*S. frugiperda* S2	*S. frugiperda* S3	P value
Feed	Wild	Wild	Wild	
Moisture	10^{a}	8.218 ± 0.2^{ab}	6.469 ± 0.3^{b}	0.04
Dry matter	90^{a}	91.782 ± 0.4^{ab}	93.531 ± 0.3^{b}	0.04
Ash	5.6^{a}	7.4 ± 0.1^{a}	7.4 ± 0.2^{a}	0.13
Crude fibre		9.6 ± 0.4^{a}	9.1 ± 0.3^{a}	0.12
NDF	17.8			
Crude protein	36.9^{a}	63.54 ± 1^{b}	61.84 ± 0.7^{ab}	0.04
Fat	22.9^{a}	17.8 ± 0.4^{a}	21.1 ± 1.6^{a}	0.17
Carbohydrates		1.65 ± 0.9^{a}	3.3 ± 2.7^{a}	0.44

Means followed by the same letter a cross a row are not statistically significant from each other at p< 0.05.
Source: Data from current study.

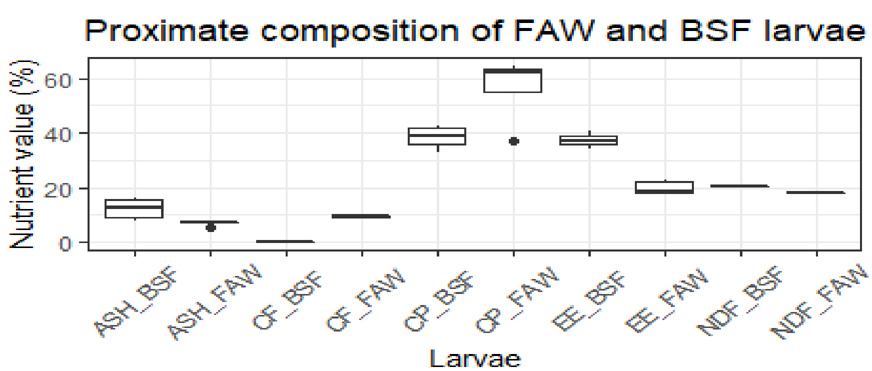

Figure 2. A plot for the proximate analysis of BSF larvae and FAW larvae on Dry matter basis (%DM). ASH_BSF = ASH for BSF larvae, CF_BSF = Crude fibre for BSF larvae, CP_BSF = Crude protein for BSF larvae, EE_BSF = Ether extract for BSF larvae, NDF_BSF = Nutrient detergent fibre for BSF larvae, ASH_FAW =ASH for FAW larvae, CF_FAW= Crude fibre for FAW larvae, CP_FAW= Crude protein for FAW larvae, EE_FAW = Ether extract for FAW larvae, NDF_ FAW= Nutrient detergent fibre for FAW larvae.
Source: Data from current study, Mohammed et al., 2017, Shumo et al., 2019, Ewald et al., 2020 and Ebeneezar et al., 2021

Table 2. A comparison of proximate composition of FAW larvae (n=3) and BSF larvae from four studies BSF_1, BSF_2, BSF_3, and BSF_4 (n=4) means, on dry matter basis (%DM).

Parameter	Sample				Mean		p value
	BSF_1	BSF_2	BSF_3	BSF_4	BSF	FAW	
Feed	KW	KW	HW	DC			
CP	42.6	33	36.6	41.44	38.41[a]	56.222[a]	0.05
CF	NA	NA	NA	0.08	0.08 [a]	9.333 [a]	0.21
NDF	NA	20.4	NA	NA	20.4 [a]	17.8 [a]	0.48
EE	36.9	34.3	40.7	35.69	37.3 [a]	19.655 [b]	0.04
ASH	15.3	9.6	16.3	7.87	12.27 [a]	7 [b]	0.01
Reference	(Mohammed et al. (2017)	Shumo et al. (2019)	Ewald et al. (2020)	Ebeneezar et al. (2021)	Current study		

Means followed by the same letter in a row are not statistically significant different from each other. CP= Crude protein, CF= Crude fibre, NDF= Nutrient detergent fibre, EE=Ether extract, HW= Household waste, Kitchen waste and DC= Departmental Canteen waste.
Source: Data from current study, Mohammed et al., 2017; Shumo et al., 2019: Ewald et al., 2020 and Ebeneezar et al., 2021

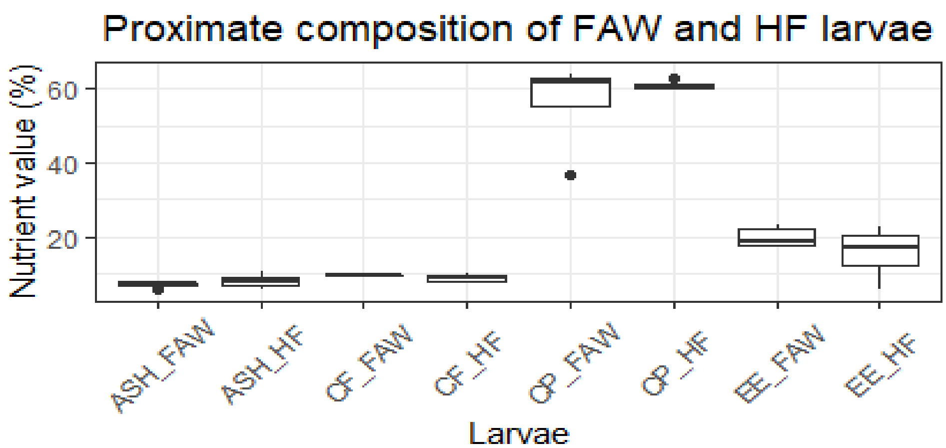

Figure 3. A plot for the proximate analysis of housefly (HF) larvae and FAW larvae on Dry matter basis (%DM). ASH_HF = ASH for HF larvae, CF_HF = Crude fibre for HF larvae, CP_HF = Crude protein for HF larvae, EE_HSF = Ether extract for HF larvae, ASH_FAW =ASH for FAW larvae, CF_FAW= Crude fibre for FAW larvae, CP_FAW= Crude protein for FAW larvae, EE_FAW = Ether extract for FAW larvae, NDF_ FAW= Nutrient detergent fibre for FAW larvae.
Source: Data from current study, Pieterse and Pretorius, 2014; Hussein et al., 2017; Fitches et al., 2019 and Elahi et al., 2020

edible insects. In this study, the difference could have resulted from the method that was used for the analysis. *S. frugiperda* (S1) was analyzed at KALRO while *S. frugiperda* (S2) and *S. frugiperda* (S3) were analysed at Egerton University. The difference could also result from the stage of the larvae that was harvested; for *S. frugiperda* (S1) it was L5/L6, while the larval stages of *S. frugiperda* (S2) and *S. frugiperda* (S3) ranged from L2 to L6. Therefore, the study suggests that further research be conducted on the nutritional profile of different larval stages.

The percent crude protein of *S. frugiperda* was comparable to that of *Spodoptera littoralis* 51.2% (Sayed et al., 2019). Our findings are in agreement with those reported by Williams et al. (2016) that the percent crude protein of *S. frugiperda* fed on artificial diet and *S. frugiperda* fed on fresh plant materials were 59.0 and 59.3% respectively. When the crude protein of FAW larvae was compared to BSF larvae (Table 2) and housefly (HF) larvae (Table 3) and Soya bean (Table 4), there were no statistical differences in their means. These results indicate that FAW larvae is rich in protein. Besides, caterpillars in the order lepidoptera have been reported by several authors to be rich in protein (Braide et al., 2010; Sayed et al., 2019; Williams et al., 2016).

There were no statistically significant differences in the amount of crude fibre available in *S. frugiperda* (S2) and *S. frugiperda* (S3) (Figure 1). A comparison of the crude fibre of FAW larvae, BSF larvae, HF larvae and Soya bean indicated that the amount of crude fibre was the

Table 3. A Comparison of proximate composition of FAW larvae (n=3) and HF larvae from four studies HF_1, HF_2, HF_3, and HF_4 (n=4) means, on dry matter basis (%DM).

Parameter	Sample				Mean		p value
	HF_1	HF_2	HF_3	HF_4	HF	FAW	
CP	60.38	59.87	60.51	62.98	60.94 [a]	56.22[a]	0.44
CF	8.59	7.11		9.64	8.45 [a]	9.33 [a]	0.36
EE	14.08	19.64	22.21	5.58	15.33 [a]	19.66 [a]	0.34
ASH	10.68	7.06	5.27	8,15	7.79 [a]	7 [a]	0.26
Reference	Pieterse and Pretorius (2014)	Hussein et al. (2017)	Fitches et al. (2019)	Elahi et al. (2020)			

Means followed by the same letter in a row are not statistically significant different from each other at p<0.05. CP= Crude protein, CF= Crude fibre, NDF= Nutrient detergent fibre, EE=Ether extract.
Source: Data from current study, Pieterse and Pretorius, 2014; Hussein et al., 2017; Fitches et al., 2019 and Elahi et al., 2020

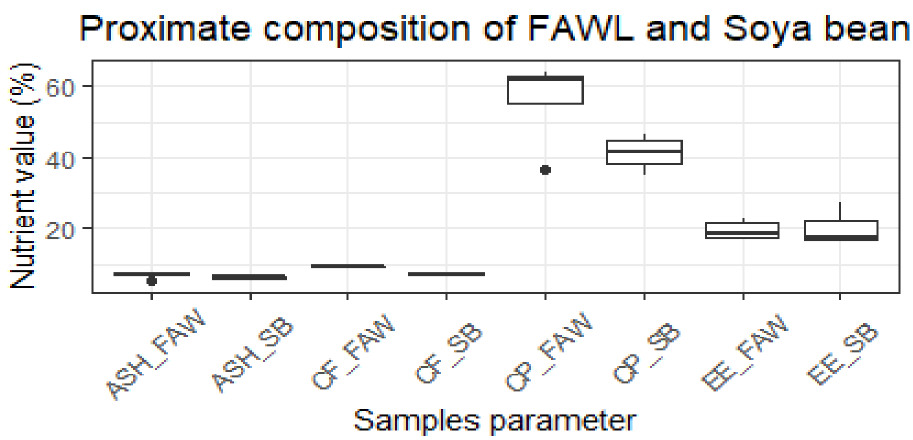

Figure 4. A plot for the proximate analysis of fall armyworm larvae (FAWL) and Soya bean on Dry matter basis (%DM). ASH_SB = ASH for Soya bean, CF_SB = Crude fibre for Soya bean, CP_SB = Crude protein for Soya bean, EE_SB = Ether extract for Soya bean, ASH_FAW =ASH for FAW larvae, CF_FAW= Crude fibre for FAW larvae, CP_FAW= Crude protein for FAW larvae, EE_FAW = Ether extract for FAW larvae.
Source: Data from current study, Kwikiriza, et al., 2016; Khan, et al., 2018; Sayed et al., 2019 and Świątkiewicz et al., 2021

Table 4. Comparison of proximate composition of FAW larvae (n=3) and Soya bean from four studies SB_1, SB_2, SB_3, and SB_4 (n=4) means, on dry matter basis (%DM).

Parameter	Sample				Mean		p value
	SB_1	SB_2	SB_3	SB_4	SB	FAW	
CP	39.28	46.4	44	34.8	41.12 [a]	56.22[a]	0.16
CF		6.75	7.3	7.5	7.18 [B]	9.33 [a]	0.03
EE	16.37	27.18		17.5	20.35 [a]	19.66 [a]	0.7
ASH	6.61	6.65		5.2	6.15 [a]	7 [a]	0.12
Reference	Kwikiriza et al. (2016)	Khan et al. (2018)	Sayed et al. (2019)	Świątkiewicz et al. (2021)			

Means followed by the same letter in a row are not statistically significant different from each other. CP= Crude protein, CF= Crude fibre, NDF= Nutrient detergent fibre, EE=Ether extract.
Source: Data from current study, Kwikiriza, et al., 2016; Khan, et al., 2018; Sayed et al., 2019 and Świątkiewicz et al., 2021

same (Tables 2 to 4). Crude fibre of < 10% for *S. frugiperda* in the current study is in line with the report of Williams et al. (2016), which is an indication that their bodies were not hardened.

The average ash content did not have any significant differences among the *S. frugiperda* samples in this study

(Table 1). This was similar to the report by Williams et al. (2016) of 5.7 for *S. frugiperda* fed on artificial diet but they also reported a slightly higher value of 11.6 for *S. frugiperda* larvae fed on fresh plant products. According to Braide et al. (2010), ash content of 6.42% is an indication of high mineral content. Therefore, this research also found the ash content of 5.6 and 7.4, hence *S. frugiperda* is rich in minerals.

A comparison of FAW larvae ash content to HF larvae (Table 3) and Soya bean (Table 4) did not have statistical significant differences. Therefore, this shows that FAW larvae possibly have the same mineral content as HF larvae and Soya bean. Nevertheless, there was statistical significant difference when it was compared to BSF larvae (Table 2). This indicates that BSF larvae could be having higher amount of minerals compared to FAW larvae.

There was no significant difference in the fat content of *S. frugiperda* S1 (22.9%), S2 (17.8%) and S3 (21.1%) (Table 1). The results are consistent with the reports by Williams et al. (2016) that *S. frugiperda* fed on artificial diets had 20.6% fat but lower in *S. frugiperda* fed on fresh plants 11.7%. A comparison of FAW larvae fat content (19.66%) to HF larvae (15.33%) (Table 3) and Soya bean (20.33%) (Table 4) showed that the fat content was the same but there was a statistical significant difference when the fat content of FAW larvae was compared to BSF larvae (37.3) (Table 2) ($p = 0.04$) which can also be seen in Figure 2. These findings are in agreement with the report by Kouřimská and Adámková (2016) who opined that averagely edible insects contain about 10 to 60% of fat in dry matter.

Insects have been reported to be having very low levels of carbohydrates (Fombong et al., 2017). This study reports carbohydrates of (1.65 – 3.39%) for *S. frugiperda* S2 and *S. frugiperda* S3 (Table 1) which are close to 5.2 for *S. littoralis* (Sayed et al., 2019). Since FAW larvae is comparable to BSF larvae, HF larvae and Soya bean in terms of crude protein and crude fiber except for fat and ash content with BSF larvae, there is sufficient evidence the FAW larvae could be a potential source of poultry feed. However, there is need to study if regions could possibly have an effect on their nutrient content.

Utilizing FAW larvae as a source of protein could contribute to improved global food security through feed, new business ventures, create new jobs, improve income by providing a cheaper source of poultry feed and reducing food - feed competition (Abro et al., 2020; Veldkamp and Bosch, 2015).

CONCLUSIONS AND RECOMMENDATIONS

Based on the findings of this study, it is evident that *S. frugiperda* has sufficient nutrients for chicken feed. Therefore, there is a possibility that FAW larvae could be utilized as an alternative source of protein for the indigenous chicken feed, since FAW is rich in crude protein at (36.9 - 63.54%), crude fibre (9.1 - 9.6%) and crude fat (17.8 - 22.9%). Even though *S. frugiperda* has depicted a potential to be utilized as poultry feed due to its rich nutrients, there is still need to do further analysis to determine its safety as food or feed.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Abro Z, Kassie M, Tanga C, Beesigamukama D, Diiro G (2020). Socio-economic and environmental implications of replacing conventional poultry feed with insect-based feed in Kenya. Journal of Cleaner Production 265:121871.

Allegretti G, Schmidt V, Talamini E (2017). Insects as feed species selection and their potential use in Brazilian poultry production: World Poultry Science 73:928937.

Atela J, Ouma P, Onjoro P, Nyangweso S (2016). A comparative performance of indigenous chicken in Baringo and Kisumu Counties of Kenya for sustainable agriculture. International Journal of Agricultural Policy and Research 4(6):97-104.

Ayieko MA, Ogola HJ, Ayieko IA (2016). Introducing rearing crickets (gryllids) at household levels: Adoption, processing and nutritional values. Journal of Insects as Food and Feed *2*(3):203–211.

Braide W, Sokari TG, Hart AD (2010). Nutritional Quality of an Edible Caterpillar of a Lepidopteran. Advances in Science and Technology 4(1):49-53.

Day R, Abrahams P, Bateman M, Beale T, Clottey V, Cock M, Colmenarez Y, Corniani N, Early R, Godwin J, Gomez J, Moreno GP, Murphy ST, Oppong-Mensah B, Phiri N, Pratt C, Silvestri S, Witt A (2017). Fall armyworm: Impacts and implications for Africa. Outlooks on Pest Management 28(5):196-201.

Dobermann D, Swift JA, Field LM (2017). Opportunities and hurdles of edible insects for food and feed,: Nutrition Bulletin 42(4):293-308.

Duinkerken G, van Huis A, Boekel T (2012). Insects as a sustainable feed ingredient in pig and poultry diets : a feasibility study = Insecten als duurzame diervoedergrondstof in varkens- en pluimveevoeders : een haalbaarheidsstudie. Food Chemistry 50:192-195.

Ebeneezar S, Tejpal CS, Jeena NS, Summaya R, Chandrasekar S, Sayooj P, Vijayagopal P (2021). Nutritional evaluation, bioconversion performance and phylogenetic assessment of black soldier fly (Hermetia illucens, Linn. 1758) larvae valorized from food waste. Environmental Technology and Innovation 23:101783.

Elahi U, Ma Yb, Wu Sg, Wang J, Zhang Hj, Qi G (2020). Growth performance, carcass characteristics, meat quality and serum profile of broiler chicks fed on housefly maggot meal as a replacement of soybean meal. Journal of Animal Physiology and Animal Nutrition 104(4):1075-1084.

Ewald N, Vidakovic A, Langeland M, Kiessling A, Sampels S, Lalander C (2020). Fatty acid composition of black soldier fly larvae (Hermetia illucens) – Possibilities and limitations for modification through diet. Waste Management 102:40-47.

Food and Agriculture Organization (FAO) (2013). Poultry Development Review. Rome: FAO pp. 60-63. Available at: https://www.fao.org/3/i3531e/i3531e00.htm

Fitches EC, Dickinson M, De Marzo D, Wakefield ME, Charlton AC, Hall H (2019). Alternative protein production for animal feed: Musca domestica productivity on poultry litter and nutritional quality of processed larval meals. Journal of Insects as Food and Feed 5(2):77-88.

Fombong FT, Borght MVan Der, Broeck JV (2017). Influence of freeze-drying and oven-drying post blanching on the nutrient composition of the edible insect Ruspolia differens. Insects 8(3):102.

Goergen G, Kumar PL, Sankung SB, Togola A, Tamò M (2016). First report of outbreaks of the fall armyworm spodoptera frugiperda (JE

Smith) (Lepidoptera, Noctuidae), a new alien invasive pest in West and Central Africa. PLoS ONE 11(10):1-9.

Hussein M, Pillai VV, Goddard JM, Park HG, Kothapalli KS, Ross DA, Ketterings QM, Brenna JT, Milstein MB, Marquis H, Johnson PA (2017). Sustainable production of housefly (Musca domestica) larvae as a protein-rich feed ingredient by utilizing cattle manure. PLoS ONE 12(2):1-19.

Khan S, Khan RU, Alam W, Sultan A (2018). Evaluating the nutritive profile of three insect meals and their effects to replace soya bean in broiler diet. Journal of Animal Physiology and Animal Nutrition 102(2):e662-e668.

Kouřimská L, Adámková A (2016). Nutritional and sensory quality of edible insects. NFS Journal 4:22-26 https://doi.org/10.1016/j.nfs.2016.07.001

Kwikiriza G, Tibenda VN, Wadunde AO, Abaho I, Ondhoro CC (2016). Proximate nutrient composition and cost of the selected potential fish feed ingredients in Lake Victoria basin, Uganda. International Journal of Fisheries 4(3):611–615.

Latitude.tob. (2021). Latitude and longitude of Siaya County In Kenya. Retrieved from https://latitude.to/articles-by-country/ke/kenya/39121/siaya-county

Latitude.toc. (2021). Latitude and logitude of Homa Bay County. Retrieved from https://latitude.to/map/ke/kenya/cities/homa-bay

MOA (2017). ATTENTION!!! ATTENTION!!! New pest on cereals and pasture in kenya. Retrieved from https://www.kalro.org/sites/default/files/Fall-Army-Worm-brochure-april-2017.pdf

Mohammed A, Laryea TE, Ganiyu A, Adongo T (2017). Effects of black soldier fly (hermetia illucens) larvae meal on the growth Performance of Broiler Chickens. UDS International Journal of Development 4(1):35-41.

Nduko JM, Maina RW, Muchina RK, Kibitok SK (2018). Application of chia (*Salvia hispanica*) seeds as a functional component in the fortification of pineapple jam, (September) pp. 2344-2349. https://doi.org/10.1002/fsn3.819

Pieterse E, Pretorius Q (2014). Nutritional evaluation of dried larvae and pupae meal of the housefly (Musca domestica) using chemical-and broiler-based biological assays. Animal Production Science 54(3):347-355. https://doi.org/10.1071/AN12370

Prasanna B, Huesing JE, Eddy R, Peschke VM (2018). Fall Armyworm in Africa: A Guide For Intergrated Pest Management. CIMMYT, Mexico, CDMX P 120.

Rumpold BA, Schl OK (2013). Nutritional composition and safety aspects of edible insects. Molecular Nutrition and Food Research 57(5):802-823.

SANBI (2018). The South African National Biodiversity Institute. https://www.sanbi.org/animal-of-the-week/fall-armyworm/ 10/16/2018

Sayed WAA, Ibrahim NS, Hatab MH, Zhu F, Rumpold BA (2019). Comparative study of the use of insect meal from spodoptera littoralis and bactrocera zonata for feeding japanese quail chicks. Animals 9(4):136. https://doi.org/10.3390/ani9040136

Shumo M, Osuga IM, Khamis FM, Tanga CM, Fiaboe KK, Subramanian S, Ekesi S, van Huis A, Borgemeister C (2019). The nutritive value of black soldier fly larvae reared on common organic waste streams in Kenya. Scientic Reports pp. 1-13. https://doi.org/10.1038/s41598-019-46603-z

Świątkiewicz M, Witaszek K, Sosin E, Pilarski K, Szymczyk B, Durczak K (2021). The nutritional value and safety of genetically unmodified soybeans and soybean feed products in the nutrition of farm animals. Agronomy 11:6. https://doi.org/10.3390/agronomy11061105

Van Huis A (2016). Conference on ‘ The future of animal products in the human diet : health and environmental concerns’ Boyd Orr Lecture Edible insects are the future? Proceedings of the Nutrition Society pp. 294-305. https://doi.org/10.1017/S0029665116000069

van Huis A, Oonincx DGAB (2017). The environmental sustainability of insects as food and feed. A review. Agronomy for Sustainable Development 37:43. https://doi.org/10.1007/s13593-017-0452-8

Veldkamp T, Bosch G (2015). Insects: A protein-rich feed ingredient in pig and poultry diets. Animal Frontiers 5(2):45-50. https://doi.org/10.2527/af.2015-0019

Williams JP, Williams JR, Kirabo A, Chester D, Peterson M (2016). Chapter 3 - Nutrient Content and Health Benefits of Insects. Elsevier Inc. pp. 61-84. https://doi.org/10.1016/B978-0-12-802856-8/00003-X

Zaklouta M, Hilali El-Dine M, Nefzaoui A, Mohammad H (2011). Animal Nutrition and Product Quality Laboratory Manual International Center for Agricultural Research in the Dry Areas. Aleppo, Syria: ICARDA (International Center for Agricultural Resea rch in the Dry Areas).