Consumers' perception towards eggs from laying hens fed commercial black soldier fly (*Hermetia illucens*) larvae meal-based feeds

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ABSTRACT Increased demand for animal protein has motivated the search for more efficient livestock production systems. In recent years, there has been growing interest to incorporate insect meal as an alternative source of protein to fish/soybean meal in chicken feed for improved nutrition, sustainability, and animal welfare benefits. Black soldier fly larval (**BSFL**)-based feeds has been shown to increase egg production in a cost-effective manner. However, poultry consumers perception towards the consumption of eggs from layers fed diet integrated with BSFL-based meal have received limited research attention. This study evaluates consumers' perception towards eggs from hens fed BSFL-based diets and socioeconomic factors influencing the conceived perceptions. The study adopted an exploratory factor analysis (**EFA**) and binary logit regression models to establish perceptions of 200 consumers in Kiambu County, Kenya. Our results revealed that 65% of the consumers were aware of the benefits of integrating insect protein in poultry feed. Over 70% of respondents showed preference and willingness to consume egg products from hens fed diets with BSFL-based feeds. The EFA identified perceived benefits, ethics and traceability as the key aspects that influence consumer intention to consume eggs. Binary logit model revealed that consumer characteristics such as household size, gender, awareness of insects as feed, off-farm income, household income, nature of buying place, and access to credit were important factors driving consumers perceptions. Our findings provide insight into the market perception and potential of eggs from laying hens fed BSFL-based feeds. Our findings demonstrated that increased awareness creation and evidence-based demonstration on the benefits of BSFL-based feed in poultry production would improve consumer perception and foster uptake of this rapidly growing and emerging technology. This work contributes to the limited knowledge on BSFL-based feeds and paves way for further linkages between farmers, public private partners, policy makers, and consumers.

Key words: black soldier fly larvae meal-based feeds, chicken eggs, consumer perception, sustainability, food security

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INTRODUCTION

The increasing global population has resulted in higher demand for protein rich foods specifically animal proteins, consequently requiring an increase in their production (FAO, 2017). This requires increased productivity of the livestock subsector which plays a vital role in the Kenyan economy accounting for about 12% of the national GDP (2018). Among the important subsectors of the Kenyan livestock sector is the poultry subsector accounting for about 30% of the sector's GDP (Netherlands Africa Business Council NABC, 2019). The poultry subsector contributes to incomes in rural and urban households and improves nutrition by the provision of meat and eggs as there is a growing demand for poultry products (GOK, 2019).

The growth of the poultry subsector has been slow but has steadily increased over the years (Kenya Bureau of Standards KEBS, 2017). The slow growth is attributed to high cost of production mainly due to feed materials used and lack of quality feed (Shaw, et al., 2019). The commercial feeds sector uses conventional protein sources (soy bean and fish meal) which account for 60 to 70% of production costs (Veldkamp and Bosch, 2015; Ravindran, 2013). The use of conventional proteins in animal

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feed is faced with challenges such as land and water scarcity, food-feed-fuel and climate change competition which make it unsustainable (Van Huis et al., 2015).

As a practical solution, the use of insects in animal feed has received growing interest as a viable alternative to soy bean and fish meal as protein sources due to its contribution to sustainable development in terms of nutritional and environmental benefits (Van Huis et al., 2015). Insects have been reported to improve egg production, quality, and taste when used as an alternative protein source in poultry feed. (Thirumalaisamy et al., 2016; Star et al., 2020). Besides, it is a natural behavior for chickens raised using backyard farming systems to forage and feed on insects (Gasco et al., 2019). Insects have shown high nutritional value, high protein level, and unlike the production of plant based and livestock based protein sources, insects need less land and water to be produced (Van Huis et al., 2015).

In 2017, Kenya Bureau of Standards (**KEBS**) approved the use of dried insect products in formulated conventional animal feed (Kenya Bureau of Standards KEBS, 2017). Although some products from animals fed insect-based feeds and insect-based foods have already entered the market, there is limited research attention toward the development of consumer-driven high-value product (Kelemu et al., 2015; Alemu et al., 2017; Pambo et al., 2018; Szendrő et al., 2020). There has been a growing interest by private and public sectors partnering with the International Centre of Insect Physiology and Ecology (***icipe***) to explore the use of insects for poultry feed. Black soldier fly Larval (**BSFL**) have been identified for mass rearing due to their ability to convert organic waste into high-quality crude protein (**CP**), fat, amino acids, fatty acids, vitamins and minerals that are comparable or superior to that of fishmeal and soybean (Onsongo, 2017; Ssepuuya et al., 2017; Onsongo et al., 2018).

The growing demand for proteins is associated with increased urbanization, changing lifestyles and changes in consumer preference. The rise in demand has seen an increase in acceptance of products produced with insect-based feed (Van Huis et al., 2013; Verbeke et al., 2015; House, 2016; Domingues et al., 2020; Szendrő et al., 2020;). However, extant studies have sighted avoidance of new foods (neophobia) and disgust as barriers to accommodating insects into their human diets (Van Huis et al., 2013). In Kenya, the use of insects as food and feed may be more challenging since their consumption is only found among few communities, particularly in Western Kenya. In Western Kenya, lake flies, termites, black flies, and grasshoppers have traditionally been consumed by locals (Alemu et al., 2015). Neophobia can be overcome by availing information to households on the perceived benefits of consuming products produced with insect-based feed (Lombardi et al., 2019; Szendro et al., 2020). This study aligns well with those that seek to introduce insects more easily by incorporating them into animal feed (Kim et al., 2019).

Prior to the introduction of the innovations, understanding the context and interests of the target groups plays a vital role in positive reception of the product. There has been growing interest in increasing existing literature on consumer's perception towards insect-based feed and the products (egg and meat) derived from livestock fed insect-based feed (Verbeke et al., 2015). Previous research by Mawia (2018) to understand the preference and willingness to pay (**WTP**) for poultry meat derived from chicken fed on insect-based feed showed 93% acceptability with 59% of the consumers willing to pay a premium. Mawia (2018) recommended the urgent need for awareness creation to boost consumers' preferences. These findings are consistent to that reported by Ferrer Llagostera et al. (2019) in Spain with over 60% of consumers willing to pay a premium for insect-fed fish products. Thus, understanding the key drivers of perception such as price, animal and environmental welfare provides an accurate representation of consumers' background and factors that might hinder their acceptance to products developed from this new technologies (Domingues et al., 2020; Spartano and Grasso, 2021). Recent literature has shown positive perception on commercial insect-based feed (**IBF**) by farmers (Chia et al., 2020; Okello et al., 2021) but published information on consumers' willingness to pay for products derived from livestock fed IBF is lacking.

Several studies have shown growing acceptance for products derived from insect-fed fish and chicken in the European markets (House, 2016; Sogari et al., 2017; Biasato et al., 2019; Szendrő et al., 2020; Domingues et al., 2020), while limited research on the same has been reported in Africa. Perception is defined in this study as an understanding of aspects related to eggs produced from insect-fed hens and potential consumption. The current study builds on the work described by Mawia (2018) by investigating factors that can potentially create a positive shift in consumer behavior toward the consumption of eggs from insect-fed hens. Information on factors that influence consumer perception and acceptance is crucial and underlies the success of a new product in the market. This information could significantly provide insight in the design of enabling policies and dissemination of information aimed at increasing the use of insects in poultry feed. Thus, this study uses an exploratory factor analysis (**EFA**) to construct 3 perception factors that are used subsequently in the binary logit regression to evaluate factors influencing consumers' perception towards eggs produced from chickens fed on commercial insect-based feed.

MATERIALS AND METHODS

Definition and Measurement of Variables

In order to study consumer perceptions of eggs derived from BSF-based feed, statements were drafted to measure similar concepts explored by previous studies on introduction of insect based food products (Mawia, 2018; Kisaka et al., 2018). We measured perception statements on eggs derived from BSF-based feed relate to different aspects which included purchasing concerns,

perceived benefits, ethics, and the advantages of consuming these eggs. Previous studies have developed their perception statements on food products based on what consumers expected from their purchases (Mawia, 2018; Szendrő et al., 2020). In this study eighteen statements relating to perception of eggs were selected and respondents were asked to rate their level of agreement on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The statements focused on consumer concerns when making purchase decisions such as knowledge on chicken feed, labels on eggs, prices of eggs, the difference between eggs derived from BSF based feed and eggs produced from conventional feed, perceived benefits associated with consuming eggs derived from BSF based feed, and ethical concerns of consuming eggs derived from BSF based feed.

Data Sources and Sampling Procedure

The survey was conducted from a size random sample of 200 consumers who were deemed responsible for their household or family purchases. The sample came from 3 regions in Kiambu County in the subcounties of Kikuyu, Kabete, and Ruiru which were purposively selected because of their being periurban and strong engagement in production and trading of poultry products. Proportional to the population of the subcounties, the following numbers of households were selected per study community: 49 households in Kikuyu, 53 households in Kabete, and 98 households in Ruiru subcounties. A simple random sampling technique was applied to select every third shopper in the egg purchase outlets located in the markets and residential areas as shown in Figure 1. The sample comprises of a population in periurban areas that represents diverse features of urbanization including tastes and incomes. Data were collected from the selected households using pretested semistructured questionnaire (contained a mixture of open-ended and closed ended questions) by trained and experienced enumerators. Data collected included household demographic characteristics, awareness of insects use in animal feed, the perceptions on eggs derived from chicken fed on BSFL-based feeds, and consumption expenditure. Whether the consumers were aware or not, the hypothetical perceptions were presented after the respondents were informed on the prospective use of insects and their advantages as an alternative protein additive in poultry feed. This explanation was necessary to increase awareness that insects can be used in chicken feed.

Data Analysis

This study employs binary regression analysis to estimate the factors influencing consumers' perception of eggs derived from insect fed hens in Kiambu County, Kenya. The dependent variables of the binary regression equation are the perception indices composed using an EFA, while the independent variables consist of consumer characteristics. According to (Cakmakyapan and Goktas, 2013) a binary logit regression is used in estimating generalized linear models particularly when the dependent variable is binary. This approach is well-

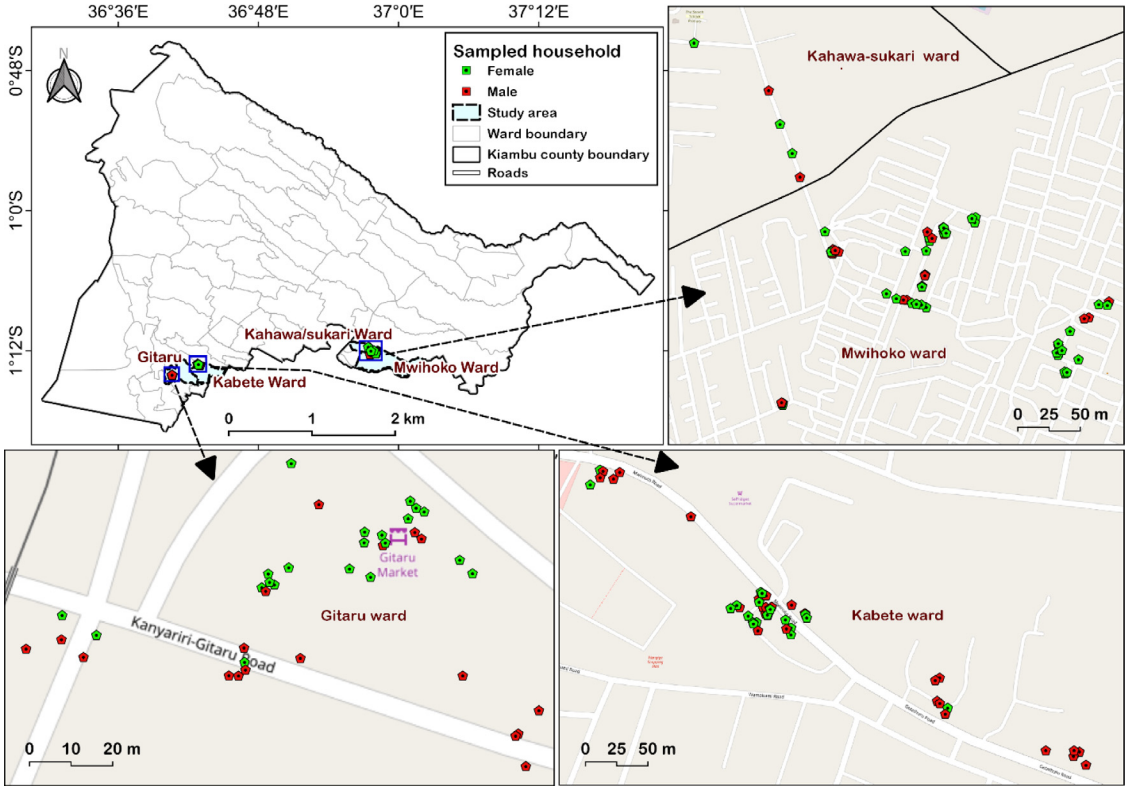

Figure 1. The map of the study area. Source: Survey (2020). This map shows the sampled households (200) for the survey. It Is categorized into male-headed and female-headed households. The sampled areas are in three sub counties, Ruiru subcounty, Kabete subcounty, and Kikuyu subcounty.

suited in this case due to the binary nature of perception indices. Whereas EFA reveals latent construct variables representing consumers' perceptions on eggs produced from hens fed BSFL-based feed, the binary logit provides in-depth analysis of the factors affecting the perception and this can be conveyed to other value chain actors concerned with insect-based feed.

EFA EFA was used to summarize perception statements and identify the hypothetical factors which explain the covariance among observed variables. EFA is a statistical model whose purpose is to understand what constructs underlie given data and reduce dimension of correlated variables (Taherdoost et al., 2014). A factor consists of interrelated observed variables that are influenced by the same underlying construct and are grouped together based on their loadings. The criterion to define the number of factors retained was to have an eigen value greater than one (Hair et al., 2010). The component loadings are subjected to an orthogonal varimax rotation that produces uncorrelated factor scores for ease of interpretation. Items were retained in a factor if the factor loadings were above 0.4 for use in constructing perception indices. The results of the EFA were then used to construct a normalized index of a scale of between 0 and 1 which was used in the subsequent binary regression (logit regression). Normalization was important for generating a common scale lying between 0 and 1 without distorting the differences in the ranges of values of the different factors. The index was calculated as:

$$Normalize\ index\ (X) = \frac{x - min}{max - min} \tag{1}$$

X being the index scaled between 0 and 1
Min being the minimum value in the scaled index
Max being the maximum value in the scaled index.

A binary score was subsequently derived from the normalized scores; where scores equal to or greater than the mean were assigned "positive perception" and those less than the mean assigned the "negative perception".

To further understand the association between consumers' perception and socioeconomic characteristics, we conduct binary regression analysis. This was used to model association between a select set of socioeconomic characteristics and consumers' perception. The dependent variables comprise of 3 individual perception indices that are a binary index of the normalized scores (perceived benefits, ethics, and traceability) of the key perception factors whereas the consumers' characteristics are the explanatory variables. Following (Hosmer et al., 2013) the binary regression is expressed as follows:

$$log\frac{(P_i)}{(1-P_i)} logP_i + \beta_0 + \beta_i X_i \tag{2}$$

For simplicity Equation (2) was expressed as:

$$P_i = \frac{1}{1 + e^{-Zi}} \tag{3}$$

$$1 - P_i = \frac{1}{1 + e^{-Zi}} \tag{4}$$

where,

P_i is the probability of positive perception
1-P_i is the probability of negative perception
e^{-Zi} is the irrational number e raised to the power of Z
Z_i is a function of N-independent variables and expressed as

Accordingly

$$Z_i = \beta_0 + \beta_i X_i + e_i,\ i = 1, 2, 3, \ldots, n \tag{6}$$

where, X_i is the set of independent variables, β_i is the coefficient of independent variables such as: age, gender, household size, income, time, off farm income, nutrition group, Information, credit, awareness, purchase outlet, and willingness to consume and e_i is the error term.

Previous studies have shown there is an association between consumers' potential to stimulate consumption of a new product and various socioeconomic characteristics and the (Van Huis et al., 2013; Sogari, 2015; Domingues et al., 2020). The respondents social demographics such as age, gender, education were included as control variables. Sethi (2018) included physiological variables (such as awareness of information) to inform the perception of individuals on the knowledge of use of insects and to improve the predictions provided by the models. Domingues et al. (2020) evaluated factors influncing consumers' willingness to accept use of insects in animal feed using logistic regressions based on factor scores in Brazil. The study included sociodemographic characteristics such as age, gender, region and income in the regression models. We also included consumers' choice of purchase outlets, household size, access of credit and group membership to capture unique characteristics of Kiambu County consumers.

RESULTS

Consumer Characteristics

Selected socioeconomic characteristics of sampled consumers are presented in Table 1. Overall, the sample consisted of 59 (29.5%) female-headed households and 141 (70.5%) male-headed households. There were significant differences between male-headed and female-headed households according to the findings. Particularly, there was a difference ($P < 0.1$) in age between male-headed and female-headed households. Membership in nutrition groups was relatively low in both male-headed and female-headed households. However, more females that males belonged to nutrition groups ($P < 0.05$) compared to other groups. The difference ($P < 0.01$) in income earned by female-headed households was significantly higher than that for male-headed households. There was a difference ($P < 0.05$) in earning off-farm income between male-headed and female headed households. Additionally, awareness on the use of insects in poultry feed was generally high at 65% and majority of the consumers (70%) were willing to consume eggs produced from insect-fed layer chicken. In

Table 1. Descriptive statistics for consumers' characteristics.

Variable	All households (n = 200)	Male-headed (n = 141)	Female-headed (n = 59)	Statistical differences
				T-statistic
Age	36.52 (10.9)	35.6 (9.96)	38.6 (12.58)	1.771*
Time to market (minutes)	11.5 (12)	10.40 (11.28)	12.92 (13.62)	1.348
Household size	3.76(1.766)	3.801(1.729)	3.661(1.863)	−0.512
				Chi-square
Off-farm income (% yes)	29.50	24.82	40.68	5.028**
Income (% yes)				17.601***
<10,000	33.00	24.11	54.23	
10,001-20,000	34.00	38.30	23.73	
20,001-30,000	17.00	18.44	13.56	
30,001-40,000	9.00	10.64	5.08	
>40,001	7.00	8.51	3.39	
Access to credit (% yes)	54	55.32	50.85	0.335
Awareness (% yes)	65.50	65.25	66.10	0.013
Nutrition information (% yes)	27.50	21.99	40.68	7.289***
Group membership (% yes)	9.00	6.38	15.25	3.997**
Willingness to consume (%)	70.50	30.50	40	6.839
Purchase outlet				
Open market (% yes)	45.5	42.55	52.54	1.674
Kiosk (% yes)	44	45.39	40.68	0.375
Farm gate (% yes)	41.5	41.84	40.68	0.023
Supermarket (% yes)	2	2.13	1.63	0.397

Note: Statistical differences are between male and female headed households.
*P 0.10.
**P 0.05.
***P 0.01.

regards to the preferred purchase outlet, there are no significant differences between the two consumer categories. Supermarkets were the least preferred market outlet as compared to other outlets, overall.

Consumers' Rankings on Perception of Eggs Produced From Hens Fed BSFL Based Feed

Consumers were asked to rate how they agreed with constructed perception statements considered when choosing eggs to buy as shown in Table 2. Value close to 5 suggested agreement with the perceptions while values closer to one indicated disagreement. Notably, the statement that had the highest mean ranking was "*Eggs produced from chicken fed on BSFL based feed are rich in nutrients*" at a mean of 4.00. The next strongly agreed with statement was "*the eggs are healthy*" which had a mean of 3.88. The mean level of agreement with statements concerning hygiene and environment were favorably perceived as indicated with means of 3.72 and 3.69, respectively. The need for labeling the eggs was also an important consideration for consumers with a mean score of 3.60. Aspects concerning religion and cultural values, which have been known to shape behavioral patterns, had means of 1.64 and 1.62, respectively.

Factors Influencing Consumers' Perception on Use of BSFL as Feed

Eighteen statements were used to find the factors that related to consumers' perceptions on eggs produced from hens fed insect-based feed characteristics. Factor

Table 2. Mean rankings and standard deviations of perception statements.

	Variable	Mean	Std. dev
1.	Eggs produced from chicken fed on BSFL feed are rich in nutrients	4.00	0.75
2.	Consuming eggs produced from BSFL feed is healthy	3.88	0.80
3.	I am unbothered on what chicken feed on	3.74	1.31
4.	Eggs produced from chicken fed on BSFL feed are hygienic	3.72	0.85
5.	Consuming eggs produced from chicken fed on BSFL feed is environmentally friendly	3.69	0.77
6.	Eggs produced from BSFL feed should be labeled	3.60	1.33
7.	Eggs produced from chicken fed on BSFL feed have no chemical residue	3.55	0.99
8.	I would buy eggs produced from chicken fed on BSFL feed regardless of the price	3.35	1.17
9.	Eggs produced from chicken fed on BSFL feed are medicinal	3.17	0.81
10.	Eggs derived from BSFL based feed are different from conventional eggs	3.07	1.11
11.	I require health authority recommendations to buy eggs derived from BSFL feed	3.05	1.30
12.	I have adequate knowledge on feed	2.96	1.22
13.	Eggs produced from chicken fed on BSFL meal are different from fish and meat	2.60	1.03
14.	Use of insects as chicken feed will lower the price of eggs	2.46	1.22
15.	Eggs produced from chicken fed on BSFL feed are a luxury	2.43	1.07
16.	I take into consideration on what chicken feed on before I buy eggs	1.94	1.08
17.	Use of BSFL feed as chicken feed goes against my religious beliefs	1.64	0.91
18.	Use of BSFL feed as chicken feed goes against my culture	1.62	0.91

Note: Scale ranging from 1 (strongly disagree) to 5 (strongly agree) Source: Survey Data (2020).

Table 3. Rotated factor matrix of consumers' perception.

Perception statements	Perceived benefits	Ethics	Traceability
I have adequate knowledge on feed	0.2244	−0.0046	0.2554
I take into consideration what layer chicken are fed on before I buy eggs	0.0777	0.0851	**0.5498**
I am unbothered on what chicken feed on	−0.0422	−0.0279	**−0.5423**
Eggs derived from BSFL based feed are different from conventional eggs	0.1351	−0.0824	−0.1276
Eggs produced from chicken fed on BSFL meal are different from fish and meat	−0.1585	−0.0446	−0.2901
I would buy eggs produced from chicken fed on BSFL feed regardless of the price	0.359	0.0801	0.4062
Eggs produced from chicken fed on BSF feed are hygienic	**0.7724**	−0.0751	0.21
Consuming eggs produced from BSF feed is healthy	**0.7438**	−0.1912	0.0627
I require health authority recommendations to buy eggs derived from BSFL feed	0.1116	0.1917	0.2265
Eggs produced from chicken fed on BSFL feed have no chemical residue	**0.5331**	−0.0346	−0.0368
Consuming eggs produced from chicken fed on BSFL feed is environmentally friendly	**0.6912**	−0.2751	0.035
Eggs produced from chicken fed on black soldier fly larvae meal are rich in nutrients	**0.8233**	−0.1729	−0.0697
Eggs produced from chicken fed on BSFL feed are medicinal	−0.1027	0.3009	−0.0756
Eggs produced from chicken fed on BSF feed are a luxury	−0.2162	0.0075	−0.1477
Use of insects as chicken feed will lower the price of eggs	−0.1853	**0.8636**	0.0839
Use of BSF feed as chicken feed goes against my religious beliefs	−0.1753	**0.867**	−0.0245
Use of black soldier fly larvae as chicken feed goes against my culture	0.0035	0.2983	0.2905
Eggs produced from black soldier fly should be labeled	18.00	12.50	20.50
Total variance explained (%)	47	30	18
Cumulative variance explained	47	77	95

Note: Factor loading taken is >0.4 are in bold and eigenvalue is over 1.
Kaiser-Meyer-Olkin (KMO) of sampling adequacy = 0.733.

analysis on these statements using EFA combined with varimax rotation shows that there are three factors underlying consumers' perception as shown in Table 3. The Kaiser-Meyer-Olkin (**KMO**) test was used to determine if the data was suitable for further analysis. Since the KMO value was 0.733 (minimum threshold being 0.50) and the Cronbach's alpha for the data was 0.804 (minimum threshold being 0.7), the data were considered reliable for further analysis. The retained factors explained 95% of the total variation.

Following some adaptations of Verbeke et al. (2015) and Mawia (2018) work, the components were labeled according to similarities of the statements that had significant loadings on them. The factors were labeled 'perceived benefits', 'ethics on the use of BSFL', and 'traceability of feed'. The first factor relates to perceived benefits regarding the use of BSFL based feed in egg production. It explains the largest variance (47.17%) in the components. The second factor focuses on the ethics which can be defined as principles that govern ones' behavior. It explains 30.11% of the variance. The third factor focuses on the traceability of feed and explains 18.41% of the variance. It is concerned with whether consumers have an interest to find out the feed used in egg production and whether consumers considered it relevant during purchase of eggs. These factors are retained to be used as dependent variables in the binary regression.

Binary Logit Results

Table 4 shows the results of the binary regression analysis. For each respondent, we predict the retained component for the three factors and regress the normalized scores against the household characteristics outlined earlier. The results show that only 8 independent variables have significant association with consumers' perception of eggs produced from hens fed BSFL based feeds. The variables that were found to have a significant association with consumers' perception on eggs produced from hens fed BSFL based feed included; access to credit ($P < 0.01$) and ($P < 0.05$), off-farm income at ($P < 0.01$), awareness at ($P < 0.01$), income at ($P < 0.05$), household size at ($P < 0.01$) kiosk at ($P < 0.05$) and open-air market as a purchase outlet at ($P < 0.05$).

Overall, low incomes, access to credit, off-farm income, awareness, and open-air market positively and significantly influenced consumers' perception of the perceived benefit factor. The more aware a consumer is the more the benefits aspect is important. Consumers who had other sources of income other than agriculture were more likely to positively perceive the benefits factor. Average income earners in comparison to low-income earners are more concerned about the benefits of eggs but as income increases, the less the concern by consumers. Consumers who purchase eggs from open air markets were more concerned with the perceived benefits. The ethics factor was positively influenced by household size. Consumers whose household sizes were larger were more likely to have a favorable perception of the ethics factor. Consumers with average income were less likely to have positive perception on the ethics factor. Similarly, consumers with access to credit were less likely to positively perceive the ethics factor. Male-headed households had higher likelihoods of being concerned with the traceability factor. Finally, households who purchased eggs from open air markets and kiosks were more likely to be concerned with the traceability factor than those who purchased from other outlets.

DISCUSSION

The present study used binary logit to assess perception of eggs from layer chicken fed on insect-based feed. The results indicate that majority of consumers in this study positively perceived these eggs and were willing to

Table 4. The estimated coefficients of the binary logit for consumer perception and economics on sustainability of egg production using insect-based feeds in hens diets.

	Binary regression parameter estimates			
Explanatory variables	Perceived benefits	Ethics	Traceability	VIF
Age	0.001 (0.017)	0.004 (0.016)	−0.024 (0.016)	1.23
Gender	0.378 (0.413)	−0.495 (0.380)	0.778 (0.366)*	1.19
Household size	0.076 (0.100)	0.310 (0.103)**	0.0105 (0.092)	1.14
Income (base Ksh <10,000)				
Ksh 10,001−20,000	0.909 (0.427)*	−0.123 (0.407)	0.279 (0.394)	1.5
Ksh 20,001−30,000	1.041 (0.525)*	−1.021 (0.510)*	−0.033 (0.466)	1.37
Ksh 30,001−40,000	0.485 (0.641)	−0.316 (0.614)	−0.348 (0.598)	1.24
Ksh >40,001	1.009 (0.821)	−0.222 (0.675)	−0.969 (0.714)	1.29
Access to credit	0.999 (0.340)**	−0.825 (0.323)*	−0.009 (0.311)	1.03
Off-farm income	1.270 (0.431)**	−0.004 (0.392)	0.178 (0.372)	1.24
Distance to market	0.013 (0.016)	0.015(0.014)	−0.005 (0.014)	1.21
Nutrition information	0.232 (0.417)	0.744 (0.392)	0.534 (0.385)	1.21
Group membership	−0.889 (0.621)	0.130 (0.621)	0.091 (0.581)	1.18
Awareness	1.407 (0.374)**	0.608 (0.342)	0.226 (0.332)	1.06
Open air market	0.936 (0.433)**	−0.976 (0.407)	0.851 (0.398)*	1.57
Kiosk	0.374 (0.440)	−0.710 (0.406)	0.824 (0.407)*	1.61
Supermarket	1.923 (1.396)	-2.289 (1.323)	2.086 (1.483)	1.19
Farm gate	0.403 (0.413)	−0.680 (0.388)	−0.203 (0.373)	1.46
Constant	−3.720 (0.963)	−0.046 (0.817)	-0.416 (0.804)	
Adjusted R-squared	0.2171	0.1503	0.0953	
Observations (n)	200			

Abbreviation: VIF, Variance inflation factor.

** $P \leq 0.01$ level and

* $P \leq 0.05$. Standard errors are in parentheses. Goodness of fit statistics for the model "perceived benefit": $\chi^2 = 200.96$; $P = 0.1596$. Goodness of fit statistics for the model "perceived benefit": $\chi^2 = 198.92$ $P = 0.1852$. Goodness of fit statistics for the model "perceived benefit": $\chi^2 = 200.54$ $P = 0.1647$.

consume them. The perception statement regarding nutrition and health aspects of the eggs were the most highly ranked with means of 3.88 and 4.00, respectively. This is in line with the findings of other surveys (Nichani, 2005; Onyango et al., 2006) that health and nutrition status of foods are among the major concerns of consumers. Labeling the eggs was also an important consideration for consumers with a mean score of 3.60. This indicates the need to label the products for consumers to be aware of the variety of eggs in the market. However, Balcombe et al. (2016) challenged the viability of increasing nutrition literacy for consumers citing that labeling may not be sufficient to inform consumers on the products. The study found that alternative marketing policies and providing consumers with information using media such as advertisements, may positively improve the perception of food products.

The EFA approach was used to derive three perception factors from the perception statements; perceived benefits, ethics and traceability of feed. These factors explained 95% of the variation and the three factors were used as the response variables in the binary regression analysis. The factor perceived benefits was positively and significantly influenced by low income, access to credit, off-farm income, awareness, and open market as a purchase outlet. The aspect ethics was influenced by household size, income, and access to credit. We also found that gender, open air market as a purchase outlet and kiosk as a purchase outlet to positively and significantly influence consumers' perception in regards to the traceability aspect. These findings suggest that consumers who were aware of the use of insects, who earned low incomes, who purchased eggs in open air markets and kiosks, had access to credit and had off-farm income source had an increased likelihood to positively perceive and accept eggs produced from layer hens fed BSFL-based feed.

Perceived benefit aspect of these eggs was positively correlated with consumers who were aware of the inclusion of insects in poultry feed. This shows that raising awareness and disseminating information are critical steps in adopting eggs produced from hens fed insect-based feed among egg consumers. These findings are consistent with previous studies, which revealed that people who were aware of new products had a favorable perception toward them (Bonti-Ankomah and Yiridoe, 2006; Angulo and Gil, 2007; Verbeke et al., 2015). Sogari et al. (2017) also reported better consumer acceptance of edible insect-based food when introduced into the market after considerable press and mass media coverage on entomophagy. Perceived benefit aspects such as nutrition and health of the eggs were perceived to be more important by middle-income earners than low-income earners. This might be due to the fact that middle-income earners have increased disposable income allowing them to have options when purchasing than those with low income who purchase less healthy foods. Similarly, consumers with access to credit perceived the benefit factor positively than consumers without access to credit. This implies that an increase in economic resources may permit them to purchase a variety of eggs available in the market. Consumers who preferred open air market as a purchase outlet perceived benefit aspect more importantly than those who preferred other purchase outlets. Open air markets are known to be convenient, offer variety, and fresh and nutritious agricultural produce (Cherono and Otieno, 2016).

The ethics aspect of eggs perception focused on the effect of culture on perception of eggs from layer

chickens fed on BSFL based feed. Previous studies suggested culture as an important aspect with regard to acceptance and preference of insect-based foods (Tan et al., 2015). Increased household size had a positive and significant correlation with the ethics factor. This might be due to the diverse opinions by members of the household hence increasing the perception of new foods. Consumers who had access to credit were less likely to positively perceive eggs produced from insect fed layer chickens. Middle level income earners (Ksh 20,000−30,000) perceived the ethics aspect to be less important than those who earned relatively lower incomes. This might be explained given that insects are affiliated with primitive people and often associated with poverty (Osimani et al., 2018; Alemu and Olsen, 2020).

The traceability aspects of the eggs were perceived to be more important by male headed households. Also, consumers who preferred open air markets and kiosk as purchase outlets were keener on the traceability issue. This implies that labeling of these eggs is important in marketing to differentiate them from conventional eggs.

CONCLUSIONS AND RECOMMENDATION

The inclusion of insects in feeds for poultry production systems could be one way of diversifying the commercial feed sector. Economic incentives and environmental benefits promote the use of insects as a substitute for conventional protein in animal feed. Despite the benefits, there is little knowledge on whether consumers would accept poultry products from chicken fed insect-based feed. Previous studies have largely focused on consumer acceptance and perception in developed countries, while the current study has focused on Africa, particularly in Kenya as a market due to the growing interest and rapid uptake of the emerging insect farming industries. Our results indicate consumers had a positive perception toward eggs derived from insect-fed hens as an alternative to eggs obtained from hens fed on conventional fishmeal/soya bean-based feeds.

Consumer awareness on the use of insects in animal feed, off-farm income, open market as purchase outlet, and credit access were significant drivers and had a positive impact on their perception toward eggs from insect-fed hens. Over 65% of the consumers were aware that insects are used in poultry feed as a source of protein. Further studies should explore consumer perception of new food products to improve on findings other than socioeconomic factors. These findings provide a platform for the food industry and policy makers to communicate relevant information regarding the use of insects as high-quality protein ingredients in animal feeds to consumers, particularly through labeling of these new products or development of alternative point of sale promotion such as free samples to make consumers aware of the products they are purchasing. These methods may increase consumers' nutrition literacy as this is a major detriment to introducing new food products in the market. To increase consumer confidence and trust, regulatory frameworks should be developed to ensure precise insect inclusive legislation standards for regulating the production and use of insects across the food and feed value chain.

It is worth noting that this study was hypothetical, hence, it did not exploit the real market situation and sensory attributes among others that could influence consumers' perception. Understanding consumer perception from consumers with previous experience in sensory characteristics of the new food products would add novelty to these results, particularly with regard to levels of perception, preferred eggs and the influence of socioeconomic characteristics. Another limitation is that the study was carried out in Kiambu County, which is 1 out of the 46 Counties in Kenya. Therefore, our findings should be interpreted with care and not considered as full representative of the entire Kenyan population.

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DISCLOSURES

The authors declare no conflict of interest.

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