Analysis of the Emerging Market for Poultry By-Products in Ghana

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Abstract

The paper examined the emerging poultry by-products market, delving into the nature, revenue generation, influencing factors, and constraints of the market, using data from poultry farmers, aggregators, and cattle farmers. The paper described the nature of the market using descriptive statistics and a flow chart, estimated its contribution to poultry revenue, and examined the factors influencing the proportion of revenue contributed using a Tobit model. Kendall's coefficient of concordance was used to measure the level of agreement among the poultry farmers in ranking identified constraints. The poultry by-product market is currently characterized by only poultry droppings trading, with Côte d'Ivoire as the largest user (76% of the consumption) in cross-border informal trade and an average selling price of 8.39 USD per metric ton. The emerging market for the by-products can be described as seasonal. Annual revenue per poultry farmer for poultry droppings is 1,072.26 USD. Management type, production scale, and membership of poultry farmers' association influenced the proportion of revenue contributed from poultry droppings. The emerging poultry droppings market provided an opportunity for small-scale farms to earn additional income and organic manure to support sustainable farming. The key constraints among the poultry farmers participating in the by-products market were low prices and a lack of processing and storage facilities. The study recommended that agriculture sector development agencies should support the development of value chains for poultry droppings and other poultry by-products to help expand the market for sustainable agriculture production under the circular economy framework.

Keywords: constraints; Kendall's coefficient; poultry droppings; revenue; Tobit model

INTRODUCTION

Agriculture continues to play an essential role in contributing to socio-economic development in several developing countries, including Ghana (Abban et al., 2021). Raising poultry has become a significant commercial activity within the livestock subsector, holding great potential to drive economic growth quickly (Onumah et al., 2023). In the last decade, global poultry production has increased drastically due to the world population growth and the high demand for poultry products (Ayoo et al., 2019), resulting in the generation of large quantities of organic by-products in the form of excreta (droppings), broken eggs, viscera (internal organs), feet, heads, bones, blood and feathers (Dalólio et al., 2017; Romero-Garay et al., 2022). While the use of poultry by-products like droppings for plant nutrition and soil improvement is not a new practice (Maqsood et al., 2022), its extensive global utilization has been limited, posing threats to climate change, environmental safety, and human health (Maqsood et al., 2022; Zhang et al., 2023). Poultry manure is rich in nitrogen but also contains significant quantities of phosphorous and

potassium and thus is used to produce fertilizers and soil improvers (Dróżdż et al., 2020). Maximum utilization of poultry by-products in sustainable production practices is crucial for reducing the burden on the environment and circular economy principles in agriculture (Pajura, 2024; Vigneswari et al., 2024).

In recent times, the Ghana's poultry producers tend to face intense competition from chicken importers, whose prices are about 30 to 40% cheaper (Ahiale et al., 2019). Apike et al. (2024) reported that Ghana's decline in poultry production is associated with higher cost of labor, feed, day-old chick, and other variable input costs. Yevu and Onumah (2021) also reported that the feed and labor costs reduce profit levels of poultry producers in Ghana. These high costs and competition from importers are compelling most poultry farmers in Ghana to exploit additional revenue sources or exit the sector. Investors are unwilling to put resources into the business contributing significantly to the exit of numerous poultry firms, particularly broiler production (Ragasa et al., 2020; Banda and Tanganyika, 2021). Therefore, a market for poultry waste provides an opportunity for the farmers to earn additional revenue.

Raising awareness and supporting farmers to use green and animal manure to enhance soil fertility will help to ensure long-term impact on food security and poverty reduction (Sugiarto et al., 2019). Encouraging the use of crop and animal manure will require a functioning market(s) for such products with information on characteristics or nature. Nkansa et al. (2020) indicate that while some poultry farms in Ghana sell their poultry by-products, others are still disposing their by-products into forest in their localities. This practice often builds up cost of production due to labor and transportation costs involved in moving the waste from the farm to dumping sites. This phenomenon can be attributed to poultry producers' lack of sufficient information on the nature of the poultry by-product market. Moreover, improper management of poultry by-product has adverse effects on the environment and human health posing significant threats to climate, suggesting the need for sustainable approaches in poultry production to mitigate its environmental impacts (Gržinić et al., 2023). Over the past decades, the poultry production sector has experienced notable advancements to address emerging challenges and adapt to evolving changes (Castro et al., 2023). For example, a growing demand for organic foods

and produce (Nkansa et al., 2020) presents poultry producers with myriad of opportunities to handle and sell poultry by-products to organic food producers, cut down their production costs, and diversify their revenue sources. Consequently, it is imperative for poultry farmers in Ghana to embrace progress in processing and selling by-products. This strategic evolution will foster sustainable agricultural practices and allow farmers to simultaneously enhance their revenue streams. Nevertheless, there is inadequate knowledge on the poultry by-product market in Ghana, how the market has grown, who the key actors are, and how the market operates (e.g., volumes, value addition, channels, etc.) and associated challenges, if any. Thus, there is a knowledge gap regarding the market dynamics, revenue contribution, value addition practices, and challenges of the poultry by-product market in Ghana. To expand the sale of poultry by-product and make it more rewarding to local poultry producers, while meeting demand of users and solving waste management issues concurrently, it is important to understand the functioning of the market and bridge the knowledge gap to help in identifying the right policy frameworks and technologies to improve the markets for poultry by-product.

The theory of by-product synergy refers to the idea that by-products from one process can be used as inputs in another process, creating additional revenue streams and reducing waste (Zhou et al., 2020). By-product synergy can be achieved by identifying a process's by-products and finding out how to use them as inputs in another process (Batista et al., 2015). For instance, in the agricultural sector, crop waste can be used as livestock feed, lowering the demand for additional resources and generating a second source of revenue. The theory of by-product synergy is also related to the concept of circular economy, which seeks to minimize waste and pollution by maintaining products, components, and materials at their highest utility and value at all times (Sikdar, 2019). Circular economy contributes to resource conservation by maximizing resource efficiency, minimizing waste generation, and promoting sustainable resource management practices (Venkatesh, 2022), diverging from the notion that increasing revenue is inherently linked to ever-increasing resource use and consumption (Kuik et al., 2023). By identifying and utilizing by-products, businesses and organizations can create value from what would otherwise be considered waste,

and support sustainable development (Zhou et al., 2020). By-product synergy can also reduce the environmental impact of a process by reducing the need for new resources, lowering energy consumption and reducing waste. It can also improve the overall efficiency of a process or industry by making better use of existing resources and creating new revenue streams. Overall, the theory of by-product synergy is a powerful tool for creating additional revenue streams, reducing waste, and increasing the overall efficiency of a process or industry. The production of the organic fertilizers based on bird droppings is important in the disposal of poultry waste, for improving the fertility and phytosanitary condition of soil (Apaeva et al., 2020). The profit of grain production from the use of the organic fertilizers based on bird droppings increases in 1.7 times (Apaeva et al., 2020). The use of organic fertilizer significantly increases crop productivity and income, which help in reducing poverty of farm households (Martey, 2018). However, not much is documented of the gains of the originators of the poultry by-products, the poultry farmers. Much of the available literature is on the benefits of poultry by-products and the processing technologies, with little on the markets for the by-products and the participation of the poultry farmers in such markets. The novelty of this study lies primarily in describing the nature of the market, the gains and hindrances of the farmers, in particular, in participating in the emerging market.

With a focus on the generators of poultry waste, the aim of the study is to provide an understanding of the emerging market for poultry by-products in Ghana, a developing economy. The specific objectives of the study included: (i) to describe the nature of the market for poultry by-products in Ghana; (ii) to estimate contribution to the farmers' revenue from poultry by-products and examine the determinants of such revenue contribution, and (iii) to describe the constraints encountered by poultry farmers in the poultry by-product market. The findings of this study are significant for understanding the nature or functioning of the poultry by-product market, its participants/actors, and identifying its potential for growth and sustainable farm production practices. It is expected that it will help to bridge the knowledge gap surrounding the market characteristics, revenue contribution, determinants, and constraints faced by poultry farmers, who generate the waste; provide vital market insights for growth and development; and

ultimately, like suggested by Batista et al. (2015) and Geissdoerfer et al. (2017), lead to the adoption of sustainable agriculture and profitable practices in the poultry sector in line with the principles of circular economy practices. Policymakers and industry players alike will benefit from evidence-based decision-making, resulting in improved livelihoods, environmental sustainability, and overall growth of Ghana's poultry sector through effective management of poultry waste. The findings highlight the international dimension of this emerging market, with Côte d'Ivoire as a major consumer in a cross-border informal trade. This aspect emphasizes the potential for regional collaboration and knowledge exchange in adopting sustainable agricultural practices. The findings of this study would help stakeholders to collaborate to implement interventions that address the constraints and enhance the poultry by-product market and contribute to the broader development of the agriculture, in general. Thus, the findings offer some insights for strategic interventions.

MATERIALS AND METHOD

Sampling and data collection

A multistage sampling procedure was used to select the respondents. It allowed for a systematic and structured approach to ensure a representative sample is selected for the study. The study, which followed the mixed method research (using both qualitative and quantitative methods), was purposively conducted in the Bono and Ashanti regions, which are the top poultry-producing regions in Ghana and have the country's largest local markets and commercial centers for agricultural commodities (FAO, 2014; Sikdar, 2019). In the second stage, three poultry-producing districts were purposively selected from each of the regions based on the population of poultry farmers, size, and availability of the poultry products activities. Dormaa Central, Dormaa East, and Dormaa West were selected from the Bono region, while Ejisu-Juabeng, Atwima Kwanwoma, and Atwima Nwabiagya were selected from the Ashanti region (Figure 1). In the third stage, two communities were purposively selected from each district. Communities were sampled purposively to ensure that the data collected were representatives of the production district. Also, the intensity of poultry production and sale of poultry by-products activities were considered in the purposive sampling of communities. Finally, a systematic
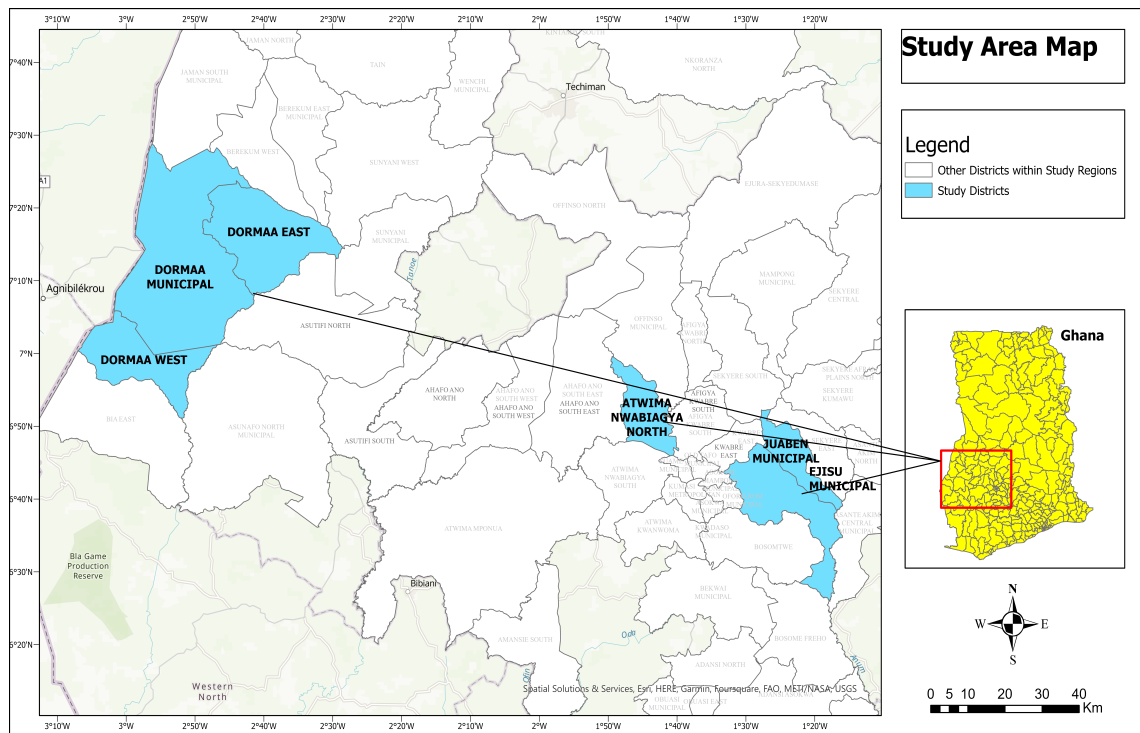
Figure 1. Map of sampled poultry-producing districts

random sampling technique was used to sample 10 poultry farmers commercializing poultry by-product from each community to obtain a total sample size of 120 poultry farmers. A snowball sampling technique was used to identify 7 aggregators and 3 cattle farmers, referred by poultry farmers purchasing poultry droppings. The aggregator samples included 4 aggregators from Côte d'Ivoire and 3 from Ghana. The data were collected using pretested semi-structured questionnaire.

Data analysis

Description of the markets for poultry by-products

The available poultry by-products sold along channels were identified to describe the poultry by-product market. The preferred channels of selling, volumes of poultry by-product supplied to the preferred channels, and their prices for the identified poultry by-product were analyzed using averages and percentages. A flow chart diagram was used to depict the nature of the marketing channel for better understanding of the distribution of poultry by-product to the various channels.

Estimating the proportion of revenue contributed by poultry by-products

A poultry farmer's revenue from the sale of the products within a production cycle was estimated from the quantities and selling price per unit for the main products (eggs, processed

meat, and spent layers). Revenue from the sale of the by-product was similarly estimated. The total revenue was estimated by adding all the revenues. The proportion of revenue contributed from the by-product to a poultry farmer's total revenue was valued. The summary statistics for the estimates are presented and discussed. The revenue estimations were done based on poultry farmers' output from their entire production season (72 weeks). The annual estimates (52 weeks) were then deduced from results from the production season estimations. The average weight of a bag of poultry dropping was measured to be 80 kg or 0.08 metric tons (MT).

Determinants of the extent of revenue contribution from poultry by-products

The Tobit regression technique was used to examine the factors influencing the extent of revenue contribution of poultry by-products. A Tobit model was utilized because the dependent variable, revenue proportion of poultry by-product, is a limited dependent variable. The empirical Tobit model estimated is specified using Equation 1.

$$P_b^* = \beta_0 + \beta_i X_i + u \qquad (1)$$

The error term is normally distributed with zero mean and constant (or homoscedastic) variance ($u \sim N(0, \sigma^2)$), i = 1, ..., n, Xi is a vector of explanatory variables and P_b^* is the observed

revenue proportion from poultry by-product for the ith respondent. The regression variables are defined in Table 1.

The estimated Chi-squared value was used to check the overall fitness of the estimated Tobit model, while the *p*-values were applied to indicate the statistically significant of the explanatory variables. The estimates for the marginal effects are discussed for the significant explanatory variables.

Identifying constraints poultry farmers encounter in the poultry by-product market

A list of constraints encountered during marketing of poultry by-products, obtained from literature and from respondents during pre-testing of questionnaire, was presented to respondents to rank according to level of severity. The level of agreement among the respondents was measured using the Kendall's coefficient of concordance (W). It rates the level of agreement on a scale from 0 to 1. The W is estimated using Equation 2.

$$W = \frac{12\left[\sum T^2 - \frac{\sum T^2}{n}\right]/n}{nm^2(n^2-1)} \qquad (2)$$

Where, T = sum of ranks of each constraint being ranked, m = number of farmers, and n = number of constraints being ranked. The tested hypothesis is:

Hypothesis 1

H$_0$: There is no agreement among the rankings by the respondents.
H$_a$: There is agreement among the rankings by the respondents.
The chi-square statistic (χ^2) was used to determine the significance of W.

RESULTS AND DISCUSSION

Socio-economic characteristics of the respondents

The socio-economic characteristics of the actors are presented in Tables 2 and 3. Majority (85%) of the respondents were males. This finding was consistent with a report by Mensah-Bonsu et al. (2019) who indicated that poultry production is dominated by men as the occupation is one that requires a great deal of energy and capital, which most women do not possess. Most (about 90%) of the respondents had at least basic education (Table 2). This was considered impressive as formal education is generally important for combatting poverty and elevating economic productivity. Table 2 presents that majority (59%) of the farmers selling poultry by-product (poultry dropping) were small-scale producers. Majority of poultry farmers in Ghana were into small-scale poultry production and contributed tremendously to the poultry value chain (Chen et al., 2021).

Table 1. Variable description, measurement and a priori expectation

Variable description	Measurement	A priori
Dependent variable		
Revenue proportion from poultry by-product (P_b^*)	Percent	
Independent variables		
Gender of respondent (X_1)	Dummy: 1 = male, 0 = female	+
Age of respondent (X_2)	Years	-
Experience in selling poultry by-product (X_3)	Years	+
Ownership (X_4)	Dummy: 1 = farm owner, 0 = otherwise	+
Litter size (X_5)	*Scale: 1 = 50–5,000, 2 = <5,000–10,000, 3 = above 10,000	+
Quantity of poultry by-product sold (X_6)	Continuous (MT)	+
Price of poultry by-product (X_7)	Continuous (USD per MT)	+
Respondent is a member of any Poultry Farmers' Association (X_8)	Dummy: 1 = yes, 0 = no	+/-
Number of spent layers sold (X_9)	Continuous (number)	+
Time of payment for by-product (X_{10})	Dummy: 1= outright, 0 = otherwise	+/-
Price of egg (X_{11})	Continuous (GHS per crate)	-
Pre-purchase arrangement/agreement with buyers (X_{12})	Dummy: 1 = yes, 0 = no	+/-

Note: *Based on Aning's (2006) classification of the Ghanaian poultry farmers into large-scale (above 10,000 birds), medium-scale (5,000–10,000 birds) and small-scale (50–5,000 birds), GHS = Ghana Cedi

Table 2. Socio-economic characteristics of respondents: Discrete variables

Variables	Frequency	Percentage (%)
Gender		
Female	18	15.0
Male	102	85.0
Education		
Non formal education	5	4.0
Primary	7	6.0
JHS/Middle school	37	31.0
SHS/SS	47	39.0
Tertiary	24	20.0
Ownership		
Owner-managed	79	65.8
Employee-managed	41	34.2
PFA membership		
Member	110	92.0
Non-member	10	8.0
Litter size		
50–5000 birds	71	59.2
< 5000–10,000 birds	22	18.3
Above 10,000 birds	27	22.5
Access to veterinary services		
Had access	120	100.0
Had no access	0	0.0
Contract		
Yes	72	60.0
No	48	40.0
Terms of payment		
Outright	102	85.0
Otherwise	18	15.0

Note: JHS = Junior High School, SHS = Senior High School, SS = Secondary School

Majority of poultry farms (66%) were owner-managed, while the rest were employee-managed (Table 2). This phenomenon can be attributed to owners having a personal stake in a business's success and were more likely to take actions that benefit the long-term profitability and sustainability of the farm (Achoja and Ananenu, 2019). Owner-managers often had an entrepreneurial mentality and a strong drive to innovate (Asenge et al., 2018). Majority (92%) of respondents were members of a Poultry Farmers Association (PFA) (Table 2). Farmers' associations played an important role in the development of poultry production in Ghana by providing members with services such as training, technical support, and access to markets. All the respondents had access to veterinary services, a key factor in poultry production in Ghana. Poultry farmers with access to veterinary services had more profitable operations than those who did not have access to these services, as reported by Adams and Ohene-Yankyera (2015). The poultry farmers selling poultry by-product (poultry dropping) were economically active, with a mean age of 41 years (Table 3). The poultry farmers sold on the average about 143.9 MT of poultry droppings per year.

Nature of poultry by-product market

Availability of poultry by-products

There were different forms of poultry by-products (droppings, viscera, feathers, eggshells, and blood) which were available in the study area, but only poultry dropping was commercialized by the poultry farmers. About 12,437 MT of poultry dropping were sold in the Bono and Ashanti regions of Ghana at an average price of 8.39 USD (72.50 GHS) per MT within the production season. Given that there were no markets for the other poultry by-products, their economic values were hidden and they were perceived as "free". Agricultural markets are essential for commercializing agricultural by-products, creating value from them, and using them efficiently (Ayoo et al., 2019). However, a number of agricultural by-products were characterized by the lack of market and infrequently traded, as found in the present study with the exception of the droppings.

The farmers indicated that, poultry droppings that were currently sold, were previously disposed-off in neighboring bush and burnt due to the absence of market for it. This transformation in waste management practices strongly supports the assertions of Ayoo et al. (2019) and Boateng et al. (2009) that poultry farmers discarded and burnt poultry by-products in forests and therefore would have to be encouraged to regard by-products as potential sources of additional revenue. Meanwhile, Boateng et al. (2009), Martey (2018), and Apaeva et al. (2020) showed that poultry manure is a valuable fertilizer and can serve as a suitable alternative to chemical fertilizer.

Mapping of actors in the poultry by-product market

Figure 2 depicts the actors in the poultry droppings market, their roles, and the activities they carry out. It presents the flow of poultry droppings from the poultry farmers to the end users. The main actors identified were the poultry farmers, aggregators (from Côte d'Ivoire and Ghana), cattle farmers, and organic fertilizer manufacturers. As the first actors in the marketing

Table 3. Socio-economic characteristics of respondents: Continuous variables

Variables	Min	Max	SD	Mean
Age	18	68	10.41	40.80
Years of selling dropping	1	30	6.70	8.00
Price of egg (USD per crate)	1.38	2.86	0.28	1.99
Price of dropping (USD per MT)	2.86	17.30	3.51	8.39
Number of spent layers sold	0	38,000	8,093	5,973.00
Quantity of dropping (MT)	4.98	1,329.23	195.35	143.87

Note: GHS to USD currency conversions were done using prevailing exchange rate (time of data collection) of 1.000 GHS to 0.115 USD

channel, poultry farmers performed several important tasks to begin the marketing process. These included negotiating the quantity they wanted to distribute to a particular channel and the price they were willing to charge the potential buyers. Secondly, poultry farmers negotiated convenient day and time for the removal and conveyance of the poultry droppings, as well as temporarily moving available flock of birds into other empty pens before the removal of dropping by buyers. The poultry farmers indicated that their choice of buyers depended on two major factors, including the buyers' willingness to purchase a certain quantity of chicken droppings and their ability to transport the droppings quickly off farms. Poultry farmers considered this necessary to avoid the build-up of diseases in the pens because of excess accumulation of nitrous oxide and gas (methane).

Aggregators played an important role in moving poultry droppings in huge volumes from poultry farms to processing sites and end users across Ghana and Côte d'Ivoire (Figure 2). Aggregators were responsible for scouting poultry farms and establishing contacts with farm owners or managers for information on the availability of
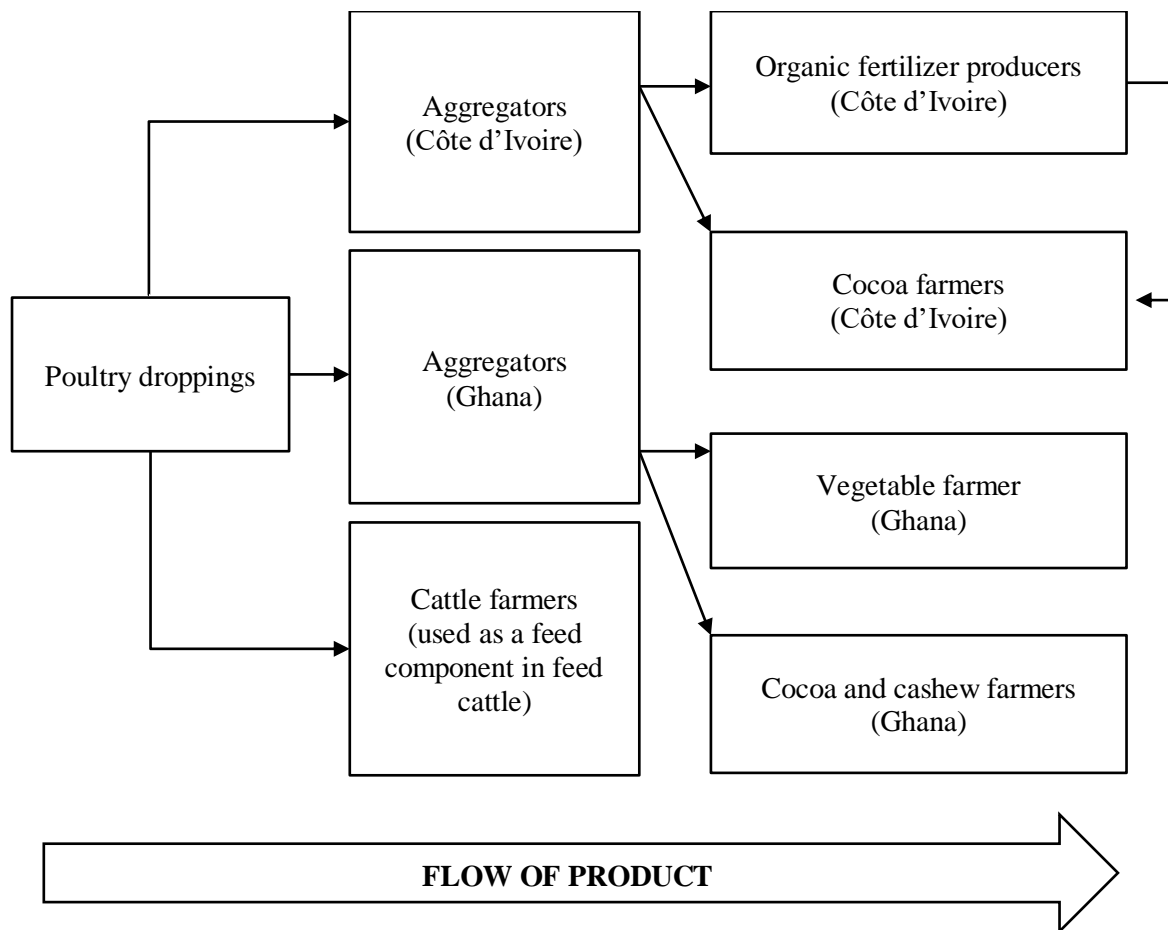

Figure 2. Channels of marketing poultry droppings

poultry droppings. Aggregators bore all costs involved in moving the poultry by-product from the farm gate to processors and other end-users. The costs incurred by aggregators included purchasing of packaging materials (bags), hiring, as well as paying laborers to remove, bag, and pack poultry droppings from the pens onto trucks. Cost of transporting droppings to processors and various users is also the responsibility of the aggregators. As detailed in Figure 2, aggregators were classified in two distinct categories based on their origin: the Ghanaian aggregators and the Ivorian aggregators.

Cattle farmers were also key actors in the poultry-dropping market (Figure 2). They practiced a direct link with farmers where poultry droppings were bought to feed their cattle. Livestock farmers had also been reported to be constrained by expensive feed materials and were therefore resorting to cheaper sources of feed materials (like poultry droppings) for animal consumption (Konlan et al., 2014). Cattle farmers explained that the poultry droppings they purchased were dried to a minimal moisture content and mixed with copper cake and other essential trace minerals before fed to their cattle. This finding was consistent with Ayoo et al. (2019), noting that poultry dropping can be used as livestock feed in a dry condition because it contains a good amount of crude protein (nitrogen), fiber, fat, and potash.

Distribution of poultry by-product to marketing channels

Over 9,600 MT of poultry droppings were sold to aggregators from Côte d'Ivoire representing about 76% of the total quantity of poultry dropping produced in the production cycle (Table 4). About 2,594 MT of poultry droppings was also sold to Ghanaian aggregators, representing about 20% of the total quantity of poultry droppings sold in the production cycle. The farmers reported that they preferred selling their droppings to Ivorian aggregators than selling to other buyers in the marketing channel, because the Ivorian aggregators purchased larger quantities and were extremely very fast in negotiations. The finding on the distribution of the droppings was consistent with Onumah et al. (2023) findings for live birds. Onumah et al. (2023) reported that approximately 42% of broiler birds were directly exported by producers in Ghana to neighboring countries like Cote d'Ivoire through contracting, whilst the rest were sold to wholesalers (30%), processors (10%), retailers (2%), and directly to consumers (14%). According to Onumah et al. (2023), these farmers directly sold to the neighboring countries due to their inability to process the live birds into dressed and cut parts (drumstick, breast, thigh, wings, backs, and necks) because of insufficient processing centers in particular. The cattle farmers purchases represented only 1.30% of the total quantity of poultry dropping produced, while the remaining proportion represented the amount used by the poultry farmers on their own crop farms (Table 4). The poultry farmers stated that the dropping was used in growing maize, which is an essential component of poultry feed. The distribution indicated that the demand and use of poultry dropping were higher among users in Côte d'Ivoire than in Ghana.

Contribution of poultry droppings to poultry farmers' revenue

From Table 5, the price for poultry droppings per MT ranged from 2.86 USD (25.00 GHS) to 17.30 USD (150.00 GHS). The average price per MT was 8.39 USD (72.50 GHS). The study noted that Ivorian aggregators paid slightly less price than the estimated average price, while most of the Ghanaian aggregators and livestock farmers purchased the poultry dropping at a higher price than the average. The respondents attributed this occurrence to the fact that Ivorian aggregators purchased more quantities of the poultry droppings than Ghanaian aggregators and livestock farmers did. Therefore, they negotiated for bulk purchase deals with associated discounted price. The output price was a motivating factor for producers to increase their

Table 4. Quantity of poultry dropping distributed to each channel

Channels	Obs	Quantity (MT)	Mean quantity (MT)	Proportion of total (%)
Aggregators (Côte d'Ivoire)	120	9,681.28	80.68	76.16
Aggregators (Ghana)	120	2,594.00	21.61	20.40
Cattle farmers	120	161.84	1.34	1.30
Own-farm use (poultry farmers)	120	274.00	2.28	2.14

Note: Obs = observation

Table 5. Proportion of revenue contributed by poultry dropping

Variables	Obs	Mean	SD	Min	Max
Price of dropping (USD per MT)	120	8.39	3.51	2.86	17.30
Revenue: Poultry dropping (USD)	120	1,072.26	1,327.76	54.14	6,417.00
Revenue: Main products (eggs, meat, spent layers) (USD)	120	239,397.75	341,436.39	6,774.42	1,767,631.00
Total revenue (USD)	120	241,245.21	341,731.35	6,850.85	1,769,541.80
Proportion of poultry by-product (%)	120	0.44	0.39	0.36	0.79

Note: GHS to USD currency conversions were done using prevailing exchange rate (time of data collection) of 1.000 GHS to 0.115 USD

market supply, which in return increased their revenue.

The estimates showed that a poultry farmer accrued averagely about 9,324.00 GHS (1,072.26 USD) from the sale of poultry droppings within a production season, representing less than 1% of the total revenue (241,245.21 USD) accrued by an average poultry farmer in a production season (Table 5). Therefore, the contribution of poultry droppings to the farmer's total poultry revenue was negligible, though it saved the removal and disposal costs for the poultry dropping, by creating value for other users, in line with the by-product synergy innovation.

Determinants of revenue proportion contributed by poultry droppings

Table 6 presented the results from the Tobit regression analysis, showing the factors that influence the proportion of revenue contributed from the sale of poultry dropping. The estimated Chi-squared value suggested that the overall Tobit model was statistically significant and therefore it was a good fitted model. Table 6 revealed that the ownership variable had a significant and positive effect on the proportion of revenue contributed by the droppings, implying that owner-managed poultry farms were more likely to have higher proportion of revenue contributed from poultry droppings than employee-managed poultry farms. Farmers who owned their poultry businesses may have more control over the management and utilization of poultry droppings, which led to a higher proportion of revenue from the droppings. Additionally, owners may be more motivated to maximize profits from all aspects of the business, including by-products like droppings. This finding aligned with that of Achoja and Ananenu (2019) that owner-managed poultry farms performed better than employee-managed farms. This may be due to the fact that owners had a greater stake in the farm business and

therefore take managerial decisions that will increase their farm income.

Being a member of a PFA negatively influenced the proportion of revenue from poultry droppings. This was statistically significant at 1%, which implied that respondents who were not part of poultry farmers' association had more revenue contribution from poultry droppings than respondents who were members. This result might be because PFA members had access to other more profitable revenue streams within the poultry industry, which could divert their focus away from the sale of droppings. Additionally, the association may have policies or regulations in place that limited the ability of its members to profit from selling poultry droppings. This finding validated the study by Sitoe and Sitole (2019), that generally, non-members of farmers' associations generate more income from their farm businesses than members.

The study also found quantity and price of droppings to positively influence the proportion of revenue contributed from poultry droppings (Table 6). The estimated marginal effect implied that an additional metric ton of poultry droppings sold resulted in an increase in the proportion contributed by poultry droppings by about 0.275. Farmers may explore strategies to enhance and optimize the quantity of droppings they sell, such as improving droppings management practices, increasing flock sizes, or exploring partnerships with businesses that require droppings-based products. The highly significant and positive marginal effect of 0.110 for the price variable suggested that increasing the price of droppings was associated with a higher proportion of revenue from poultry droppings (Table 6). The implication of this finding is that the poultry farmers can potentially maximize their revenue from droppings by strategically setting higher prices or agreeing on a minimum price below which farmers should not sell or participate in the

Table 6. Determinants of revenue proportion contributed by poultry droppings (Tobit regression results)

Variables	Marginal effect (dy/dx)	Standard error	t-value	P>t
Gender	-0.018	0.070	-0.250	0.801
Age	-0.001	0.003	-0.210	0.835
Ownership	0.162***	0.060	2.690	0.008
Member of PFA	-0.271***	0.098	-2.770	0.007
Years of selling dropping	0.001	0.005	0.150	0.882
Time of payment	0.053	0.077	0.680	0.498
Quantity of dropping	0.275***	0.034	8.010	0.000
Price of egg	0.003	0.012	0.230	0.817
Price of dropping	0.110***	0.012	9.190	0.000
Number of spent layers sold	-0.002***	0.000	-5.110	0.000
Litter size[1]				
Medium scale (5,000–10,000 birds)	-0.186**	0.072	-2.570	0.012
Large scale (> 10,000 birds)	-0.328***	0.115	-2.850	0.005
Pre-arrangement with buyer	0.020	0.057	0.350	0.729
Constant	-1.601	0.344	-4.650	0.000

Pseudo R^2 = 0.7795   Log Likelihood = -17.2203
LR Chi^2(13) = 121.60   Prob > Chi^2 = 0.0000
Note: [1]The compared litter size is small scale (<5,000 birds); *** indicates significance at the 1% level

droppings market. Ye et al. (2023) have found out both the basic attributes and responsible production attributes of broilers are positively related to their market selling price. Thus, the poultry farmers could be involved themselves in the bagging of the droppings to develop described attributes for their poultry by-products for enhanced selling price. As suggested by Ye et al. (2023), this demonstrates the need for sustainable marketing practices.

As presented in Table 6, both "medium scale" and "large scale" categories of litter size had significant and negative coefficients. This implied that small-scale poultry farms had a higher proportion of revenue from droppings compared to the larger farms. The finding agreed with the report of Chen et al. (2021) that small-scale farmers are increasingly involved in making value-added products because it allows them to expand profits, while reducing waste. Therefore, the poultry droppings market provided a good opportunity as additional source of income for small-scale farms.

The number of spent layers sold was estimated to have a significant but negative relationship with the proportion of revenue contributed from poultry droppings (Table 6). The estimated marginal effect suggested that selling spent layers were associated with a lower proportion of revenue from poultry droppings. The finding implied that the poultry farmers who sold spent layers may not rely much on revenue generated

from poultry droppings. Probably, the poultry farmers would have to face a tradeoff between selling spent layers and keeping the droppings for use on their crop farms. These farmers could be sensitized on the available/emerging market for poultry droppings, where their poultry waste notably the droppings can be sold for additional income instead of discarding as waste if not needed for use on their farms.

Constraints faced by poultry farmers in the poultry by-product market

A perceived low price of poultry droppings was the biggest constraint of the respondents with a mean rank of 2.66 (Table 7). Market price for poultry droppings was dictated largely by the aggregators within the market, and farmers rarely had much say in the pricing, though they accepted relatively lower price offered by Ivorian aggregators due to volume of trade involved. Low prices tend to discourage farmers from investing in new technologies or techniques that can add value (Macours, 2019). There could be several reasons for the low prices of poultry droppings, such as oversupply in the market, discounted price for bulk purchases, lack of awareness among farmers about the benefits of poultry droppings as a fertilizer, lack of proper storage and packaging, and lack of proper transportation facilities. Farmers may need to find ways to increase the value of their droppings, such as processing them into a more valuable product like compost or by finding new markets for their droppings.

Table 7. Ranking of constraints in the poultry dropping market

Constraints	Mean rank	Rank
Low price	2.66	1st
Lack of processing and storage facilities	3.15	2nd
Seasonal demand	3.24	3rd
Distance from buyers	3.39	4th
Lack of market information	3.90	5th
Access to credit	5.71	6th
Poor road network	5.95	7th

Note: Sample size N = 120, Kendall's W = 0.47, Chi-square = 262.25, df = 6, Asymp. Sig. = 0.000***

Lack of processing and storage facilities for poultry droppings within the study area was ranked as second major constraint (Table 7). There were no processing and storage facilities in the study area to process and store the droppings or any other by-product for future utilization. The availability and operationalization of processing and storage facilities for poultry by-products could foster the culture of forward integration among respondents, thus adding value to not just the droppings but also other poultry by-products. Price per unit of the poultry droppings when processed would increase thereby increasing the proportion of revenue contributed. Also, because poultry farmers had no form of storage facilities, poultry droppings were left in coops until buyers arrived for collection. The presence of processing and storage facilities will allow for the efficient processing and storage of not only poultry droppings for their sustainable distribution and use in agriculture, but also all other poultry by-products, such as the viscera, head, feet and feathers. Macours (2019) had suggested that simple technologies that do not require much additional change in practices or knowledge have a clear premium for smallholders and should be supported with intensive extension services. However, available technologies could be expensive and may not be affordable to small farm investors. According to Ayub et al. (2022), technologies for sustainable recycling of poultry litter to value-added products exist in Asia and Europe, though they come with different levels of costs and investment requirements, with the studied countries in South Asia focusing mainly on biological conversions and neglected the thermal technologies.

Seasonal demand for poultry droppings within the study area was ranked as the third constraint (Table 7). Demand for poultry dropping in the study area was erratic especially from Ivorian aggregators who constituted the biggest force within the poultry droppings market. The Ivorian aggregators interviewed revealed that, their demand for poultry dropping was influenced by weather conditions. They indicated that it was usually not possible to purchase poultry droppings in the wet or rainy season due to the deterioration of roads leading to the farms. Roads leading to the farms were inaccessible by their trucks during this period, though poor road networks turned out to be the least constraining factor for the poultry farmers. For the farmers poor road networks could be a regular feature for them, hence its low ranking among their challenges, but it had implication for the price of their products and it could be linked to the low price for the by-product, which they had indicated as the most constraining factor. Regular levelling and maintenance of the feeder and connecting/link roads by the State Department of Feeder Roads and spillover from cocoa roads maintenance program of Ghana Cocoa Board (COCOBOD) will help to sustain the trade relations in the poultry by-product and the poultry sector, in general.

The estimated Kendall's W was 0.47 and significant at the 1% level, indicating 47% level of agreement among the respondents in the ranking of the constraints within the poultry droppings market. Therefore, the alternate hypothesis that there was agreement among the poultry farmers in the ranking of their constraints was not rejected. Consequently, the poultry farmers had similar constraints for the emerging poultry by-product market that stakeholders including the government and development partners can help to address in an all-inclusive manner for sustainable agricultural production under the circular economy. Stakeholders in the poultry sector should intervene with strategies that embrace technology, fair trade practices, and environmental consciousness to help the poultry by-product market to overcome its current constraints and emerge as a beacon of sustainable agricultural practices. This transition is not just

an economic necessity but a vital step toward fostering a circular economy and ensuring the long-term viability of poultry sector.

CONCLUSIONS

The emerging poultry by-product market included only poultry droppings with an average selling price of 8.39 USD per MT and annual revenue per poultry farmer of 1,072.26 USD. The emerging market for poultry droppings was found to be seasonal in nature, which provided an opportunity for small-scale farms to earn additional income and organic manure to support sustainable farming. The most prevailing constraints among poultry farmers for developing the by-products market were low prices, and lack of processing and storage facilities, while the deterioration of roads, particularly in the wet/rainy season, deter the purchases by the aggregators. The study recommended that the development agencies including the government should support the development of value chains for poultry by-products, particularly, poultry droppings to address the challenges to help expand the market for sustainable agriculture production.

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