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Full Research Article

Traditional poultry farmers' willingness to pay for using fly larvae meal as protein source to feed local chickens in Benin

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Abstract. This study estimated poultry farmers' willingness to pay (WTP) for fly larvae meal as animal protein source to feed local chickens in Benin. A double-bounded contingent valuation approach was used to collect data from 480 poultry farmers, and an interval regression model was performed. We found that 82.10% of poultry farmers are willing to pay for using fly larvae meal. The average WTP was estimated at FCFA/kg 225.10 (€/kg 0.34), indicating a potential and reliable demand in fly larvae meal. Our analysis suggests that public actions can sensitize poultry farmers and support innovative small companies to produce and market fly larvae meal.

Keywords. Animal feeding, Benin, Fly larvae, Poultry farmer, Willingness to pay.

JEL codes. Q120, Q160, Q180.

1. Introduction

Poultry farming plays an important role in traditional agricultural production systems in Africa. Poultry farming is ideal for all families, even the poorest (Bell, 1992), given the low individual needs of the animals involved and the low investment costs (Guèye, 2002). It provides a significant share in the supply of animal protein calories (Buldgen *et al.,* 1992) and of cash income. Therefore, poultry farming contributes to poverty reduction. Edible domestic poultry includes chickens, pigeons, geese, ducks, guinea fowls, quails, turkeys, etc. (Njue *et al.*, 2002). In developing countries, chicken (domestic fowl) is the most widely accepted and appreciated species (Ideris *et al.*, 1990) and makes up the bulk of the poultry industry (Spradbrow, 1997). Three traditional poultry production systems exist and have been studied: the scavenging system, the semi-scavenging system and, the confinement system (Gunaratne *et al.*, 1993).

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The most common system in rural Africa is based on scavenging poultry (Kitalyi, 1998). Although productivity is modest, even a few live poultry and eggs generate a net benefit for poultry farmers because of the very low production costs (Buza and Mwamuhehe, 2001). The deficit in poultry products in developing countries, particularly in sub-Saharan Africa, is mostly due to the low productivity of traditional poultry (Guèye, 1998) and other factors as well. As shown by Narrod *et al.* (2008) and Delgado *et al.* (2008) the production technology for exotic breeds of poultry meat is widely available and has in fact been used by farmers in developing countries. To overcome these deficiencies, many African countries have supported the development of short-cycle poultry species hoping to provide people cheap and with highly nutritive animal products. The constraints of traditional poultry farming include access to animal feed and healthcare, improving productivity as well as commercial issues. In particular, the dominant local breeds are of low productivity and the traditional chicken farming methods are prone to diseases, which sometimes decimate entire flocks.

Feed represents the major constraint to the development of small-scale poultry farming in Africa. Feed given to local poultry is often insufficient in quantity and quality because its protein content is low, especially during dry seasons (Goromela *et al.*, 2006). In particular, scanty provision of dietary protein by rural farmers to scavenging poultry does not optimize productivity and profitability of their enterprise. The use of unconventional food resources such as local legume seeds, leaves and tubers, and various animal by-products, which availability or cost is not a limiting factor, could be a solution. The interest in these resources in recent years has particularly increased with the grain crisis of 2007. The conventional protein sources such as soybean and peanut de-oiled cake (DOC) and fish meal are indeed rare and therefore expensive. The demand and the price of fish meal, which is used as protein in animal feeding, have particularly increased these recent years (FAO, 2014). Various studies attempted to use locally available animal and vegetable proteins to substitute some or all of the conventional proteins (Basak *et al.*, 2002; Amaefule and Osuagwu, 2005; FAO, 2014; Mutungi *et al.*, 2017). The introduction of snail flour or meat in animal diet has been explored (Barcelo and Barcelo, 1991; Farina *et al.*, 1991). The positive influence of the use of termites as a protein source on production parameters of guinea fowl in villages has been demonstrated (Chrysostome, 1997). Earthworms have been bred as a protein source for feeding chickens (Vorsters *et al.*, 1994). Broilers can receive 3.6% of earthworm flour to substitute 5% of meat meal without affecting their growth performance (Agbédé *et al.*, 1994). Also fly larvae, in particular house fly (*Musca domestica*) and black soldier fly (*Hermetia illucens*) proved to be an excellent source of protein, and can replace fish meal partly or entirely in animal diets (Kenis *et al.*, 2014; Makkar *et al.*, 2014). Pomalégni *et al.* (2016; 2017) indicated the use of fresh fly larvae by small poultry farmers in Benin, and most of them had a good perception of its use in poultry feeding. Pomalégni *et al.* (2017) showed that 5.6% of traditional poultry farmers in Benin use fly larvae at least occasionally to feed their poultry, with variations among regions. The use of fly larvae in animal feed is safe if the standards of production on substrates are respected (Charlton *et al.*, 2015; Nkegbe *et al.*, 2018). One of the current constraints in the widespread adoption of fly larvae in poultry farming is their unavailability on the market. Seeking an economic measure of fly larvae valorization is a prerequisite to generate relevant indicators needed for better decision-making.

This study explores the terms of use of fly larvae meal in traditional poultry farming diet that may offer new opportunities in terms of value creation, human health preservation and nutritional value improvement of local chickens. It uses the double-bounded contingent valuation procedure to analyze the possibility that traditional poultry farmers could accept to pay for fly larvae meal. The procedure considers nutritional value and contribution to the improvement of production performance of local chickens in Benin. If farmers are willing to pay, how much are they willing to pay? What are the factors affecting their willingness to pay (WTP)? The contingent valuation method is often used to reveal the monetary value of services, public goods, public dimensions of private goods and non-market assets (Roe *et al.*, 2004; Mogas *et al.*, 2006; Wu *et al.*, 2016). It is also used to reveal farmers' and consumers' preferences for new agricultural technologies or products (Wei *et al.*, 2016; Drichoutis *et al.*, 2016). It is based on the intentions of respondents, *i.e*, not on observed behavior (Vidogbéna *et al.*, 2015; Wu *et al.*, 2016).

This paper provides useful information to international Non-Governmental Organizations, international organizations, food policies-makers; and enterprises dealing with food and nutritional security, who intend to promote and/or produce fly larvae meal as a protein source on a large scale to poultry farmers in developing and developed countries.

2. Material and Methods

2.1 Sampling and data collection

This study was conducted in 12 provinces of Benin where traditional poultry farming is practiced. A pilot survey was first made to determine the importance of traditional poultry farming in the provinces, districts and villages of Benin (Pomalégni *et al.*, 2016). The result of that preliminary survey was used to test the validity of the levels of bids proposed for the contingent valuation procedure and to elaborate, test and validate the survey questionnaire. This preliminary survey allowed to select the districts and villages where the real study would be carried out.

Based on information provided by extension officers, one district was chosen in each province according to the relative number of poultry farmers, the genetic diversity, and the supply of poultry. In each district, two villages were selected according to the importance of livestock. Twenty-four villages were visited. The sample size was determined using a formula (Dagnelie 1998):

$$n = \frac{Pi(1-Pi)U^2_{1-\alpha/2}}{d^2} \tag{1}$$

Where Pi is the proportion of traditional poultry farmers considering the number of farmers at the national level and was estimated at 50.00 %. We used Pi =0.5 as it is not possible to make any assumption regarding the traditional poultry farmers coverage in Benin (Lwanga and Lemeshow, 1991). $U_{1-\alpha/2}$ = 1,96 represents the value of the normal random variable for a risk α equal to 0.05 (confidence level). The margin of error *(d)* provided for any parameter to be estimated from the survey was 4.47%. Thus, the sample size n of traditional poultry farmers has been determined as 480. Based on this sample size, 20 poultry farmers were surveyed in each selected village and respondents were randomly selected accordingly.

An in-person contingent valuation survey was administrated to the 480 poultry farmers. Individual surveys were conducted from March to April 2017, which is the best period of the year for interviews since few people work in the field during the dry season. The questionnaire was written in french (Appendix) but the interviews were entirely conducted in the respondents' local languages. Face-to-face interviews were conducted in the presence of a translator when needed. This face-to-face interview was more appropriate as it helps to clearly explain the contingent scenario and background information to illiterate and poorly educated respondents thus avoiding hypothetical bias (Shi *et al.*, 2014). The face-to-face interviews are also more flexible and reliable (Hoyos and Mariel, 2010) and they are better than inquiries made by e-mails, telephone or postal survey (Arrow *et al.*, 1993) in helping to substantially reduce the protest rate and non-responses. Nevertheless, the "social desirability bias" also called "cheap talk" was controlled during the administration of the questionnaires with frequent exchanges with agricultural extensions officers who knew the respondents better than us.

Most of the questions were closed-ended, although some open-ended questions were included to investigate respondents' perception on fly larvae meal use. Outside the principal research questions (the willingness to pay), data were also recorded on socioeconomic characteristics[1] of respondents. At the end of the investigations in each village, the feedback was made in the presence of poultry farmers and agricultural extensions officers.

2.2 WTP elicitation methods

This study used a field experimental bid to reveal small poultry farmers' preferences for fly larvae meal use to feed traditional chicken. The double-bounded contingent valuation procedure was used. The traditional poultry farmers were submitted to a sequence of open-ended questions which gradually helped narrow the WTP. In contrast to single-bounded contingent valuation format, a double-bounded format provides more econometric precision than closed-ended questions lose compared with open-ended questions (Hanemann *et al.*, 1991; Hoyos and Mariel, 2010). The hypothesis of the double-bounded contingent valuation method is that the responses to the two bids are underlying to the same value of WTP and therefore the second bid increases the information on the true WTP of the respondent (Alberini, 1995). To overcome some problems arising in the double-bounded approach, the second bid is only presented to the respondents if it is consistent with the respondent's previous answer. The double-bounded contingent valuation approach is generally preferred over open questions, which are more practical in email survey (Shi *et al.*, 2014). As the survey was conducted face-to-face, protest responses with zero or extremely high values could be given by the poultry farmers (Watson and Ryan, 2007).

Fly larvae may be used fresh, especially at the small-scale farm (Rakotonirina, 1990), or can be made into meal (Hwangbo *et al.*, 2009; Makkar *et al.*, 2014). For industrial or

[1] Such as age, gender, occupation, educational level, main occupation, number of family workers, income, motivation for fly larvae meal use, etc.

semi-industrial production, the meal form is recommended because of the long-term conservation constraints of live fly larvae, which quickly pupate. The nutrients contained in the meal form are as acceptable as those of the fresh form (Makkar *et al.*, 2014). In this study, fly larvae meal option was considered rather than fresh fly larvae to allow a proper comparison with fish meal that is sometimes used in poultry feed. After being informed about the use of fly larvae in animal feeding, traditional poultry farmers were questioned regarding the payment vehicle for the fly larvae meal usage. The respondents who did not protest the payment vehicle were submitted to the contingent scenario with the payment bids, where respondents face a list of bids randomly drawn (Hoyos and Mariel, 2010).

In the experiment, the structure of the contingent scenario was as follows: "Fish meal is used as protein source for chicken feed. The international prices of fish meal are between FCFA 1,000 (€ 1.52) and FCFA 1,200 (€ 1.83) per kg. Fish meal is imported and sold at the local market at FCFA 550 (€ 0.84) per kg by one major importer firm which dominates the market of animal provender in Benin. The low prices can be attributed to the low-quality of the fish meal with lower protein content. Fly larvae meal are an appropriate source of animal protein for traditional chickens. They improve the performances of local chickens (e.g. Average Daily Gain, Food Conversion Ratio, etc.) and they reduce the cost of feed protein. They can replace low-quality fish meal that is used to feed poultry. Would you be willing to pay a sum of FCFA M_i^I per kg to feed your local chickens with fly larvae meal? ". M_i^I is a random value taken into a vector of 7 bids (600; 700; 800; 900; 1,000; 1,100; 1,200). The bids containing seven levels of the monetary payment can be considered reasonably efficient (Carson and Hanemann, 2005). The minimum bid of FCFA 600 (€ 0.91) corresponds to the minimum cost of producing 1 kg of fly larvae meal. Knowing that 1 kg of fly larvae meal required 4 kg of fresh fly larvae, the minimum bid is equivalent to 4 kg of fresh fly larvae, which are produced at a minimum cost of FCFA/kg 150 (€/kg 0.23) (600 = 150 *4). The maximum bid of FCFA 1,200 (€ 1.83) corresponds to the present production cost of 1 kg of fly larvae meal. It is also equivalent to 4 kg of fresh fly larvae, which are produced at a cost of FCFA/kg 300 (€/kg 0.48) (1,200 = 300*4) (M. Kenis and S.C.B. Pomalégni, adapted from Roffeis *et al.*, 2018). These costs are likely to decrease when production systems improve. The first bid M_i^I was followed by the second bid, M_i^U increased when the first bid was accepted, or M_i^L decreased when the first bid was refused by FCFA 100 (€ 0.15), which corresponds to the additional cost to increase or decrease, to a certain level, the quality of the fly larvae meal (content, presentation, etc.). Each poultry farmers surveyed had a first bid M_i^I and the following bid M_i^L or M_i^U according to their response to the first bid, where $M_i^L \prec M_i^I \prec M_i^U$ (Table 1). Four possible responses were used: (a) both responses were "Yes"; (b) both responses were "No"; (c) "Yes" response followed by "No" response; d) "No" response followed by "Yes" response.

An ex-ante approach was used to correct the hypothetical bias on WTP (Loomis, 2011). During the investigation, it was clearly explained to the poultry farmers surveyed that the amount (bids) proposed would be paid for the coming years so that they have fly larvae meal in the markets. This information was given to make a choice that was as realistic as possible. Furthermore, the poultry farmer should feel that his/her response will have policy implications so that he/she feels comfortable supporting or opposing the proposed policy.

Table 1. Random bid schemes used in the double-bounded contingent valuation procedure.

Bid schemes	Decreased follow-up bid in FCFA (if 'No' for M_i^I	Initial bid in FCFA (M_i^I)	Increased follow-bid in FCFA (if 'Yes' for M_i^I)
Scheme 1	500	600	700
Scheme 2	600	700	800
Scheme 3	700	800	900
Scheme 4	800	900	1,000
Scheme 5	900	1,000	1,100
Scheme 6	1,000	1,100	1,200
Scheme 7	1,100	1,200	1,300

2.3 Data and empirical model

2.3.1 Data

The main socioeconomic characteristics of the sample were as followed. In total, 23.75% of poultry farmers surveyed were females whereas 76.25% were males. The average number of local chickens owned by the investigated poultry farmers was around 25. The poultry flock species by descending order of importance were chickens (97.92%), guinea fowl (28.96%), ducks (24.79%), pigeons (11.25%), and turkeys (3.33%) and others (20.83%). The ecotypes of local chickens encountered among the respondents' flock were: the southern ecotype or "Yaya" (83.13%), the "Fulani" ecotype (19.42%), a hybrid ecotype called "Yovokloklo" which is a cross between local and exotic roosters and hens (11.25%), the "Holli" ecotype (7.71%), "Sahwé" ecotype (4.38%) and other local races (0.42%). The poultry farming methods were dominated by the scavenging method (55.05%) followed by the semi-scavenging (42.54%) and confinement methods (2.37%). The average age of respondents was 44 years, with an average age of 45 years for female farmers against 43 years for male farmers. The average years of experience in poultry farming was 16. Although the respondents were all poultry farmers, 61.25% and 10.63% of them had agriculture or livestock and trade as main occupation, respectively. There were 52.29% literate or educated against 47.70% illiterate and only about 4.37% of them were members of a professional organization of poultry farmers. The overall annual income per poultry farmer varied and averaged FCFA 610,663.50 (€930.95). The average annual agricultural income was FCFA 421,563.50 (€ 642.67), representing 69.03% of the average annual overall income of poultry farmers. Poultry production contributes on average to 25.15% of the annual agricultural income (FCFA 106,023) of the poultry farmers surveyed.

Poultry farmers surveyed were aware of the possibility of using fly larvae as poultry feed (92.50%) against only 7.50% who did not know this usage before our survey. Despite this, only 8.54% of poultry farmers surveyed had used fly larvae to feed their chickens against 91.45% who had never used them. In total, 394 poultry farmers (82.08%) were motivated to use fly larvae meal for feed chicken. The motivations varied among respondents. Most, (80%) respondents were motivated by the improvement of the nutritional quality and performance (growth and laying) of their local chickens and (65.42%) respondents mentioned the reduction of feed costs as motivation. At the time of the study, only 41 poultry farmers surveyed (8.54%) had used fish meal as chicken feed, and 39 of them (8.13%) would have liked to replace the fish meal with other protein sources, the rest does not currently use protein to feed their poultry. The motivations behind replacing fish meal with other proteins were: high price of fish meal (37.78%), bad quality of fish meal (26.67%), non-availability of fish meal on the local market (13.33%) and others factors (22.22%). The low use of protein to feed poultry generates low zootechnical performances in many farms.

2.3.2 Econometric model and specification

An interval regression model was developed to determine the factors influencing the WTP and to estimate sample WTP as function of the characteristics of the respondents (Breffle *et al.*, 1998; Fu *et al.*, 2011; Kpadé *et al.*, 2017). Because bids proposed to respondents are defined in certain intervals, interval regression was used to model outcomes that have interval censoring. To elicit WTP, each respondent *i* was considered to accept the payment vehicle for a WTP of fly larvae meal which is equal to Y_i^* and related to the characteristics X_i by the equation:

$$Y_i^* = X_i\beta + \varepsilon_i \tag{2}$$

where β is the coefficient associated to each characteristic, and ε_i is assumed to have zero as average and follows a normal distribution. The data were organized as left-censored for the "No -No" responses, right-censored for "Yes-Yes" responses, and interval-censored for "Yes-No" or "No-Yes" responses for each poultry farmers surveyed. Following Hanemann *et al.* (1991), Y_i^* is not observed, but each respondent WTP *i* was in the interval $\left[M_i^L, M_i^U\right]$. The probability of "Yes-No" response is:

$$\Pr\ (M_i^I \prec Max\ \text{ WTP } \leq M_i^U) \tag{3}$$

The probability of "No-Yes" response is:

$$\Pr\ (M_i^I \succ Max\ \text{ WTP } \geq M_i^U) \tag{4}$$

The probability of the right-censored data, "Yes-Yes" response is given by:

$$\Pr(M_i^I \leq Max\ \text{ WTP and } M_i^U \leq Max\ \text{ WTP}) \tag{5}$$

And the probability for the left-censored data, "No-No" response is as follows:

$$\Pr(M_i^I \succ Max\ \text{ WTP and } M_i^L \succ Max\ \text{ WTP}) \tag{6}$$

The econometric software Stata MP V.13 software (StataCorp. 2013. Stata Statistical Software: Release 13. College Station, TX: StataCorp LP) was used to estimate the maximum likelihood function through interval regression model. The interval regression model estimates the probability that a latent variable is included in a given interval (Cawley, 2008; Fu *et al.*, 2011; Kpadé *et al.*, 2017). At last, the estimations of the interval regression model were used to calculate the individual WTP (post-estimation prediction), the average and median WTP of the sample. Table 2 lists the bids and explanatory variables used in the econometric analysis. Four types of variables could potentially affect the respondents' WTP: personal characteristics of poultry farmers, characteristics of poultry farms, type of flock, factors of motivations. The personal characteristics of poultry farmers, the characteristics of poultry farms, and the factors of motivation were considered to positively affect the WTP whereas the type of flock was considered to positively or negatively affect the respondents' WTP.

Table 2. Statistics of bids and explanatory variables for WTP.

Variables	Description	N	Minimum	Maximum	Mean *(Standard Deviations)*	Expected Signs
Bids						
Upper bound of WTP	Upper bound level (FCFA)	196	500	1300	788.77 *(193.42)*	
Lower bound of WTP	Lower bound level (FCFA)	274	500	1300	850.00 *(209.70)*	
Initial bid of WTP	Bid level proposed (FCFA)	480	600	1200	826.00 *(189.00)*	
Independent variables						
Sex	Sex of poultry farmer (1 = male, 0 = female)	480	0	1	0.76 *(0.40)*	+
Age	Age of poultry farmer (years)	480	17	80	43.57 *(12.84)*	+
Gross income	Annual total income received by the poultry farmer, including non-farm income (FCFA)	480	45,000	7,000,000	610,633.54 (*862,225.36*)	+
Farm income	Annual farm income of poultry farmer (FCFA)	480	0	7,000,000	421,563.50 *(744,196.80)*	+
Percent poultry income	Part of poultry income in annual farm income (%)	480	0	100	25.15 *(31.17)*	+
Scavenging farming	Scavenging poultry farming (1=Yes, and 0 if not)	480	0	1	0.55 *(0.49)*	+
Semi- scavenging farming	Semi-scavenging poultry farming (1=Yes, and 0 if not)	480	0	1	0.42 *(0.49)*	+
Confinement farming	Confinement poultry farming (1=Yes, and 0 if not)	480	0	1	0.02 *(0.15)*	+
Credit access	Credit access for poultry farmer (0= Not access; 1= Yes)	480	0	1	0.17 *(0.37)*	+
Experience in poultry farming	Experience in poultry farming (years)	480	0	60	16.00 *(11.53)*	+
Education	Formal or functional education (years)	480	0	16	3.00 *(4.05)*	+

Variables	Description	N	Minimum	Maximum	Mean *(Standard Deviations)*	Expected Signs
Fly larvae use awareness	Farmer awareness on fly larvae as feed (0= Not known; 1= Yes)	480	0	1	0.92 *(0.26)*	+
Fly larvae use	Adoption of fly larvae in poultry feeding before (0= Not used; 1= Yes)	480	0	1	0.09 *(0.28)*	+
Family workers (number)	Number of family workers on the poultry farming	480	0	16	4.00 *(3.00)*	+
Local chicken (number)	Number of local chickens of the poultry farmer	480	0	500	24.58. *(35.83)*	+
Farming as main occupation	Main occupation of poultry farmer (1=agriculture or livestock; 0=else)	480	0	1	0.61 *(0.48)*	+
Fish meal use	Fish meal using in farm for local chicken feed (1= Yes, and 0 if not)	480	0	1	0.08 *(0.28)*	+
Motivation to improve chicken nutritional quality	Motivation for fly larvae use to improve nutritional quality of local chicken (Yes = 1, if not 0).	480	0	1	0.80 *(0.16)*	+
Motivation to improve poultry performances	Motivation for fly larvae use to improve performances of local chicken (Yes =1, if not 0).	480	0	1	0.80 *(0.16)*	+
Motivation to reduce feeding cost	Motivation for fly larvae use to reduce feeding cost (Yes =1, if not 0).	480	0	1	0.65 *(0.40)*	+

Note: If the lower bound of WTP was less than FCFA 500 (€ 0.76), or if upper bound of WTP was over FCFA 1,300 (€ 1.98), then they were set to missing values.

3. Results

3.1 Payment vehicle

In the double-bounded contingent valuation procedure, respondents were first subjected to the acceptance or not of the payment vehicle. Out of the 480 respondents, 86 poultry farmers (17.90%) protested the payment vehicle because of: the lack of trust placed on fly larvae (36.03%), the lack of means of payment (25.73%), for the fact that fly larvae are an available natural resource for which there is no need to pay (13.97%), and others reasons (24.26%). Comparing the socioeconomic characteristics of the accepters and the protesters of the payment vehicle, Table 3 showed that accepters were younger, more educated, had a higher number of local chicken in their farms, had higher gross annual and farm incomes and depended more on poultry farming financially.

Table 3. Comparison of characteristics of accepters and protesters of payment vehicle.

Characteristics	Mean (*Standard Deviation*)		Pr (|T| > |t|)
	Accepters	Protesters	
Age (years)	43.10 (*12.27*)	45.73 (*15.11*)	0.085*
Experience in poultry farming (years)	16.22 (*11.56*)	14.22 (*11.33*)	0.145
Education (years)	3.56 (*4.08*)	2.54 (*3.83*)	0.035**
Local chickens (number)	27.18 (*38.67*)	12.64 (*11.96*)	0.000***
Family workers (number)	4.30 (*2.64*)	3.32 (*1.81*)	0.001***
Gross income (FCFA)	696,166.20 (*925,410.70*)	218,941.90 (*201,994.50*)	0.000***
Farm income (FCFA)	483,270.30 (*805,606.60*)	138,860.50 (*147,641.30*)	0.000***
Percentage of poultry income (%)	26.62 (*31.37*)	18.40 (*29.46*)	0.026**

*Significant at 10%; **Significant at 5%; ***Significant at 1%.

Table 4. Traditional poultry farmers' responses to double bids.

Answer to first bid	Answers to second bid		Total Frequency *(%)*
	Yes Frequency *(%)*	No Frequency *(%)*	
Yes	198 *(50.24)*	25*(6.35)*	223*(56.59)*
No	50*(12.70)*	121*(30.71)*	171*(43.41)*
Total	248*(62.94)*	146*(37.06)*	394*(100.00)*

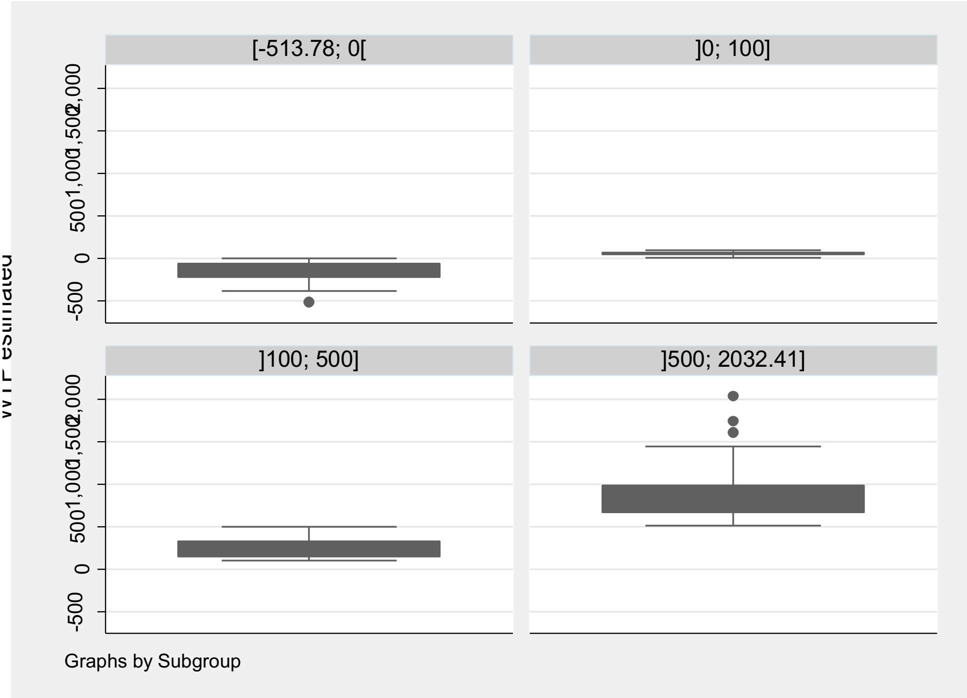
3.2 Bids acceptance

Out of the 394 traditional poultry farmers having accepted the payment vehicle (82.10%), 56.59% had accepted the first bid against 43.41% who refused. In total, 50.24% accepted both bids when the first was increased by FCFA 100 (€ 0.15) against 30.71% who refused both bids even when a decrease of FCFA 100 (€ 0.15) to the first bid was proposed (Table 4). Also, 6.35% of the poultry farmers accepted the first bid but refused the second bid, while 12.70% refused the first but accepted the second bid proposed. In the econometric modeling, the 86 poultry farmers that protested the payment vehicle were not considered as they refused to participate in the fly larvae meal market development. The development of the scenario contingent was also stopped at this step for these 86 poultry farmers. Only the 394 poultry farmers who accepted the payment vehicle were considered in the WTP estimation.

3.3 Factors affecting traditional poultry farmers WTP

Table 5 shows the results of the interval regression model to identify the factors influencing the WTP. In total, 19 out of the 20 explanatory variables were retained in the final

Figure 1. Distribution of WTP per kg of fly larvae according poultry farmers in Benin.



model, as two variables, motivation to improve poultry performances and motivation to improve chicken nutritional quality, were correlated. Eight factors significantly affected the respondents' WTP (sex, education, farming as main occupation, scavenging poultry farming, gross income, fly larvae use awareness, fly larvae use, motivation to reduce feeding cost) (Table 5). Five of these factors positively affected the respondents' WTP (sex, farming as main occupation, gross income, fly larvae use, motivation to reduce feeding cost) whereas three factors affected negatively the WTP, namely education, scavenging poultry farming and fly larvae use awareness. The signs of the coefficients of those three factors were opposite to what was expected (Table 2).

Based on the post-estimation of the interval regression model predictions, 394 individual WTP were estimated. In total, 134 respondents had negative WTP between -513.78 and 0 with a standard deviation (SD) of FCFA/kg 99.78; 31 respondents had WTP between 0 and 100 (SD= FCFA/kg 24.19); 180 respondents had WTP between 100 and 500(SD = FCFA/kg 112.71) and 49 respondents had WTP between 500 and 2,032.41(SD = FCFA/kg 328.46) (Figure 1). In total, 134 respondents had negative WTP. Respondents with the negative WTP were considered as a zero value in the sample because those respondents were not able to pay for the fly larvae meal according their profile, even though they accepted the payment vehicle. The 260 individual positive WTP were considered with no right-truncation because those respondents could financially pay fly larvae, independently to the amount they can afford. Finally, the average WTP for the sample in

Table 5. Factors affecting respondents' WTP.

Explanatory variables	Coefficients (*Standard Error*)
Sex (1= male, 0=female)	181.30*** (*67.04*)
Age (years)	-2.78 (*2.98*)
Experience (years)	0.39 (*3.51*)
Education (years)	-14.58** (*7.28*)
Family workers (number)	3.78 (*12.05*)
Farming as main occupation (1 =Yes, 0=No)	166.25**(*66.14*)
Local chicken (number)	1.10 (*1.05*)
Scavenging farming_(1=Yes, and 0 if not)	-293.05* (*162.46*)
Semi-scavenging farming (1=Yes, and 0 if not)	88.88 (*162.64*)
Confinement farming (1=Yes, and 0 if not)	88.67 (*220.88*)
Farm income (FCFA)	-4.61e-5 (*1.03e-4*)
Gross income (FCFA)	1.97e-4** (*8.60e-5*)
Percent poultry income (%)	0.07 (*0.89*)
Credit access (1 =Yes , 0= No)	-7.04 (*74.30*)
Fly larvae use awareness (1 =Yes, 0=No)	-262.01* (*142.66*)
Fly larvae use (1 =Yes, 0=No)	189.60** (*93.48*)
Fish meal use (1= Yes, and 0 if not)	-85.13 (*96.80*)
Motivation to improve chicken nutritional quality (1 =Yes, 0=No)	2300.99 (*68858.25*)
Motivation to reduce feeding cost (1 =Yes, 0=No)	303.06*** (*94.82*)
Constant	-1445.13 (*68858.73*)
/lnsigma	5.97*** (*0.09*)
sigma	393.16 (*34.61*)

Observations summary:
394 observations
121 left-censored observations
198 right-censored observations
75 interval observations
Log likelihood = -388.06; LR chi2(19) = 144.10; Probability > chi^2 = 0.000

* Significant at 10%; ** Significant at 5%; *** Significant at 1%

post estimation was FCFA/kg 225.10 (€/kg 0.34) of fly larvae meal against a median WTP estimated at FCFA/kg 127.81 (€/kg 0.19). The standard deviation was FCFA/kg 300.70 (€/kg 0.46).

4. Discussion

This study evaluated WTP of traditional poultry farmers in Benin to use fly larvae meal as a source of animal protein in local chicken feed, and analyzed the factors influencing their WTP. The protest rate found in this study is low compared that of other similar studies, e.g. 58% founded by Grappey (1999) or 44.06% reported by Drichoutis *et al.*(2016). In this study, protesters were excluded in the WTP estimation to distinguish protest bids from true zero. Protesters are typically considered to be outside the market and should thus be omitted from the analysis used to derive WTP estimates (Villanueva *et al.*, 2017). Protest bids are often registered by respondents who may place a higher- or lower-than-average value on the commodity in question but refuse to pay based on ethics or other reasons (Halstead *et al.*, 1992; Ready *et al.*, 1995). Moreover, the payment vehicle plays a major role in the decision making of the respondents (Loomis, 2011; Diederich and Goeschl, 2014). The payment vehicle provides the context for payment (Morrison *et al.*, 2000) and needs to be credible, coercive and incentive compatible (Hoyos and Mariel, 2010). Special attention has been given to the choice of the payment vehicle (Travisi and Nijkamp, 2008), which alters the resulting WTP (Rowe *et al.*, 1980). In willingness to pay scenarios, the payment vehicle must be presented fully and clearly, and should be convincingly described with the relevant budget constraint emphasized (Arrow *et al.*, 1993).

4.1 Variation in respondents' WTP

The traditional poultry farmers' WTP varied according to their very heterogeneous socio-economic conditions, fly larvae perception, costs and benefits associated with the use of fly larvae as a protein source to feed local chickens. This result conformed with numerous studies on natural resources valuation (Perman *et al.*, 2011; Wu *et al.*, 2016). Based on the interval regression model, out of the eight factors significantly affect poultry farmers' WTP.

Five were positively correlated with WTP. Primarily, sex has a positive significant effect on the WTP. Men have a higher WTP compared to women, indicating a gender effect on the level of traditional poultry farmers WTP, as observed by Vidogbéna *et al.* (2015) and Wu *et al.* (2016). Farming as main occupation also had a positive effect on WTP. Respondents whose main occupation is agriculture or farming had higher WTP compared to those who have another primary occupation. Moreover, the gross income had a positive effect on the respondents' WTP, confirming previous studies which found a positive effect of income from the field of environment and natural on WTP (Mogas *et al.*, 2006; Halkos and Jones, 2012). The econometric analysis highlighted that respondents that had already used fly larvae were willing to pay more, probably because they were convinced of the advantages of the use of fly larvae in poultry feeding. They saw fly larvae as an alternative feed, even though it was not marketed yet. The current users of fly larvae produced themselves limited quantities to feed their poultry. Feed cost is a major constraint limiting the competitiveness of small poultry farms in Africa. Even though the local price of fish meal is lower compared to the international due to its notoriously of bad quality (Proteinsect, 2017), the analysis of the respondents attitudes showed that, the more poultry farmers were motivated to reduce their poultry feed cost by replacing fish meal, the higher was their WTP. Poultry farmers saw fly larvae meal as an innovation that could be adopted to help them to reduce the cost of poultry production.

Three factors negatively affected WTP of the respondents. The education level had a significant negative effect on WTP. This result was similar to that of Jaleta *et al.* (2013). It suggests that poultry farmers who were illiterate or less educated had more time to look after their livestock and their feed. More educated poultry farmers probably had other professional occupation and, thus, were less available to care for their livestock. Moreover, respondents with higher levels of education may initially be more critical and suspicious of innovative approaches and the cost involved. They may finally end up adopting the innovative approaches after some analysis. On the other hand, it is often observed that low education levels of respondents often block the adoption of new production techniques (Sall *et al.*, 2010). Scavenging farming was negatively related to WTP. In scavenging mode, chickens can easily pick up food residues and invertebrates and, therefore, the poultry farmer feels he/she does not need to pay a high price for the purchase of the protein ingredients. This kind of farmers did not usually pay for protein ingredients to feed poultry. To valorize fly larvae on farms, a poultry farmer understands that the proposed fly larvae and other insects are already being searched by these chickens in garbage piles and other wastes. However, they may not realise that adding fly larvae to the diet of scavenging flock could strongly enhance their growth and survival. Therefore, a policy to promote fly larvae meal in scavenging poultry farming could be subsidies to support fly production or purchase among smallholder farmers to demonstrate the benefits of fly larvae meal before its selling on the market. Fly larvae use awareness was also negatively related to WTP because those respondents had already information on fly larvae as feed and were less incited to pay for its use in poultry feeding. Our finding showed that fly larvae could be a cheap and sustainable source of protein that can be promoted and sold to small poultry farmers at an affordable price.

4.2 Development of fly larvae meal market

The post estimation of the average WTP indicated a wide heterogeneity among respondents. This heterogeneity increased the standard deviation because the distribution was not normal. Other studies also highlighted that some individuals had negative WTP for the change (Fu *et al.*, 2011; Pavel *et al.*, 2015). The average WTP was calculated by considering the negative WTP as zero (Fu *et al.*, 2011). The average WTP estimated for fly larvae meal in this study was 59% lower compared to the local market price of fish meal with low quality. This is also probably lower than the expected production costs in a small fly larvae production system. Roffeis *et al.* (2018) calculated the cost of producing house fly larvae on chicken manure in a small system in Mali to vary between 1.09 and 2.08 €/kg. If the demand of fly larvae meal increases, the challenge faced by fly larvae producers will be to produce and to sell fly larvae meal at an acceptable price for small poultry farmers. This will oblige enterprises to be innovative in their production process to ensure financial benefits.

5. Conclusion

Poultry farmers are facing a major constraint of feed, representing about 70% of the total production costs in developing countries. Finding a sustainable and cheaper ingredient for poultry farming is needed to increase their competitiveness. This study applied a field bid experiment to assess the economic feasibility of fly larvae meal as an alternative feed in replacement for fish meal. Then, we analyzed WTP for using fly larvae as a protein source to feed traditional poultry in Benin. Respondents were mostly willing to pay for it and are ready to use it, although the amount they are willing to pay is different according to poultry farmers. The average WTP estimated at FCFA/kg 225.10 (€/kg 0.34) for fly larvae was lower than the local price of fish meal. Meeting the demand of fly larvae meal for poultry farmers in Benin requires that it is produced on a large scale. This production requires the creation of small-scale innovative enterprises and the development of equipment that can reduce production costs thus making the enterprises financially viable. Information sharing and sensitization on fly larvae meal use as a low cost protein source and as a sustainable alternative of fish meal in traditional poultry farms is required for better food and nutritional security.

6. References

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Appendix

QUESTIONNAIRE FOR ESTIMATING TRADITIONAL POULTRY FARMERS' WTP IN BENIN

Survey sheet N°|_____________| Date of survey: |____|____|____| Name of investigator:……………………

The purpose of this survey is to determine if Beninese's poultry farmer is willing to use fly larvae as protein source to feed his livestock of local chicken. If yes, how much is he willing to pay for?

A. SOCIO-ECONOMIC CHARACTERISTICS OF THE RESPONDENT

CHARACTERISTICS	Code	Responses
1. Province (DEPART)	1= Alibori, 2 = Borgou, 3= Atacora, 4= Donga, 5 = Collines, 6=Zou, 7=Plateau, 8 = Ouémé, 9= Atlantique, 10=Littoral, 11=Mono, 12= Couffo	
2. Dstrict (COMMUNE)	Enter the name of the District	
3. Village (VIL)	Enter the name of the village	
4. Name and surname of the respondent (NPENQ)	Enter correctly the name and the surname of the poultry farmer	
5. Socio-cultural groups (ETHNIE)	1. Fon and related 2. Bariba and related 3. Dendi and related 4. Adja and related 5. Yom & Lokpa related 6. Betamaribe and related 7. Peulh and related 8. Yoruba and related 9. Other socio-cultural groups of Benin 10. Foreign	
6. The different animals constituting the livestock of the poultry farmer (ANIMAL)	1= chicken ; 2= guinea fowl ; 3= duck ; 4= pigeons ; 5= turkey ; 6= other	
7. Number of the dominant species in the livestock (ED)	Enter the species and the number	
8. What are the local chicken ecotypes of your farm (RAPL)?	1=holli ; 2=fulani ; 3=sahwè ; 4= yaya ; 5=yovokoklo ; 6= other	
9. Number of local chicken (EFFEC)	Enter the number	
10. Type of Livestock farming (ME)	1=Scavenging ; 2= Semi-scavenging ; 3=Confinement	
11. Marital status (SIMA)	1=married ; 2=divorced ; 3=single, 4 = widower, 5=other	
12. Number of agricultural assets (AE)	Enter the number	
13. Household size of the poultry farmer (EMEL)	Enter the number	
14. Age (AGE)	Enter the poultry farmer's personal response (number of years) or make an approximation in case of no response	
15. Education level (NINST)	0=Not literate; 1= literate ; 2= primary ; 3= secondary, 4= professional training ; 5= higher ; and enter the number of years of study	
16. Main occupation (PROFPRI)	1=Farmer or livestock farmer; 2= trader ; 3= agri-food processor; 4= official in activity ; 5=Mechanic ; 6=Carpenter ; 7=other (specify and continue the list)	

17. Number of years in poultry farming (EXPE)	Enter the response (number of years)	
18. To which network or livestock farmer association do you belong to (RESEAU)?	Enter the response	
19. Do you have access to a micro finance institution (AIMF)? Which one?	1=Yes, 0=No	
20. What is your annual global income? (REVGLO) ?	Enter the quantified income (data)	
21. What is your annual farm income (RAN)?	Enter the quantified income (data)	
22. What is the share of poultry income in annual farm income **(**PARAN)**?**	Enter the response (on 10)	
23. Do you know that fly larvae can be used for chicken feeding (COLAMOU)?	1= Yes; 0=No	
24. Did you use fly larvae to feed local chicken (AFAS)?	1= Yes ; 0=No	
25. Do you currently use fish meal to feed local chicken (UFAP)?	1= Yes; 0= No	
26. Would you like to replace fish meal with another protein source (SUS)?	1= Yes ; 0= No	
27. If yes to question 26. Why do you want to substitute fish meal (RSFAP)?	1=bad quality, 2=unavailability of the fish meal on the local market, 3=high price, 4= other	
28. What other ingredients are used as protein source to feed local chicken (ASP)?	1= soy flour, 2 = oil cake, 3 = any, 4= other to be specified	

B. DOUBLE BID PROCEDURE TO PROPOSE

29. The fish meal is often used as protein source to feed chickens. The price per kg of fish meal on the international market is between FCFA/kg 1,000 and FCFA/kg 1,200. This fish meal is sold on the local market at FCFA/kg 550. This low price can be attributed to the low quality of the fish meal sold with low protein content. Fly larvae meal proved to be nutritional as source of animal protein for local chickens. It can replace the fish meal with low quality used to feed local chickens. In addition, the use of fly larvae meal improves zootechnical performance of your local chickens (average daily gain, consumption index, etc.) and reduce the costs of protein feeding. Would you be willing to pay for fly larvae meal as a protein source to feed your local chickens?

Yes No

30. If Yes, would you accept to pay FCFA/kg X to feed your local chickens?

The vector X[2] to be proposed is composed of 7 bids: FCFA 600; FCFA 700; FCFA 800; FCFA 900; FCFA 1,000; FCFA 1,100 and FCFA 1,200.

Yes Select and go to the question **31.** No Select and go to the question **32. with k=100**

31. Could you pay FCFA/kg X+k ? Select Yes or No and go to **34.**

32. Could you pay FCFA/kg X- k ? Select Yes or No and go to **34.**

33. If the answer for question 29 is No; so why?

No means to pay:

Refusal of payment vehicle :

No value given to fly larvae:

Other (specify and continue the list):

34. <u>If the answer to question **29** is Yes</u>, what is your level of motivation for using fly larvae (DEGMOT)?
1= very motivated; 2= motivated; 3 =indifferent: 4=not motivated; 5=little motivated.[3] |_____________|

35. Are you motivated to use fly larvae to increase the nutritional quality of your local chickens (MQUAL)? 1=Yes; 0=No |_____________|

36. If Yes, what is the level of the MQUAL (DEGMQUAL)? 1= very motivated; 2= motivated; 3 =indifferent: 4= not motivated; 5= little motivated: …………….

37. Are you motivated to use fly larvae to increase zootechnical performance of your local chickens (MPERZ)? 1=Yes ; 0=No :………………

38. If Yes, what is the level of MPERZ? 1= very motivated; 2= motivated; 3 =indifferent: 4= not motivated; 5= little motivated:…………………….

39. Are you motivated to use fly larvae to reduce the costs of feeding (MCOT)? 1=Yes; 0=No:……………….

40. If Yes, what is the level of MCOT? 1= very motivated; 2= motivated; 3 =indifferent: 4= not motivated; 5= little motivated: …………….

41. What can we do to promote the use of fly larvae to all poultry farmers (RECOM)?
a. train poultry farmers to produce fly larvae …………………………….
b. promote the consumption of poultry fed with fly larvae ……………..
c. Other (specify)……………………………………………………………………………………………………
……

[2] FCFA 600 correspond to the minimum production cost of 1 kg of fly larvae meal, *i.e.*, equivalent to FCFA 150 as minimum production cost of 1 kg of fresh fly larvae. FCFA 1,200 correspond to the maximum production cost of 1 kg of fly larvae meal, *i.e.*, equivalent to FCFA 300 as maximum production cost of 1 kg of fresh fly larvae. We increment and decrement the initial bid by 100 FCFA, which corresponds to the marginal cost to improve the quality of the fly larvae meal.

[3] We use 1-5 LikertScale to evaluate the level of motivation.