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Farmers' perceptions and willingness to adopt egg and snail shells as alternative calcium sources for poultry production in the Western region of Ghana

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ABSTRACT

This paper examined farmers' awareness, perceptions, and willingness to adopt eggshells and/or snail shells as alternative sources of calcium in the formulation of poultry feed. A multistage sampling technique was adopted to obtain data from 284 poultry farmers in the Western region of Ghana. Descriptive statistics, the perception index, and bivariate probit regression model we used in the analysis. The Likelihood Ratio test confirmed that there is a correlation between farmers' willingness to adopt eggshells and/or snail shells as alternative calcium sources ($p < 0.05$). The results indicate that, while 79.56% of the farmers were aware of the potential of eggshells as a variant source of calcium in poultry feed, only 61.97% of the farmers are aware of the same potential for snail shells. The results further suggest that poultry farmers generally have positive perceptions about the use of an alternative source of calcium in poultry feed formulation. Furthermore, 80.28% and 65.49%, of the farmers are willing to adopt eggshells and snail shells as variant sources of calcium, respectively. Factors such as years of education, household size, credit access, and extension access, and ownership of layer farms were found to significantly and positively influence the willingness of poultry farmers to adopt eggshells and snail shells as alternative sources of calcium. There is therefore the need for effective sensitisations and education through training programs by the Ministry of Food and Agriculture, Universities, Animal Research Institutions, private organizations, or poultry feed manufacturers. Credit access is also key to helping farmers invest in equipment and materials, so financial institutions should provide low-interest loans. Finally, it is crucial to have extension services that are customized to the unique requirements of farmers, considering factors such as their location, farm size, and education level, to effectively disseminate information about the advantages of egg and snail shells.

1. Introduction

The significance of poultry farming in enhancing the quality of life in rural areas, promoting food security, reducing poverty, and meeting the protein needs of people is immense. In Ghana, the poultry industry plays a crucial role in the livestock sub-sector of the agricultural sector [1]. Vaarst et al. [2] posit that poultry production offers advantages over other livestock due to their efficient conversion of feed to protein in the form of meat and eggs, which are highly nutritious. Furthermore, the poultry components acts as a form of financial security for unexpected cash requirements [3]. Despite livestock contributing only 6.2% to Ghana's agricultural GDP, its impact on employment and food security is substantial. Consequently, the government, NGOs, and other stakeholders have provided significant support to the sector over the years, including the elimination of tariffs on imported inputs, a 20% special tax on imported poultry products, farmer training, capitalization and marketing facilitation of broilers, subsidies on yellow maize and day-old chicks, and improved access to veterinary services [4].

According to Asumang et al. [5], the estimated consumption of poultry products in Ghana is 12 eggs and 1.2 kg of meat per person per

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annum, which is significantly lower than the world average of 154 eggs and 9.7 kg of meat. This implies that the reason for the insufficient consumption of animal protein in Ghana could be attributed to either insufficient production of animal protein-based products or inadequate demand for these products among consumers. Yevu and Onumah [3] notes that the demand for poultry products in Ghana far exceeds local production, indicating that the shortfall in animal protein intake is primarily a supply problem rather than a demand problem. Etuah et al. [6] also indicated that the local poultry industry satisfies just 10% of the domestic demand. Although the government and NGOs have implemented measures to enhance profits in layer production, the growth of the domestic poultry industry in Ghana continues to be sluggish, primarily because of the high production expenses [3]. Yevu and Onumah [3] further reported that the elevated cost of production renders local poultry production less competitive in comparison to imported poultry products.

The majority of poultry farmers in the Western region of Ghana opt to create their own feed owing to the expensive cost of ready-made feed offered by established companies [7]. There are estimated 1003 poultry farmers in the region, with 92% of them engaged in layer farming to produce eggs [8]. Poultry feed contributes 70–80% of the total variable cost of producing an egg or broiler, and it typically includes cereal grains, cereal by-products, protein meals, fats and oils, minerals and vitamins, and feed additives [9]. Calcium and phosphorus are essential nutrients in commercial layers and broiler diets because they contribute to the development of eggshells and strong bones in birds. Calcium also influences feed intake by stimulating the release of norepinephrine in the central nervous system [7]. Most farmers in the region use oyster shells as a source of calcium, but cheaper alternatives such as snail shells and eggshells are available in the region. One study conducted in Ghana found that the inclusion of eggshells in the diets of pullets resulted in better weight gain and feed conversion ratios than those fed with diets containing oyster shells [10]. In addition to being a good source of calcium, eggshells are also rich in other minerals like magnesium, phosphorus, and potassium, which are important for poultry growth and health [11].

These shells can be collected from hotels and food joints that use them in the meal preparation and are normally discarded. The Ministry of Food and Agriculture is promoting snail production as an additional livelihood venture. Feed accounts for more than 80% of production costs in the poultry industry of Ghana [12,13,14]. Therefore, it is necessary to identify cheaper alternative sources of feed ingredients. Calcium is an essential feed ingredient in poultry feed, and its deficiency can result in reduced shell quality as well as osteoporosis [15]. In the poultry industry, poor eggshell quality is a significant issue that has a detrimental impact on the financial outcomes of egg production. For consumers, eggshell quality is also a significant concern because the ability to withstand cracking and absence of shell deformities are vital for safeguarding against the infiltration of pathogenic bacteria into eggs.

The use of snail and eggshells as alternative calcium sources in poultry feed has generated mixed feelings among stakeholders in the poultry industry. While some people view this as a cost-effective and sustainable solution to the high cost of conventional calcium sources, others are concerned about potential health risks to the birds and the quality of the eggs produced. According to a study conducted by Buwjoom et al. [16], feeding snail shell meal to broiler chickens resulted in improved growth performance and bone strength. The researchers also noted that snail shell meal is a rich source of calcium and other minerals. However, some experts have expressed concerns about the potential for snail shell meal to harbour pathogens that could pose a risk to poultry health and food safety [17]. Similarly, the use of eggshells as a calcium source in poultry feed has been widely debated. Proponents argue that eggshells are a readily available and cost-effective source of calcium and that their use in feed can reduce the environmental impact of poultry farming [18]. However, critics have raised concerns about the potential for eggshells to contain harmful bacteria, such as Salmonella, which could be transmitted to the birds and to humans who consume their eggs [19].

According to Świątkiewicz et al. [20], eggshell is a good alternative calcium source for layers, and it has been found to increase eggshell thickness by 6%. Despite the availability of alternative sources, farmers in Ghana primarily use oyster shell as a main calcium source in feed formulation. Nonetheless, previous studies have demonstrated that eggshell is a nutritious and well-balanced supplier of calcium and is arguably the most excellent natural source of calcium [21]. Therefore, the study sought to assess the perceptions and willingness of poultry farmers in Ghana to adopt egg and snail shells as alternative calcium sources for poultry production in the Western Region of Ghana andhence explore th epotential of these calcium sources to enhence poultry production.

By examining farmers' perceptions and willingness to adopt these alternatives, teh findings from this paper will provide valuable insights into the barriers and opportunities for their adoption and hence reduce teh high dependnece on oyeter shell which tend to increase the cost of feed. This paper, therefore contributes to the development of sustainable and cost-effective poultry production practices in Ghana, which can ultimately lead to a more efficient and profitable industry. On the other hand, the study could contribute to the development of sustainable and innovative poultry farming practices that can improve bird health and welfare, while supporting the livelihoods of small-scale farmers in Ghana. Lastly, this paper makes a significant contribution to the scant literature on alternative calcium sources in small-scale poultry farming in Ghana.

The remainder of the paper is organised as follows. The next sections present a review of background of proultry production and consumption in Ghana, including factors influencing the willingness and adoption of improved techniques. Section 3 discusses the methodology, which outlines the analytical procedures employed to determine willigness to adopt the improved pountry production techniques. Section 4 presents the results and discussions of the and the last section focuses on the conclusions and policy recommendations.

1.1. Background of poultry production and consumption in Ghana

The worldwide demand for poultry items is on the rise, driven by population growth. However, in Ghana, poultry production falls far short of demand, which has resulted in an increase in imports. According to Kusi et al. [12], poultry imports in Ghana have more than quadrupled since 2002, increasing by five percent from 157,000 tons in 2012 to 165, 000 tons in 2013. This is due to urbanization, income growth, and population expansion, which have resulted in an increasing desire for animal-based products, such as poultry meat, across several African nations [22]. Poultry production in Ghana is mainly carried out by small and medium-scale farms, with more than 90% of the farms falling into this category. In Ghana, the poultry industry can be divided into two categories: backyard production systems and commercial systems. Backyard chicken rearing plays a significant role in enhancing or maintaining household livelihoods in both rural and urban settings [23, 24,25].

The poultry feed industry in Ghana has refocused its efforts towards producing feed for layers because of a decline in the domestic production of broilers. Commercial feed millers mainly produce layer feed, while small-scale backyard producers purchase broiler feed. Around 70% of the total feed production in Ghana is made up of poultry feed, with corn and wheat bran as the primary ingredients. The cost of feed has been rising, mainly due to the increasing cost of corn, which accounts for almost 30% of all corn produced in Ghana. The inclusion of soybean meal in poultry feed is minimal due to its high cost, leading feed manufacturers to opt for lower-cost alternatives like palm-kernel cake, groundnut cake, and fish meal, as well as some by-products of agro-processing. Animal feed expenses account for roughly 82% of the variable production cost, making cost control vital.

In Ghana, the poultry sector holds a prominent position within the livestock industry, accounting for 37% of the overall domestic meat production in 2018. It plays a crucial role in improving rural livelihoods, enhancing food security, reducing poverty, and meeting the protein needs of the population. However, the consumption of poultry products in Ghana remains relatively low, with an average per capita consumption of 1.2 kg of meat and 12 eggs per year. Farmers in Ghana face various challenges in feeding birds, including high cost and inadequacy in supply and formulation of feed, which can result in reduced egg production. Ghana is heavily dependent on imports, including 261 million tons of poultry meat in 2019, and the country's self-sufficiency rate has declined, leading to proposed policies to protect local producers and improve productivity. Despite this, the importance of the poultry industry in nutrition, job creation, and economic development in Ghana remains unwavering [26,6,27,28].

Eggs provide high-quality essential macronutrients that can optimize growth processes during pregnancy and early childhood due to their high digestible indispensable amino acid score [29]. Despite their nutritional benefits, domestic poultry production in Ghana is insufficient to meet increasing demand, leading to importation of cheaper chicken cut parts. The Ghana government has implemented policies such as the Ghana Shared Growth and Development Agenda II and the Ghana Poultry Project to address the supply deficit [30], which have the potential to alleviate malnutrition and poverty in rural communities across Africa. The willingness of farmers to adopt new technologies is influenced by various factors such as cooperative membership [31], credit access, and membership in farmers associations, agricultural extension visits, and educational level.

2. Methodology

2.1. Study area

Tis study was conducted in some selected districts of the Western Region of Ghana. According to the Ghana Statistical Service (GSS) [32], the Western Region covers an area of 13,842 sq. km with a population of 2,060,585. It has a double maxima rainfall pattern with an annual average of 1600 mm, and high relative humidity with temperatures varying between 26 and 31 °C. To the east of this area is the Central Region, while the west is bordered by Ivory Coast. To the north, it is adjacent to the Ashanti and Brong-Ahafo Regions, and to the south, it is adjacent to the Gulf of Guinea. Agriculture, including fishing, poultry farming, livestock farming, and hunting, is the main occupation of the people in the region. Other economic activities include transport work, sales work, and professional and technical work. The region's major industries are agriculture, mining and quarrying, manufacturing, and wholesale. The private formal and public sectors are the main employers of the region's working population. The Western Region's economy is active and has a complex demographic structure due to the significance of agriculture and industry. A map of the Western region showing all the thirteen (13) MMDAs is presented in Fig. 1.

As reported by the Animal Production Directorate of Ghana's Ministry of Food and Agriculture (2022), over 66% of the working-age population in the Western Region are self-employed individuals who do not have any employees, except for in Shama-Ahanta East, where it is 50% (Fig. 2). Poultry farming is one of the commonest self-employed

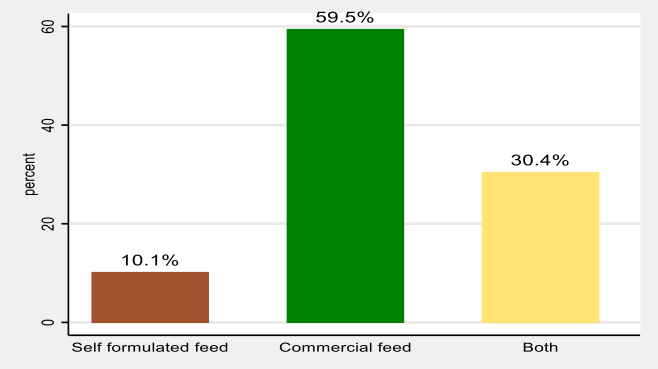

Fig. 2. Feed types used in the study area.
Source: Field Survey, 2022

Fig. 1. Map of the Western region showing all the MMDAs.
Source: Ghana Meteorological Agency, 2022

activities in the region. The Animal Production Directorate reports that there are a total of 229 poultry farmers in the region.

2.2. Sampling technique

The data was collected via the multistage sampling technique. In the first stage, the Western region was purposively selected because of its significant contribution to poultry production. Stage two involved using a purposive sample method to select six Municipal, Metropolitan, and District Assemblies (MMDAs) in the region. This is because the selected municipalities are known for their high concentration of poultry farms and farmers specializing in poultry production. In the third stage, poultry producers were chosen from the six MMDAs using a combination of proportionate and simple random procedures. The Animal Production Directorate provided a sampling frame encompassing all farmer households in the designated MMDAs to do this. From this sampling frame, lists of households were generated, and 284 farmer households were randomly selected for data collection. With such a comprehensive sampling technique, the data collected is both reliable and representative of the broader population.

2.3. Analytical framework

The theory of maximum utility, which serves as a guiding framework for this study, is frequently employed to examine the adoption of agricultural technologies and inputs. According to this theory, economic agents, such as poultry farmers, are inclined to adopt a technology when the benefits and satisfaction derived from its adoption surpass those attained from not adopting it. The random utility theory can be used to model the willingness of farmers to adopt snail and eggshells as alternative calcium sources by comparing the expected indirect utility of adoption with the indirect utility of not adopting. A farmer would be willing to adopt snail and eggshells if the value of the expected indirect utility from adoption is greater than that of not adopting [33–36].

The equation $U_w(n)$ was used to determine the indirect utility derived by poultry farmers for adopting snail and eggshells as alternative calcium sources while $U_{uw}(n)$ was used for those unwilling to adopt snail and eggshells as alternative calcium sources. The n represented a set of utilities.

Additionally, the willingness of the poultry farmers to adopt is observed however, the willingness stage of a particular choice is unobserved. Therefore, the choice of willingness can be denoted by a latent variable (G_i). To specify this latent variable, it is assumed that the willingness of the poultry farmer whether or not to adopt snail and eggshells as alternative calcium sources depend on an unobservable threshold utility $U^*(n)$. Therefore, a farmer compares the benefits of adoption to the benefits of non-adoption as:

$$U^*(n) = U_w(n) - U_{uw}(n) > 0 \tag{1}$$

$$\begin{cases} G_i = 1 \text{ if } U^*(n) > 0 \\ G_i = 0 \text{ if } U^*(n) \leq 0 \end{cases} \tag{2}$$

Since the willingness to adopt or not is dichotomous (binary), the willingness model that can estimate the probability of willingness to adopt given the observed covariates may be given as:

$$Y_i = X^t\beta + \mu \tag{3}$$

where Y_i is the farmer's willingness to adopt or not to adopt snail and eggshells as alternative calcium sources, X^t is a vector of independent variables affecting the willingness to adopt or not, β is a vector of unknown parameters and μ is a random error term.

The level of awareness of poultry producers in using egg and snail shells as alternative calcium sources were examined using four metrics:

Awareness Indicators.

- ✓ Knowing that egg and snail shells contain calcium (W)
- ✓ Knowing that, egg and snail shells can be used as alternative calcium sources (X)
- ✓ Knowing the processes involved in adding egg and snail shells to the feed (Y)
- ✓ Knowing the calcium percentage in egg and snail shells (Z)

Descriptive statistics (frequencies and percentages) were then used to summarize poultry farmers' awareness in the four perspectives above. Perception index was used to measure farmers' perception about snail and eggshells as alternative calcium sources. A five-point Likert scale comprising strongly disagree (−2) disagree (−1), neutral (0), agree (1), and; strongly agree (+2) was used to measure farmers' perception about snail and eggshells as alternative calcium sources [37]. An odd-numbered Likert scale was employed in this study to allow respondents stay neutral if they are indecisive about snail and eggshells as alternative calcium sources [38]. The mean score and perception index (PI) formula on a Likert scale is expressed as:

$$MS\frac{(1xf_a) + (0xf_n) + (0xf_d)}{N} \tag{4}$$

$$PI = \frac{\sum MS}{n} \tag{5}$$

Where f_a = frequency of agreed, f_n = frequency of neutral, f_d = frequency of disagreed, N = *sample size*. n = number of statement

The bivariate probit regression model as well as descriptive statistics were used to measure farmers' willingness to adopt alternative calcium sources and the factors influencing their willingness to adopt. Since there are two types of dichotomous dependent variables (i.e., willingness to adopt snail and/or eggshells), the bivariate probit regression model was used to simultaneously estimate the factors influencing willingness to adopt alternative calcium sources.

2.3.1. Specification of the bivariate probit regression model

Poultry farmers may be confronted with the choice of willingness to adopt eggshells and willingness to adopt snail shells. The two choices represent a desire to adopt feed ingredients that are presumed to enhance farm output and reduce costs.

The bivariate model is commonly utilized to estimate choices that are interdependent rather than choices that are separate and unrelated. When a poultry farmer considers adopting both eggshells and snail shells at the same time, the choice is considered interdependent. Therefore, the bivariate probit model is appropriate to analyze the combined willingness to adopt the two feed ingredients. The bivariate probit model is a statistical model used to estimate joint binary outcomes [39]. The binary outcomes could have a relationship with each other, with a correlation value of ρ. If there is a significant correlation between the two outcomes, then it is appropriate to use a bivariate probit (or logit) model to estimate both choices together. In other words, if the correlation between the two binary choices is not statistically significant, it suggests that the two probit models can be estimated independently. However, when there is a significant correlation, the bivariate probit model is appropriate since it can estimate both choices jointly. This model is designed to account for the interdependency of the two choices and control for their endogeneity [40].

The bivariate probit model may be expressed as a binary latent. Let Y_S represent a poultry farmer's willingness to adopt snail shells as an alternative calcium source, and Y_E represents a poultry farmer's willingness to adopt eggshells as an alternative calcium source. The unobserved latent variables may be represented as:

$$Y_S^* = x_1\beta_1 + \mu_1 \tag{6}$$

$$Y_E^* = x_2\beta_2 + \mu_2 \tag{7}$$

The latent variables Y_S^* and Y_E^* are related to the observed

willingness to adopt eggshells and snail shells respectively shown in equations (6) and (7) as Y_S and Y_E

$$Y_{S=}\begin{cases}1 \text{ if } Y_S^* > 0\\ 0 \text{ otherwise}\end{cases} \quad (8)$$

$$Y_{E=}\begin{cases}1 \text{ if } Y_E^* > 0\\ 0 \text{ otherwise}\end{cases} \quad (9)$$

The model achieves identification when there is an identical set of covariates in each equations (6) and (7). The error terms, μ_1 and μ_2 are assumed to be correlated and follow a normal distribution in eqns (6) and (7) as:

$$E[\mu_1] = E[\mu_2] = 0, \text{var}[\mu_1] = \text{var}[\mu_2] = 1$$

$$\text{and } \text{cov}[\mu_1, \mu_2] = \boldsymbol{\rho} \quad (10)$$

If the results of a Wald test indicate that ρ is not statistically significant, there is no evidence of endogeneity bias. In such a scenario, the two models can be estimated independently. However, if ρ is found to be statistically significant, it suggests a relationship between the two models, and joint estimation of the two equations becomes necessary to obtain unbiased estimates. The log-likelihood for the bivariate probit model is specified as:

$$L = \prod \Phi(-xy1\beta y1 = 1, y2 = 1)\Phi 2(xy1\beta y1, xy2\beta y2, \rho)$$

$$\prod y1 = 1, y2 = 0\ \Phi 2(xy1\beta y1, -xy2\beta y2, -\rho) \quad (11)$$

where: Φ is the standard univariate normal cumulative distribution and Φ_2 is the standard bivariate normal cumulative distribution with correlation ρ. Equations (6) and (7) are simultaneously estimated using maximum likelihood yielding unbiased parameter estimates for β and ρ.

The bivariate probit regression model is empirically specified as:

$$WTA = \alpha_0 + \alpha_1 AgeF + \alpha_2\ Fexp + \alpha_3 GendF + \alpha_4 Yedu + \alpha_5 AIncome + \alpha_6 Acess.Ext + \alpha_7 ContFarm + \alpha_8 Fsize + \alpha_9 ACredit + \alpha_{10} FBO + \mu \quad (12)$$

WTA represents the ith poultry farmer's willingness to adopt snail and eggshells as alternative calcium sources; α_0 is the constant term, *AgeF* is the age of the farmer, *Fexp* is the Farming experience of the poultry farmer measured in years, *GendF* is the gender of the farmer, *Yedu* is the years in the education of the farmer, *AIncome* is the alternative sources of income apart from poultry farming *Acess.Ext* is the farmer's access to extension services, *ContFarm* is the involvement of the poultry farmer in contract production *Fsize* is the farm size, *ACredit* is farmers' accessibility to credit, FBO is membership of the poultry farmer in poultry farmers association and μ_i is the error term. Also, α_1 , α_2,… … … … … …. α_{10} are coefficients of the explanatory variables. Table 1 provides a description of the independent variables utilized in the bivariate probit regression model.

Table 1
Description of variables to be employed in the bivariate probit regression model with their appriori expectation.

Variables	Description	Measurement	Expected Sign
Age	Years of respondent	Number	–
Household size	Number of people in the household	Years	+
Gender	Sex of respondents	Male = 1, Female = 0	+
Years of Education	Years spent by respondents in school	Number	+
Other Jobs	Engagement in other income-generating activities	Yes = 1, No = 0	+/−
Extension	Access to extension	Yes = 1, No = 0	+
Farm size	Number of birds	Number	+
Access to credit	Whether the farmer has access to credit or not	Yes = 1, No = 0	+
FBO	Whether the respondent is in any poultry farmers association	Yes = 1, No = 0	+
Farming experience	Years of poultry farming	Number	+
Ownership of layers	Whether the farmer owns layers	Yes = 1, No = 0	+
Ownership of broiler	Whether the farmer owns broilers	Yes = 1, No = 0	–
Input distance	Distance (km) from farm to nearest input shop	Number	–
Self-formulated feed	Whether the farmer prepares his/her own feed	Yes = 1, No = 0	+

Table 2
Socio-economic characteristics of respondents.

Variable	Mean	Std. Dev.	Min	Max
Gender	0.775	0.419	0	1
Age	39.5	9.24	20	69
Native	0.669	0.472	0	1
Years of schooling	8	6	0	20
Household size	5	2	1	13
Membership of FBO	0.585	0.495	0	1
Access to credit	0.324	0.444	0	1
Access to extension	0.676	0.470	0	1
Experience in poultry farming	6	4	1	30
Ownership of layer birds	0.725	0.448	0	1
Ownership of broiler birds	0.359	0.500	0	1
Input distance	9.05	6.61	1	17
Self-forumlated feed	0.227	0.421	0	1
Other businesses	0.53	0.501	0	1
Awareness sources	0.588	0.493	0	1
Total number of birds	1913	2269	45	17,500

Source: Field Survey, 2022.

3. Results and discussion

3.1. Descriptive statistics

The descriptive statistics of poultry farmers in the study are presented in Table 2. The results indicate that a significant majority (77.5%) of the poultry farmers are male, suggesting a prevalent male dominance in poultry farming within the study area. This finding aligns with Nkansa et al. [41], research. The mean age of poultry farmers in the study area is 39.5 years. This finding implies that these farmers are relatively young and likely possess abundant energy to increase poultry production, aiming to fulfill the nutritional requirements of the Ghanaian population. Bannor et al. [42], reported a similar average age (40 years) of farmers in Ghana's poultry industry. On average, a household consists of 5 members, although some households have as many as 13 members. Therefore, it can be deduced that poultry farmers typically live in nuclear families. Additionally, more than half (58.5% and 67.6% respectively) of the respondents belong to a poultry farmers' association and have extension services access.

This finding is interesting because these associations and extension services could provide training and other benefits to enhance the poultry industry in the region. However, only 32.34% of these poultry farmers have access to credit. Financial institutions have refrained from providing credit to poultry farmers due to the inherent risks associated with poultry farming. This situation highlights the need for the establishment of dedicated credit facilities tailored to meet the financial requirements of poultry farmers. Although most poultry farmers in the surveyed area have between 1 and 30 years of experience, the average is 6 years. Many farmers focus on layer birds, while only a few raise broilers. This is so due to the inconsistent demand for chicken meat (mostly demanded on special occasions such Christmas, Easter, Eid Ai-

Adha, and Eid Al-Fitr) and the lack of processing facilities in Ghana. Furthermore, 53% of farmers engage in other businesses to diversify their income, given the high risk associated with poultry farming. On average, a poultry farmer in the Western region of Ghana owns 2226 birds, with some owning as many as 17,500 birds. These findings indicate that poultry farming in the region is mainly small-scale, and this is consistent with previous research by Matilda et al. [24], showing that small and medium-sized farms comprise over 90% of the poultry industry in Ghana.

Nonetheless, out of all the poultry farmers surveyed, only a mere 10% formulate, and produce their own poultry feed, while nearly 60% rely on commercially available feed. Additionally, about 30% of farmers purchase commercial feed to augment their self-made feed.

The outcomes of the study reveal that most farmers prefer using commercially available feed instead of making their own. As for calcium sources, oyster shells were the most widely used by poultry farmers in the Western region, with a staggering 89% of farmers relying on them. In contrast, only a small percentage of farmers use eggshells and snail shells, which make up 7.75% and 4.23% of calcium sources, respectively (Table 3).

3.2. Awareness of the use of eggshells as calcium sources

Fig. 3 presents the dimensions of awareness of use of eggshell as alternative calcium sources. The results reveal that a notable majority (85.21%) of poultry farmers in the study area were aware of the calcium content in eggshells, and a considerable percentage (79.58%) recognized their potential as an alternative calcium source. However, a relatively small proportion (14.08%) possessed the knowledge of processing and incorporating eggshells into poultry feed. Furthermore, almost all farmers (97%) lacked awareness of the actual calcium percentage present in eggshells. Overall, the poultry farmers demonstrated good understanding of the potential of eggshells as a substitute for calcium, except for the specific procedures involved in preparing and incorporating them into the feed.

3.3. Awareness of the use of snail shells as alternative calcium sources

Table 3 presents the dimensions of awareness of use of snail shell as alternative calcium sources. The result revealed that 66.9% of farmers in the study area were cognizant of the calcium content in snail shells. Furthermore, 61.97% of these poultry farmers were aware that snail shells can serve as an alternative source of calcium in the formulation of poultry feed. This indicates that a majority of farmers possess knowledge regarding the potential use of snail shells as an alternative calcium source in poultry feed. However, the level of awareness is slightly lower compared to eggshells, possibly because farmers tend to utilize eggshells more frequently. While 79.56% of farmers were aware of the alternative use of eggshells as a calcium source, only 61.97% had the same awareness about snail shells. In both cases, a significant majority of farmers lacked knowledge on how to incorporate these shells into their feed ingredients.

3.4. Perceptions of poultry farmers on the use of eggshells and snail shells

Table 5 presents the perception index results obtained from the study. Among the 284 poultry farmers interviewed, the majority (59.15%) agreed that eggshells are a cost-effective source of calcium. The mean perception index for this statement was 0.87. Similarly, 55.63% of the farmers agreed that eggshells are easily accessible and available as a source of calcium, with a mean perception index of 0.69. These findings suggest that farmers perceive eggshells as a viable and affordable option for calcium supplementation in poultry feed, as well as being readily available.

Furthermore, farmers believe that using eggshells as a source of calcium can improve the hardness and thickness of eggshells, with perception indexes of 0.70 and 0.61, respectively. Additionally, they perceive eggshells as an environmentally friendly source of calcium, with only 3.52% of farmers disagreeing with this statement. 55% agreed, 17% strongly agreed, and 20% remained neutral or indifferent. The perception index for the environmental friendliness of eggshells as a calcium source was 0.79.

Overall, these results indicate a positive perception of eggshells as an alternative source of calcium for poultry feed among farmers. This perception can be leveraged to encourage the adoption of eggshells as a more sustainable and cost-effective option for calcium supplementation.

Additionally, the study found that using eggshells as a source of calcium was not perceived as a cultural taboo in the study area. Around 42% of farmers agreed with this statement, while another 34% strongly agreed. However, farmers expressed concerns about the difficulty of preparing and incorporating eggshells into their feed, with a mean score of −1.54. They also expressed concerns about the availability of enough eggshells to meet the calcium needs of their birds, with a mean score of −0.68. Despite these concerns, the Overall Perception Index (O.P.I) was a positive +0.500, indicating that poultry farmers generally hold a positive perception of using eggshells as a variant source of calcium in poultry feed. This suggests that with proper education and training, farmers may be more willing to incorporate eggshells into their feed ingredients.

3.5. Perceptions about snail shells

Table 6 reveals that poultry farmers generally have similar perception of snail shells as a variant source of calcium in poultry feed formulation. They perceive snail shells as a cheaper alternative source of calcium (mean = 0.50) but not readily accessible (mean = −0.60). However, they consider the process of preparing and including snail shells in the ingredients of poultry feed to be a difficult task. A significant proportion of the farmers (45.07%) strongly disagreed that snail shells are easy to prepare and included in the feed, with a corresponding P.I of −1.08 for this perception statement. On the positive side, they see snail shells as an environmentally friendly alternative source of calcium. About 59% of the farmers agreed with this perception statement, with only 5.63% disagreeing, and the P.I was recorded as 0.54. Nevertheless, similar to eggshells, the poultry farmers also perceive that they cannot find adequate quantities of snail shells to use as an alternative source of calcium.

The study revealed that poultry farmers in the Western region of Ghana hold favourable views towards using snail shells as a substitute source of calcium, as evidenced by the positive Overall Perception Index (O.P.I = 0.17). The results indicate that farmers generally view both eggshells and snail shells as viable alternatives to traditional sources of calcium. However, the major drawback identified is the difficulty in preparing and incorporating these sources into poultry feed. Addressing this concern through targeted education and training can help shift perceptions and increase adoption of these alternative calcium sources.

3.6. Farmers' willingness to adopt egg and/or snail shells as alternative calcium sources

To determine the determinants of willingness to adopt alternative calcium sources, the farmers' willingness was first assessed as a dummy variable. Out of the 284 poultry farmers surveyed, 80.28% expressed a

Table 3
Sources of calcium used currently.

Sources of Calcium	Users	Non-Users
Oyster Shells	254 (89.44%)	30 (10.56%)
Eggshells	22 (7.75%)	262 (92.25%)
Snail Shells	12 (4.23%)	272 (95.77%)

Source: Field Survey, 2022.

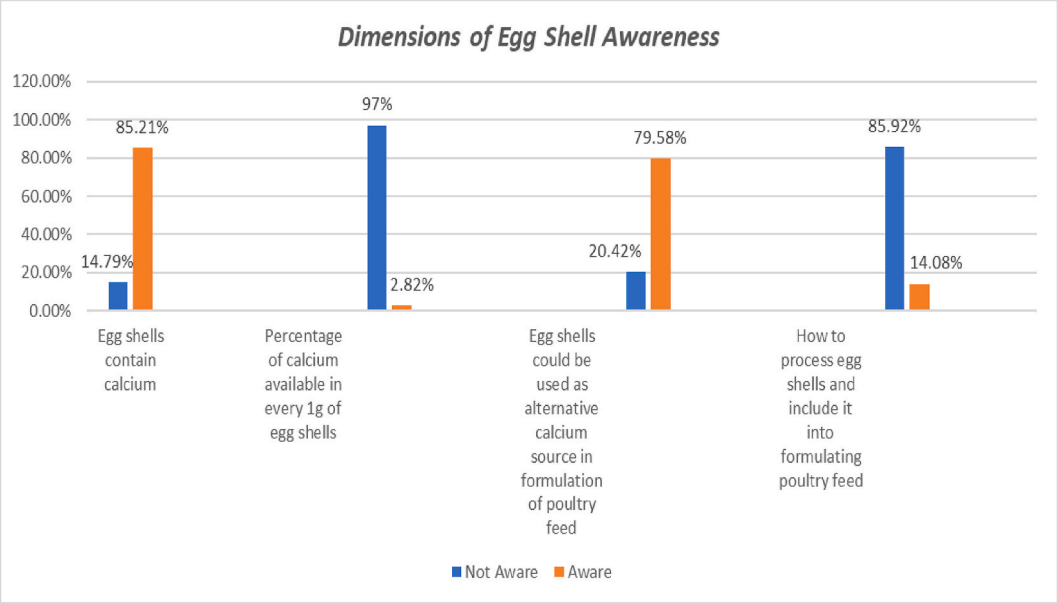

Fig. 3. Dimensions of eggshell awareness.
Source: Field Survey, 2022

Table 4
Dimensions of snail shell awareness.

Snail Shell Awareness Statements	Not Aware		Aware	
	Frequency	Percentage	Frequency	Percentage
Snail shells contain calcium	94	(33.10%)	190	(66.90%)
Percentage of calcium available in every 1 g of snail shells	276	(97%)	8	(2.82%)
Snail shells could be used as alternative calcium source in formulation of poultry feed	108	(38.03%)	176	(61.97%)
How to process snail shells and include it into formulating poultry feed	262	(92.25%)	22	(7.75%)

Source: Field Survey, 2022 (see Table 4).

willingness to adopt eggshells as an alternative source of calcium, while a majority of the farmers (65.49%) indicated a willingness to adopt snail shells as a variant source of calcium in poultry feed formulation. These figures are shown in Fig. 4, which highlights a substantial level of willingness among poultry farmers to adopt egg and snail shells as alternative calcium sources. Given this high level of willingness, it is likely that convincing these farmers to adopt these alternative sources will be relatively easy.

3.7. Factors influencing famers' willingness to adopt alternative calcium sources

The results of the bivariate probit regression analysis, which aimed to identify the factors affecting farmers' inclination to adopt egg and snail shells as alternative calcium sources in poultry feed, are displayed in Table 7. To ensure the validity of the model, a hypothesis testing was performed to examine if the error terms in the "willingness to adopt eggshells" and "willingness to adopt snail shells" equations are correlated. The results indicate that the two equations are significantly correlated, thereby validating the use of the bivariate probit model.

Gender is a crucial variable that significantly affects farmers' willingness to adopt alternative calcium sources. The study found that male poultry farmers are more willing to adopt eggshells as an alternative source of calcium than the female respondents. This could be linked to the existing resource gap between male and female respondents in Ghana, as highlighted by Ref. [43]. It is possible that women perceive eggshell preparation as a difficult task due to physical limitations, as men are generally stronger.

Education is also a critical factor that influences farmers' willingness to adopt new technologies, as noted by Ref. [44]. In line with this, the study reveals that respondents with higher levels of education are more willing to adopt eggshells as a variant source of calcium in poultry feed. This could be because more educated farmers possess a better understanding of feed formulation processes and the benefits of alternative calcium sources, compared to those with lower education levels.

The size of a poultry farmer's household has a significant impact on their willingness to use eggshells as a calcium source in their poultry feed. Essentially, the larger the household, the more likely the farmer is to adopt eggshells as an alternative. This could be due to the fact that households in Africa often serve as a source of labour for poultry farmers, which is necessary for collecting, preparing, and incorporating eggshells into poultry feed as an alternative source of calcium [45].

The study found that there is a statistically significant positive correlation (at the 5% significance level with $p = 0.03$) between access to credit and a farmer's willingness to adopt eggshells as a calcium source. This means that farmers are more likely to use eggshells as an alternative if they have access to credit. Credit is needed to purchase equipment necessary for preparing eggshells in a form that can be added to poultry feed. The study supports the findings of [46]. Furthermore, the provision of extension services exhibited a substantial positive impact on farmers' inclination to adopt eggshells as an alternative calcium source in poultry feed. As highlighted in previous research [47] and confirmed in this study, extension services offer training and guidance to farmers in various aspects of their poultry farming business, including exploring alternative, cost-effective sources of inputs and feed ingredients. Therefore, extension agents can be a powerful tool in encouraging the adoption of alternative calcium sources.

To put it differently, farmers who prepare their own feed were less inclined to use eggshells as an alternative source of calcium, as shown by the negative impact of self-formulated feed on willingness to adopt eggshells ($p = 0.004$). This is likely due to the perception that

Table 5
Perceptions about eggshells.

Variable	Frequency (Percentage)					Mean (P. I)	Meaning
	S.D (−2)	D (−1)	N (0)	A (1)	S.A (+2)		
1. Eggshells are cheaper source of calcium	12 (4.23%)	2 (0.7%)	50 (17.61%)	168 (59.15%)	52 (18.31%)	0.87	Agree
2. Eggshells are readily available/accessible source of calcium	10 (3.52%)	26 (9.15%)	28 (16.9%)	158 (55.63%)	42 (14.79%)	0.69	Agree
3. Eggshells are easy to prepare/formulate and included in the feed	234 (82.39%)	8 (2.82%)	16 (5.63%)	14 (4.93%)	12 (4.23%)	−1.54	Strongly Disagree
4. The use of eggshells as a calcium source can improve eggshell hardness	10 (3.52%)	2 (0.7%)	92 (32.39%)	138 (48.59%)	42 (14.79%)	0.70	Agree
5. The use of eggshells as calcium a source can improve nutrient composition of eggs	12 (4.23%)	4 (1.41%)	112 (39.44%)	142 (50%)	14 (4.93%)	0.50	Agree
6. The use of eggshells as a calcium source can improve eggshell thickness	12 (4.23%)	10 (3.52%)	78 (27.46%)	162 (57.04%)	22 (7.75%)	0.61	Agree
7. Eggshells are environmentally friendly	10 (3.52%)	10 (3.52%)	58 (20.42%)	158 (55.63%)	48 (16.90%)	0.79	Agree
8. I can get enough quantities of eggshells to meet the calcium requirement of my birds	96 (33.80%)	56 (19.72%)	90 (31.69%)	30 (10.56%)	12 (4.23%)	−0.68	Disagree
9. Eggshell are safe for the poultry birds	8 (2.82%)	14 (4.93%)	26 (9.15%)	22 (7.75%)	214 (75.35%)	1.50	Strongly Agree
10. Eggshells are less bulky	46 (16.20%)	34 (11.97%)	32 (11.27%)	128 (45.07%)	44 (15.49%)	0.32	Neutral
11. The use of eggshells as calcium source is not a taboo in my culture	26 (9.12%)	18 (6.34%)	24 (8.45%)	120 (42.25%)	96 (33.80%)	0.85	Agree
12. Eggshells are easy to be stored	12 (4.23%)	10 (3.52%)	82 (28.87%)	140 (49.30%)	40 (14.08%)	0.65	Agree
13. Birds will easily consume feed made from eggshells	28 (9.86%)	40 (14.08%)	66 (23.24%)	54 (19.01%)	96 (33.80%)	0.53	Agree
Overall Perception Index (O.P.I)						**0.500**	**Positive**

Source: Field Survey, 2022.

Table 6
Perceptions about snail shells.

Variable	Frequency (Percentage)					Mean (P. I)	Meaning
	S.D (−2)	D (−1)	N (0)	A (1)	S.A (+2)		
1. Snail shells are a cheaper source of calcium	22 (7.75%)	58 (20.42%)	36 (12.68%)	94 (33.10%)	74 (26.06%)	0.50	Agree
2. Snail shells are readily available/accessible sources of calcium	54 (19.01%)	124 (43.66%)	60 (21.13%)	34 (11.97%)	12 (4.23%)	−0.61	Disagree
3. Snail shells are easy to prepare/formulate and included in the feed	128 (45.07%)	80 (28.17%)	52 (18.31%)	20 (7.04%)	4 (1.41%)	−1.08	Disagree
4. The use of Snail shells as a calcium source can improve eggshell hardness	30 (10.56%)	20 (7.04%)	50 (17.61%)	128 (45.07%)	56 (19.72%)	0.56	Agree
5. The use of snail shells as calcium a source can improve nutrient composition of eggs	6 (2.11%)	24 (8.45%)	142 (50%)	104 (36.62%)	8 (2.82%)	0.30	Neutral
6. The use of snail shells as a calcium source can improve eggshell thickness	16 (5.63%)	4 (1.41%)	108 (38.03%)	132 (46.48%)	24 (8.45%)	0.51	Agree
7. Snail shells are environmentally friendly	16 (5.63%)	16 (5.63%)	66 (23.24%)	170 (59.86%)	16 (5.63%)	0.54	Agree
8. I can get enough quantities of snail shells to meet the calcium requirement of my birds	32 (11.27%)	128 (45.07%)	80 (28.17%)	32 (11.27%)	12 (4.23%)	−0.50	Disagree
9. Snail shell are safe for the poultry birds	6 (2.11%)	34 (11.97%)	94 (33.10%)	116 (40.85%)	34 (11.97%)	0.49	Neutral
10. Snail shells are less bulky	72 (25.35%)	116 (40.85%)	50 (17.61%)	28 (9.86%)	18 (6.34%)	−0.69	Disagree
11. The use of snail shells as calcium source is not a taboo in my culture	8 (2.82%)	16 (6.34%)	54 (19.01%)	126 (44.37%)	78 (27.46%)	0.87	Agree
12. Snail shells are easy to be stored	8 (2.82%)	36 (12.68%)	44 (15.49%)	94 (33.10%)	102 (35.92%)	0.87	Agree
13. Birds will easily consume feed made from snail shells	14 (4.93%)	14 (4.93%)	102 (35.92%)	134 (47.18%)	20 (7.04%)	0.46	Neutral
OVERAL PERCEPTION INDEX (O.P.I)						**0.17**	**Positive**

Source: Field Survey, 2022.

incorporating eggshells into poultry feed is a complex process. Moreover, farmers who engage in multiple economic activities may not have sufficient time and resources to focus on poultry farming and may be less interested in adopting alternative calcium sources to maximize their profits, as indicated by the significant effect of economic activities on willingness to adopt eggshells ($p = 0.011$). Thus, it is important to target initiatives promoting the adoption of alternative calcium sources to farmers who solely concentrate on poultry farming.

Membership in a poultry farming association, access to extension services, and years of experience in poultry farming are significant factors positively influencing farmers' willingness to adopt snail shells as alternative calcium sources, according to the results ($p < 0.05$). Thus,

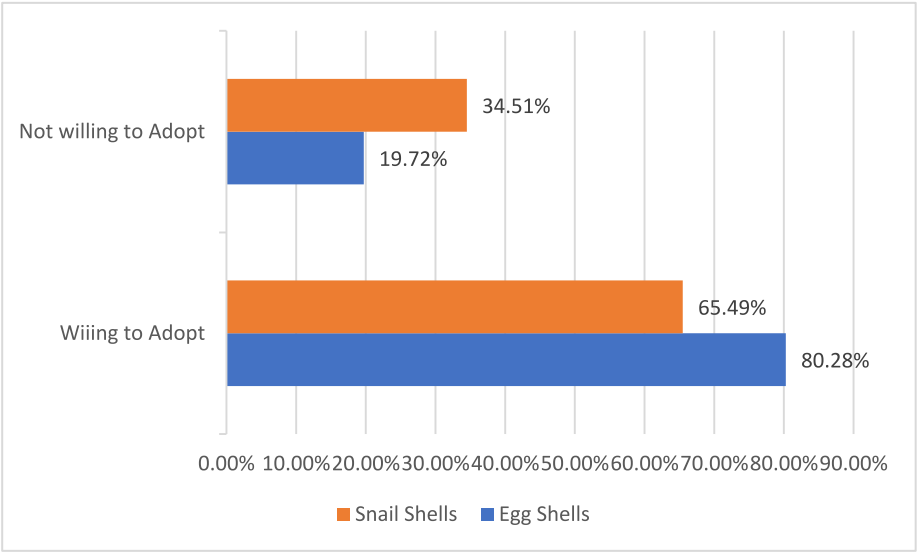

Fig. 4. Willingness to adopt egg and snail shells.
Source: Field Survey, 2022

Table 7
Bivariate probit regression estimates of factors influencing willingness to adopt alternative calcium sources for feed formulation.

Variable	Willingness to Adopt Eggshells			Willingness to Adopt Snail Shells		
	Coef.	S.E	P > z	Coef.	S.E	P > z
Gender	2.033***	0.6983	0.004	0.3869	0.3639	0.288
Age	0.022	0.0445	0.629	−0.0424**	0.0219	0.053
Native	0.3624	0.6036	0.549	−0.5849	0.3609	0.105
Years of education	0.1456***	0.0511	0.004	0.0348	0.0309	0.261
Household size	0.4773***	0.1441	0.001	−0.1168	0.0754	0.121
FBO	−0.1644	0.5629	0.770	0.6551**	0.3604	0.069
Credit Access	1.6803**	0.7879	0.033	−0.5669	0.3917	0.148
Extension Access	2.5234***	0.8956	0.005	1.8676***	0.3760	0.000
Years of poultry farming	−0.13804	0.0846	0.103	0.0985**	0.0479	0.040
Ownership of layers	3.0349***	0.8605	0.000	−0.2984	0.3774	0.429
Ownership of broilers	−0.0153	0.6533	0.981	−0.9161***	0.3481	0.008
Input distance	−0.0663	0.0410	0.106	−0.0523**	0.0255	0.040
Self-formulated feed	−1.8969***	0.6656	0.004	−0.0025	0.3610	0.994
Other economic activities	−2.1942**	0.8644	0.011	−0.4921	0.3537	0.164
Awareness source	0.8552	0.5750	0.137	0.8426**	0.3427	0.014
Total number of birds	−0.0001	0.0003	0.826	0.0001	0.0001	0.196
Constant	−5.7273***	2.2089	0.009	1.3730	1.0369	0.185
Number of obs 284						
Wald chi2(32) 70.86* **						
LR test of rho = 0: chi2(1) 5.02128 **						

Note: * signifies significant at 10%; ** signifies significant at 5% and; *** signifies significant at 1%.
Source: Field Survey, 2022.

providing education and training through poultry farming associations can be an effective strategy to encourage farmers to adopt snail shells. Additionally, offering credit schemes to more experienced farmers may increase their willingness to try alternative calcium sources. However, input distance, broiler farm ownership, and age of poultry farmers are significant factors negatively affecting willingness to adopt snail shells as a variant source of calcium in poultry feed, as suggested by the model estimation.

4. Conclusion and policy recommendation

The paper investigated the awareness and perception of poultry farmers towards eggshell and snail shells as alternative sources of calcium in poultry feed preparation. Results indicated that most pountry farmers are aware of the calcium content of eggshell and snail shells, however, few knew how to process and hence, incorporate them into poultry feed preparation. Specifically, a high percentage of farmers were aware of eggshell and snail shells as alternative sources of calcium, but only a few knew how to use them. Farmers viewed eggshells as a cheap and beneficial source of calcium that could enhance eggshell thickness and hardness, but they found them difficult to prepare and incorporate into pountry feed prpeparation. Farmers perceived snail shells as a cheaper and eco-friendly source of calcium, however, they found them difficult to prepare and also access in large quantities. Despite the challenges, a large proportion of farmers were willing to adopt egg and snail shells as alternative calcium sources. Factors such as education, household size, credit access and access to extension service, and ownership of layer farms positively influenced farmers' willingness to adopt eggshells..

The study provided several policy recommendations that can help encourage the adoption of eggshell and snail shells as alternative calcium sources in poultry feed. To increase the adoption of eggshell and

snail shells as alternative sources of calcium in poultry feed will involve effetcive, training, and education programmes organized for poultry farmers particulary on the preparation and incorporation of eggshell and snail shells into feed. These programmes could be organized by MoFA, private organizations, or poultry feed manufacturers. Access to credit may be a significant factor that positively influences farmers' willingness to adopt eggshells. Therefore, financial institutions should consider providing poultry farmers with easy access to credit at low-interest rates to enable them to invest in the required equipment and materials for eggshell preparation and incorporation into feed. Extension services are critical in disseminating information to farmers on best practices in poultry production. Therefore, Government, MoFA and other agricultural agencies should provide extension services to farmers on the benefits of egg and snail shells as alternative sources of calcium and the proper way to prepare and incorporate them into feed. Extension services should be tailored to meet the specific needs of poultry farmers, taking into consideration factors such as location, farm size, and level of education.

Declaration of competing interest

Authors declare that there is no known conflict of interest with this manuscript.

Data availability

Data will be made available on request.

Appendix

Table A1
Multicollinearity test

Variables	VIF	1/VIF
Age	1.653	0.605
Years of poultry farming	1.623	0.616
Ownership of broilers	1.608	0.622
Total number of birds	1.608	0.622
Credit Access	1.514	0.66
FBO membership	1.384	0.723
Household size	1.313	0.762
Extension Access	1.311	0.763
Other economic activities	1.311	0.763
Input distance	1.309	0.764
Native	1.248	0.802
Years of education	1.236	0.809
Awareness source	1.222	0.818
Self-formulated feed	1.183	0.845
Ownership of layers	1.157	0.864
Gender	1.093	0.915
Mean VIF	1.361	.

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