Ghanaian Journal of Animal Science
Journal of the Ghana Society of Animal Production
GJAS, Volume 17, Number 1, 2026

Nutritional Valorisation and Safety Validation of Corn-Mill Sweepings as Swine Feed: Perspectives and Practices of the Ejisu-Juaben Pig Farmers and Processors Association, Ghana

Sasu, *P., Frimpong, Y.O., Opoku-Asenso, Okai, D.B. and Boateng, M.
Department of Animal Science, Faculty of Agriculture,
College of Agriculture and Natural Resources, KNUST, Kumasi-Ghana
**Corresponding author: psasu.research@gmail.com*
https://dx.doi.org/10.4314/gjansci.v17i1.4

ABSTRACT
A 2-phase study was undertaken to investigate the viability and safety of utilizing corn-mill sweepings (CMS) as a sustainable agro-industrial by-product (AIBP) in swine nutrition. The research characterized the usage patterns, incidence, and types of contaminants present in these materials to determine their potential for effective integration into local feed systems. In the first phase, 20kg of CMS were collected from three (3) different mills each in ten different suburbs of the Kumasi Metropolis of the Ashanti Region of Ghana for physical examination. Phase 2 involved a field survey specifically targeting the Ejisu-Juaben Pig Farmers and Processors Association. Nineteen semi-structured questionnaires were administered to association members to capture data on their demographic characteristics and livestock inventory, as well as to evaluate their professional perceptions of the practical challenges and benefits of CMS as a feed resource. Data collected were analyzed using descriptive statistics via the Statistical Package for Social Sciences (SPSS) version 20. Physical examination of CMS samples was conducted to quantify contaminant weight and percentage across the study area. Results showed that a 20 kg sample of CMS contains a 1.34% mean contaminant load (0.292 kg), requiring an average of 40 minutes of manual sorting for safety utilisation. These contaminants primarily consist of caked or mouldy feed items (67%), wood (15%), plastics (7%), metals (4%), and miscellaneous debris (7%). Economically, CMS prices fluctuated between GH₵4.00 and GH₵6.00 per 20 kg, predicated on mill proximity to livestock hubs. The survey of the Ejisu-Juaben Pig Farmers and Processors Association revealed that 95% of farmers utilize CMS, with 84% managing stock sizes exceeding 100 pigs. Key utilization challenges identified included high contaminant incidence (52%), product deterioration (29%), and erratic supply (17%). It was concluded that while CMS offers a strategic opportunity for nutritional valorization, its safety is compromised by extraneous materials that increase labor costs and animal health risks. Consequently, mill operators must implement improved collection and storage protocols to enhance the ingredient's reliability for the livestock industry.

Keywords: *Agro-industrial by-products (AIBP), corn mill sweepings (CMS), contaminants, piglet diarrhoea, swine production.*

INTRODUCTION
The production of monogastric livestock is heavily dependent on the efficiency and cost-effectiveness of feeding regimes (Hutjens, 2007). Over the last decade, global feed costs have remained highly volatile, with prices escalating by approximately 40% to 60% due to a combination of geopolitical instability, global

supply chain disruptions, and the rising cost of international grain trade (Trostle, 2012). In the Ghanaian context, these price hikes are exacerbated by an overdependence on conventional feedstuffs, specifically maize, fishmeal, and soybean meal, most of which are imported and subject to volatile market conditions (Boateng *et al*., 2008). Furthermore, the intensifying competition between humans, industries, and the livestock sector for these limited primary grains has created a critical need for sustainable alternative feed resources. While maize and soybean meal remain the gold standard for monogastric nutrition, their cost is increasingly influenced by shifting agricultural policies and global oil prices (Hutjens, 2007). Although researchers are exploring advanced alternatives such as hydrolyzed proteins and free amino acids to mitigate environmental impacts and costs (Biagi *et al*., 2017), the practical application of locally formulated diets using available regional resources remains the most viable strategy for small-to-medium scale producers. Empirical evidence has demonstrated that utilizing locally available ingredients can significantly reduce the financial burden on pig production compared to commercial alternatives (Pierer *et al*., 2016). The strategic valorisation of agro-industrial by-products (AIBPs) and non-conventional feed resources (NCFR) represents a promising solution to these economic constraints (Aboh *et al*., 2013). Globally, various AIBPs have been successfully integrated into animal diets to alleviate the pressures of feed scarcity (Devendra and Leng, 2011). In Ghana, corn-mill sweepings (CMS), a composite by-product gathered from the floors of milling processing units, have emerged as a significant non-conventional resource (Boateng *et al*., 2020). This material, locally referred to as "B-Co" (Vitamin B-complex) due to its diverse ingredient profile, typically consists of residuals from the processing of maize, sorghum, millet, cassava, groundnut, and other legumes (Boateng *et al*., 2014; Boateng *et al*., 2015).

Recent investigations indicate that CMS production is substantial; approximately 75% of mill operators generate between 6 and 25 kg of sweepings daily, providing a consistent supply for dietary supplementation (Boateng *et al*., 2020). Nutritionally, CMS exhibits a wide analytical range, with crude protein levels between 8.53% and 14.51% and metabolizable energy reaching up to 3574.65 kcal/kg DM (Boateng *et al*., 2020). Despite this nutritional potential, the utilization of CMS, predominantly by pig farmers, is hampered by significant structural challenges (Balogu *et al*., 2017; Boateng *et al*., 2020).

A critical research gap exists concerning the safety validation and physical characteristics of CMS. The central hypothesis of this study posits that the floor-level collection of corn-mill sweepings inherently predisposes the material to contamination by diverse extraneous and potentially deleterious physical agents. Such contaminants present a physiological risk to the gastrointestinal integrity of pigs and may significantly attenuate the overall digestibility of the diet. To date, empirical evidence characterizing the systematic acquisition protocols, the specific physical contaminant profiles, and the subsequent health implications within the Ghanaian swine value chain remains critically deficient.

To address these research gaps and facilitate the safe integration of CMS into swine diets, this study systematically evaluated the socio-demographic perspectives and utilisation practices of CMS within the Ejisu-Juaben Pig Farmers and Processors Association. The main goal was to physically examine CMS to identify the types and amounts of contaminants present and to study how the product is currently used. This was done to provide a scientific basis for validating the safety and nutritional value of this by-product.

MATERIALS AND METHODS

Phases of the experiment and study areas

The study was carried out in 2 phases (Figure 1). In phase 1, samples of CMS were collected from ten different communities in the Kumasi Metropolis and transported to Kwame Nkrumah University of Science and Technology (KNUST), Department of Animal Science, for physical examination. Phase 2 involved conducting a survey on CMS use and the challenges experienced by pig farmers in the Ejisu-Juaben Municipality of the Ashanti Region of Ghana

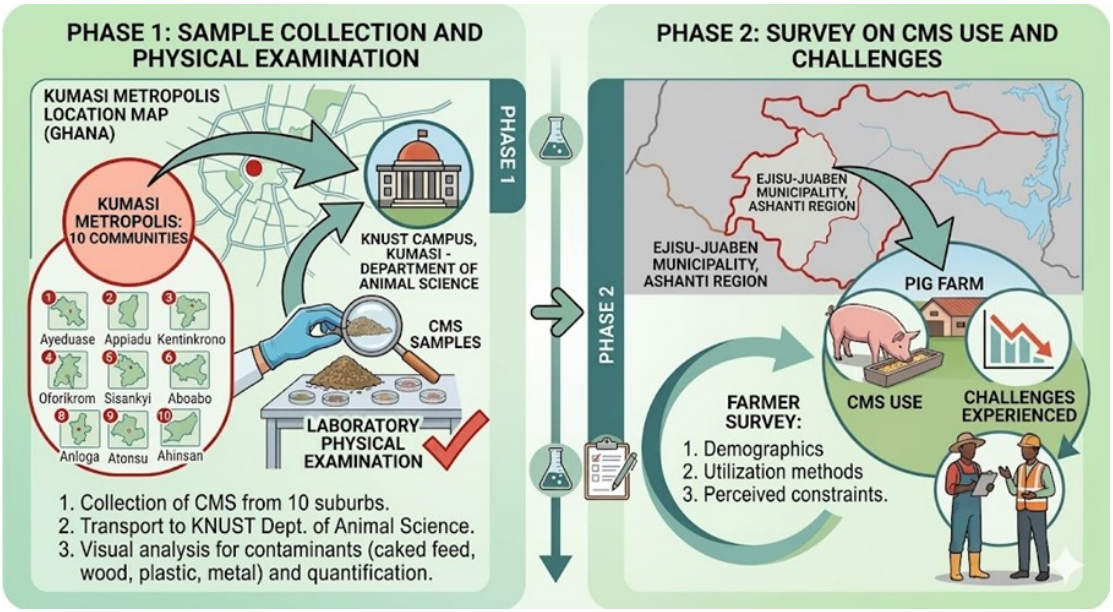


Figure 1: Graphical representation of the two-phase study design: Phase 1 involves the collection and laboratory examination of corn mill sweeping (CMS) samples from ten suburbs in the Kumasi Metropolis at KNUST, and Phase 2 details the survey on CMS utilization and farmer challenges in Ejisu-Juaben Pig Farmers and Processors Association

Phase 1: Sample collection and physical examination of samples

Twenty kilograms of corn mill sweepings (CMS) were collected from three separate mills across ten suburbs in the Kumasi Metropolis, including Ayeduase, Appiadu, Kentinkrono, Ayigya, Oforikrom, Sisankyi, Aboabo, Anloga, Atonsu, and Ahinsan. Samples were randomly examined for the presence and quantities of contaminants. To ensure the objectivity and reproducibility of the contaminant recovery process, the physical examination was conducted by two independent investigators. This dual-investigator approach was combined with a strictly timed protocol, where each investigator processed only one 20 kg sample per day. This measure was implemented to eliminate observer fatigue and maintain a consistent level of scrutiny across all thirty samples. During the procedure, samples were spread evenly on a polythene sheet to facilitate the manual removal of macro-contaminants through hand-picking (Figure 2). Following this, a bar magnet was systematically passed through the samples to isolate ferrous micro-contaminants. All recovered foreign materials were subsequently categorized into specific groups and quantified using a Master Chef digital kitchen scale (5 kg ×1 g capacity) to determine the mass proportions of the contaminants.

Phase 2: Survey on Utilization of CMS by Pig Farmers

Before the study, a reconnaissance survey was undertaken in the Municipality and the relevant establishments visited were the offices of the Ministry of Food and Agriculture (MOFA), Ejisu-Juaben Pig Farmers and Processors Association (EJPFPA), and some pig farms located in Kwamo, Besease, Asotwe and Donyina. Semi-structured questionnaires were then prepared and administered to 19 pig farmers who were all members of the EJPFPA. Questions asked were related to their biodata, their stock size, the systems of management, sources of feed and feed ingredients, types of feeds used, CMS acquisition, usage, and challenges associated with the use.



Figure 2: Protocols for sample collection and physical contaminant examination of corn mill sweepings

(a) Sample collection: Field collection of corn mill sweepings (CMS) from the milling hubs.(b) Magnetic screening: Pass of a bar magnet through the samples to separate ferrous materials (micro contaminants).(c) Physical (hand-picking) screening: Manual examination and removal of macro contaminants spread evenly on a polythene sheet.(d) Weighing and packaging of contaminants: Quantification of separated foreign materials using a digital scale and subsequent packaging into brown envelopes.

Data analysis

Data obtained from the survey were coded into similar views after which they were analyzed with the Statistical Package for Social Sciences (2007) version 16. Results obtained from the analysis were presented in tables and charts as frequencies and percentages. However, results from the physical examination of the samples were presented as mean values in tables.

RESULTS AND DISCUSSION

Physical Characterization of Contaminants in Corn Mill Sweeping

Physical examination of corn mill sweeping (CMS) samples revealed a diverse range of extraneous materials, accounting for 0.292 kg (1.45%) of the total 20 kg sample mass analyzed. The quantitative distribution of these contaminants is summarized in Table 1, while their visual characteristics are presented in Figure 3. The results indicated that caked feed products were the most prevalent contaminant, representing 66.8% of the recovered extraneous mass. Following caked items, wooden materials (14.5%) and miscellaneous organic debris (7.2%) constituted the next most significant fractions, followed by plastics (6.8%), and (4.2%). highlighting a general lack of sanitary control during the collection of sweepings for use in pig nutrition.

The high incidence of caked feed materials is associated with the practice of bagging sweepings while still wet, as observed among the mill operators during field visits to mill centers. Such practices retain residual moisture, a critical driver for fungal proliferation and the subsequent formation of caked masses. Field observations further revealed a significant correlation be-

Table 1: Mean proportions and mass distribution of contaminants in CMS samples

Contaminant	Weight (kg)	Percentage
Caked feed items	0.195	66.8
Pieces of wood	0.042	14.5
Plastics	0.020	6.8
Metals	0.012	4.2
*Miscellaneous items	0.021	7.2
Total	**0.292**	**~100**

**Includes cloth fragments, feathers, glassware, groundnut husks, and fruit peels.*

tween the degree of moldiness and the type of grain processed. Samples obtained from mills processing cassava in conjunction with maize exhibited consistently higher moisture levels and advanced spoilage. This phenomenon suggests that the high intrinsic moisture content of cassava leaches into the surrounding maize sweepings, facilitating rapid fungal development. These findings align with established literature (El-Shafey *et al*., 2004; Bijay and Singh, 2013), which identifies elevated moisture content as the primary factor predisposed to mold infestation and nutritional deterioration in stored feed matrices.

Physical Purity and Market Value of Corn Mill Sweepings

The physical purity and market value of corn mill sweepings (CMS) across the ten studied communities are summarized in Table 2. Across the entire sample pool, the average contaminant weight was 0.292 kg, resulting in a mean contamination level of 1.34%. Analysis of individual locations revealed significant variances in purity. Atonsu exhibited the highest level of impurity, with a mean contaminant weight of 0.609 kg (3.05%), followed by Kentinkrono (0.373 kg; 1.87%) and Appiadu (0.348 kg; 1.74%). Conversely, the cleanest samples were obtained from Ayeduase, which recorded the lowest contaminant weight of 0.111 kg (0.56%), and Sisankyi (0.168 kg; 0.84%). A critical observation made during the field collection was the relationship between the proximity of mills



Figure 3: Morphological representation of identified contaminants.

(a) Caked feed items (b) Wood fragments (c) Plastics (d) Metallic debris (e) Miscellaneous items.

to livestock farms and the resulting contaminant load. In communities such as Atonsu, where livestock farms were either absent or located at significant distances from the milling centers at the time of data collection, a higher degree of contamination was recorded. This trend is likely attributable to the inventory turnover rate; in the absence of immediate demand from nearby livestock farmers, mill operators stored the CMS for extended periods. This prolonged storage increased the handling frequency and the likelihood of "adulteration" through routine floor sweepings and the accumulation of environmental debris. In extreme cases, samples from these distant mills exhibited signs of decomposition and were discarded.

The labor intensity required to ensure the safety of this unconventional feed resource was high. On average, it required 40 minutes for the two trained investigators to manually sort and remove macro and micro-contaminants from a single 20 kg sample. The sorting time was highest in Atonsu (59 mins) and Appiadu (53 mins), correlating with their higher contaminant loads. This substantial time investment represents a hidden labor cost that pig farmers must account for when incorporating CMS into their feeding regimes.

Economically, the price of a 20 kg bag of CMS fluctuated between GH¢4.00 and GH¢6.00, with a mean price of GH¢4.50. The highest price point was observed in Appiadu (GH¢6.00), which corresponds to an observed strong localized demand driven by the high concentration of livestock farms in the surrounding area. This price-demand elasticity confirms that while CMS is a cost-effective alternative, its market value is sensitive to the geographical density of livestock production and the resulting freshness of the product.

Phase 2: Survey of CMS Utilization and Stakeholder Profiles

Demographic Characteristics of Pig Farmers in the Study Area

The demographic profile of the respondents, specifically age, sex, and educational attainment, serves as a critical indicator of physical labour capacity and the rate of technological adoption in agricultural systems (Idowu *et al.*,

Table 2: Quantitative assessment of contaminant load, processing labor requirements, and market pricing of corn mill sweepings (CMS) across ten study locations

Location	Mean Contaminant Weight (kg)	Percentage Contamination (%)	Average Sorting Time (mins)*	Price of CMS (GH¢/20kg)
Appiadu	0.348	1.74	53	6.00
Atonsu	0.609	3.05	59	4.00
Ayeduase	0.111	0.56	21	5.00
Aboabo	0.252	1.26	43	4.00
Ahinsan	0.245	1.23	44	4.00
Ayigya	0.250	1.25	31	4.00
Oforikrom	0.249	1.25	35	5.00
Kentinkrono	0.373	1.87	33	5.00
Sisankyi	0.168	0.84	35	4.00
Anloga	0.310	1.55	35	4.00
Average	**0.292**	**1.34**	**40**	**4.50**

**Sorting conducted by two independent investigators per 20 kg sample.*

2012; Awunyo-Vitor *et al.*, 2013). As detailed in Table 3, the study revealed a youthful and predominantly male workforce. As detailed in Table 3, the study identified a predominantly male workforce (68%) compared to female participants (32%). This male domination is likely attributed to the high labor intensity associated with medium-to-large-scale pig rearing in the region.

The age distribution of the farmers reveals a blend of experience and physical vigor. While 42% of respondents are above 50 years of age, the majority (58%) fall within the active age bracket of 20 to 49 years. These findings are consistent with previous studies conducted in the same Municipality by Frimpong (2010) and Mohammed (2010), who reported that 76% and 78% of pig farmers, respectively, were within this productive age group. The alignment of these results over a decade later highlights a stable demographic trend in the Municipal 's swine industry, where the workforce remains primarily composed of individuals in their productive years. This suggests that with appropriate extension education, production efficiency and the adoption of safer CMS processing techniques could be significantly enhanced.

Table 3: Demographic statistics of pig farmers

Item	Frequency (n*=19)	Percentages
Age		
20-29	1	5
30-39	2	11
40-49	8	42
Above 50 years	8	42
Total	19	100
Sex		
Male	13	68
Female	6	32
Total	19	100
Educational Background		
Formal education	12	63
No formal education	7	37
Total	19	100
Position Held on Farm		
Owner	16	84
Manager	2	11
Caretaker	1	5
Total	19	100

**Number of respondents*

Educational background also plays a pivotal role in the management of non-conventional feed resources. In this study, 63% of the farmers had received formal education, while 37% had none. This level of literacy mirrors the findings of Boateng *et al.* (2015), who reported that 75% of pig farmers in the area were formally educated. Such educational levels are advantageous for the successful communication of CMS processing and safety protocols.

Regarding farm management, the vast majority of respondents (84%) were owner-managers of their operations, while 11% served as managers and 5% as caretakers. This high rate of self-management is driven by both economic and qualitative factors. Respondents indicated that hiring professional external managers is often prohibitively expensive, making owner-operation a financial necessity. Furthermore, owners expressed a lack of trust in third-party personnel, reporting that hired caretakers frequently fail to treat livestock with appropriate care or may even engage in financial malpractice (Mohammed, 2010; Boateng *et al*., 2015). This finding aligns with broader concerns regarding animal welfare and neglect in the absence of direct owner oversight. For instance, negligence is a recurring theme in animal cruelty cases, often stemming from the failure of third-party handlers to provide essential care. This is supported by research in Curitiba, Brazil, which found that 13.5% of animal abuse cases were directly attributable to a lack of care by third-party agents (Alrahman, 2019). Consequently, the preference for owner-management in the Ejisu-Juaben Municipality appears to be a strategic choice to safeguard both the financial integrity of the farm and the physical well-being of the livestock.

Pig Management Systems and Stock Sizes

The management framework adopted by pig farmers is a fundamental determinant of enterprise productivity, influencing growth trajectories, reproductive efficiency, and disease resilience (Herawati *et al.*, 2019). In this study, a total transition toward commercialization was observed, as 100% of the respondents utilized the

intensive management system (Table 4). Unlike extensive or semi-intensive systems where scavenging is common, all farmers interviewed provided confined housing, structured feeding regimes, and veterinary care. This universal adoption of intensive husbandry is consistent with observations by Rekwot *et al.* (2005) and is largely attributed to the peri-urban nature of the study area, where land constraints and local regulations discourage free-roaming livestock. This shift toward intensive confinement has significant implications for regional biosecurity. By eliminating free-roaming, farmers drastically reduce the risk of environmental pathogen transmission, including African Swine Fever (ASF). As noted by Ifende *et al.* (2025), the adoption of intensive systems often correlates with an increased willingness among farmers to invest in disease control measures to protect their growing capital. Such a system ensures the production of healthier animals and stabilizes the supply chain for unconventional feed resources like corn mill sweepings (CMS).

Furthermore, the data reveals a substantial expansion in livestock inventory compared to historical benchmarks. The majority of the farmers (84.2%) maintained stock sizes exceeding 100 pigs, with over a quarter of the respondents (26.3%) managing large-scale operations of more than 300 pigs. This represents a significant upward trend from earlier reports by Boateng *et al.* (2015) in the same municipality, where 55% of farmers managed fewer than 100 pigs. The current proliferation of larger stock sizes confirms that pig rearing has evolved into a primary vehicle for household financial improvement and nutritional security in the region (Okai and Boateng, 2007). In contrast, pig production in the Northern parts of Ghana remains largely traditional; Afari (2012) reported that 80% of farmers there maintained fewer than 50 pigs, often utilizing semi-intensive systems that revert to extensive roaming during the dry season. The stark contrast between those findings and the 100% intensive adoption observed in this study highlights the geographical shift toward modernized, high-density swine production. This progression reinforces the argument that intensive systems are best suited for maximizing the potential of pig enterprises in developing peri-urban economies.

Table 4: Distribution of management systems and stock sizes

Item	Frequency (n*=19)	Percentages
System of Management		
Intensive	19	100
Semi-intensive	0	0
Extensive	0	0
Stock Size		
1-100	3	15.8
101-200	6	31.6
201-300	5	26.3
>300	5	26.3

**Number of respondents*

Pig Feeding Systems and Feedstuffs Utilization

As shown in Table 5, 100% of the surveyed farmers practiced restricted feeding, a controlled management approach where specific quantities of feed are provided at set intervals rather than allowing continuous access (*ad-libitum*). This finding is consistent with Boateng *et al*. (2014), who observed that 95% of pig farmers in the Afigya-Kwabre District also utilized restricted feeding regimes. The universal application of this method in the Ejisu-Juabeng Municipality suggests a highly disciplined approach to resource management, likely aimed at minimizing feed wastage and controlling the growth rates of the animals.

Regarding the choice of ingredients, a vast majority of the respondents (79%) relied on agro-industrial by-products (AIBPs), such as cassava peels, brewer's spent grains, spent yeast, and corn mill sweepings (CMS). The adoption of non-conventional feed resources (NCFR), specifically agro-industrial by-products (AIBP), represents a strategic response to the excessive costs of conventional feedstuffs. In contrast, only 5.7% of farmers utilized commercial preparations, citing the high cost of balanced concentrates as the primary barrier to their use. The preference for AIBPs is supported by Amoah *et al*. (2013) and Darkwa *et al.* (2013), who identified AIBPs as under-exploited resource pool that is significantly more economical than conventional grains. This data indicates a high level of "nutritional survivalism," where pig farmers in

the study area have successfully decoupled their production costs from volatile global grain markets by localizing their feed sources. The integration of these by-products into pig diets provides both environmental and economic advantages. From an ecological perspective, Erukainure *et al. (*2010*)* noted that AIBPs often become environmental pollutants if not channeled into productive uses such as animal feed. Economically, the use of AIBPs has been shown to reduce overall feed costs by 10% to 15% without compromising the growth performance of pigs (Llop*,* 2016). Furthermore, utilizing these resources alleviates competition between humans and livestock for land and cereal crops (Georganas *et al.,* 2023).

Table 5: Systems of feeding pigs

Item	Frequency (n*=19)	Percentages
System of feeding		
Restricted feeding	19	100
Ad-lib feeding	0	0
Type of ingredients used		
Commercial preparations	2	5.7
Kitchen waste	5	15.3
AIBP	12	79

**Number of respondents*

Utilization Patterns and Economic Drivers of Corn Mill Sweepings

As illustrated in Figure 4, a significant majority of the interviewed farmers (94.7%) utilize CMS in their swine diets, while a small minority (5.3%) refrain from its use. This high level of integration confirms that CMS has transitioned from a mere by-product to a primary constituent of pig nutrition in the region. The adoption rate of corn mill sweepings (CMS) within the Ejisu-Juaben Municipality accentuates its importance as a staple non-conventional feed resource. The widespread preference is fundamentally driven by cost-efficiency as the pig farmers noted that CMS is substantially cheaper than maize, making it an economically viable alternative for reducing overall production costs. This trend aligns with the findings of Boateng *et al.* (2014; 2015), who identified CMS as an essential ingredient in swine feeding across both the Afigya -Kwabre and Ejisu-Juaben Districts, primarily due to its competitive pricing relative to conventional grains. However, this heavy reliance on CMS necessitates a rigorous cautionary approach. While CMS serves as a vital cost-saving tool, the inherent nutritional variability of such by-products poses a significant challenge to precise formulation (Llop*,* 2016). To ensure that the dietary requirements of pigs, specifically energy and protein densities, are consistently met, periodic evaluation of CMS quality is mandatory. This is particularly critical in light of the 1.34% mean contaminant load identified in the physical examination phase of this study. Such contamination levels can dilute the ingredient's nutritional value and undermine the efficacy of the restricted feeding systems (100% adoption) currently practiced by the farmers.

Interestingly, the small fraction of farmers (5.3%) who opted out of using CMS cited health -related concerns as their primary deterrent. This highlights a divergence in risk perception among stakeholders; while most prioritize economic relief, others view the potential for physical or biological contamination as a risk to herd health that outweighs the financial benefits. Consequently, improving the sanitary quality of CMS at the point of collection could potentially bridge this gap, encouraging universal adoption while safeguarding animal welfare.

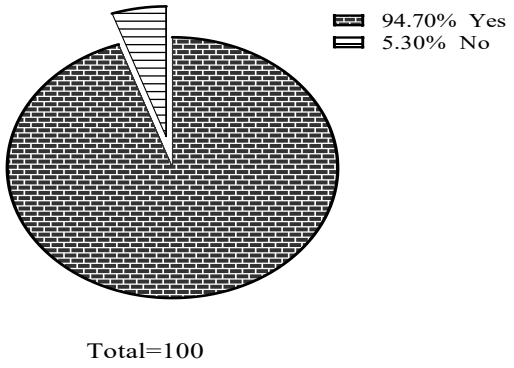


Figure 4: Percent utilization of CMS by pig farmers in the Ejisu-Juaben Municipality

Acquisition Dynamics, Physical Forms, and Pricing of CMS

The procurement patterns of corn mill sweepings (CMS) reveal a highly localized market driven by proximity and logistical convenience. The majority of respondents (74%) sourced CMS from milling centers within the Ejisu-Juaben Municipality, while 26% utilized dual sourcing from both internal and external municipal boundaries (Table 6). This reliance on local supply chains mirrors findings from Phase 1, which established that the spatial proximity of milling centers to livestock hubs is a primary determinant of adoption frequency and procurement volume.

In terms of the physical state of the feed resource, 88.9% of farmers were non-selective, obtaining the product in either wet or dry forms based on immediate availability. However, specific preferences highlight the trade-off between labour and cost. Dehydrated CMS (5.6%) was preferred by some for its reduced susceptibility to spoilage and the elimination of on-farm drying requirements. This preference is consistent with the findings of El-Shafey et al. (2004) and Amoah et al. (2013), which demonstrate that thermal stabilization of agro-industrial by-products (AIBPs), particularly brewer's spent grain, extends shelf life by reducing moisture-related deterioration and enhances microbiological safety. Conversely, high-moisture CMS (5.6%) was preferred by farmers seeking lower entry prices, as mill operators often apply a price premium to dried CMS to recoup the energy and labour costs associated with manual dehydration.

The commercialization of CMS is absolute, as evidenced by the 0% frequency of free acquisition. Market prices for a 50 kg unit ranged from GH₵11.00 to GH₵25.00, with a significant majority (73%) paying the upper-tier price of GH₵21.00–GH₵25.00. These findings validate the price-distance correlations observed in Phase 1, where CMS was valued at approximately GH₵4.00–GH₵6.00 per 20 kg. The data suggests that the "proximity-price paradox" is active in the study area, where closer proximity to mills increases demand, subsequently driving up the unit price. This competitive pricing structure likely compels the 26% of farmers who source externally to bypass local high-demand zones in favour of more cost-effective suppliers outside the municipality. Consequently, while CMS remains an economically strategic alternative to conventional maize, its cost-benefit ratio is heavily moderated by geographic location and the physical state of the product at the point of sale.

Table 6: Procurement sources, physical states, and market prices of CMS

ITEM	Frequency	Percentages
Sources of acquisition of CMS (n*=19)		
Within the Municipality	14	75.0
Both within and outside the Municipality	5	26.0
Forms in which CMS is obtained (n=18)		
Dry	1	5.6
Wet	1	5.6
Both	16	88.9
Price of CMS (₵)/50kg obtained by farmers (n=19)		
Free	0	0.0
< 5	0	0.0
6 - 10	0	0.0
11 - 15	2	11.0
16 -20	3	16.0
21 - 25	12	73.0

**Number of respondents*

Transportation Logistics and Intersectoral Mobility of CMS

The logistical framework for transporting corn mill sweepings (CMS) from processing centers to swine production units is characterized by a decentralized, small-scale operational model and a predominant reliance on intermediate transport vehicles (ITVs). Empirical data (Figure 5) indicate that 61% of producers utilize motorized tricycles, locally termed "Aboboyaa", reflecting their critical role in the Ghanaian peri-urban agricultural economy as a maneuverable, cost-effective solution for short-to-medium distance bulk conveyance. This modal dominance aligns with findings by Kokov *et al*. (2022), who observed that 94% of stakeholders reported significant overhead reductions following ITV adoption, effectively mitigating "last-mile" delivery costs which can constitute up to 33% of

total agricultural logistics expenditures (Wajszczuk, 2005; Dramaretska, 2023).

However, the remaining modal distribution, comprising tractor-trailers (11%), wheelbarrows (11%), manual portage (11%), and light pickups (6%), highlights a fragmented landscape that contrasts sharply with other agro-industrial by-products. For instance, while the procurement of brewers' spent grains is often managed through centralized, association-led logistics in the study area (Boateng *et al*., 2015), CMS procurement remains an isolated, individual-level activity. This lack of institutionalized coordination likely exacerbates supply volatility and prevents smallholders from achieving the economies of scale necessary for consistent feed security. Furthermore, the continued reliance on manual labour and primitive transport reflects systemic infrastructural deficits; poorly maintained networks artificially inflate trade costs and intensify the "price-distance paradox," where increasing transit labour eventually eclipses the nutritional value of the biomass (Mercer, 2013; Gebresenbet and Oodally, 2006). Consequently, despite the potential for digital or policy-driven optimization, the modernization of the CMS value chain remains hindered by significant infrastructure and policy gaps (Martens *et al*., 2012).

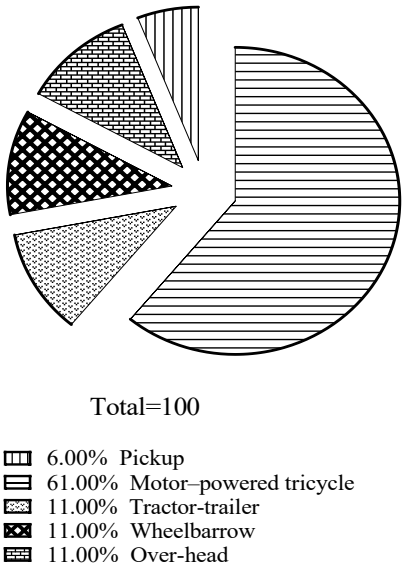


Figure 5: Distribution of transportation modalities utilized by pig farmers for CMS procurement

On-farm Post-acquisition Handling and Utilization of CMS

The post-acquisition management of Corn Mill Sweepings (CMS) is characterized by a high degree of rudimentary on-farm processing, with approximately 95% of surveyed producers engaging in manual refinement techniques (Table 7). Storage protocols predominantly involve the use of synthetic sacks (60%) or shaded ambient storage (35%); notably, the anaerobic pit storage and open-air exposure typical of high-moisture by-products like brewers' spent grain (Boateng *et al*., 2015) are entirely absent, likely due to the lower moisture content and susceptibility of CMS to rapid fungal degradation. Regarding nutritional application, 94% of farmers incorporate CMS into daily rations, though only 67% utilize it as part of a multi-ingredient mixture. While 33% of respondents utilize CMS as a sole dietary source due to acute feed scarcity, they acknowledged this as a sub-optimal strategy. This is consistent with swine nutrition principles, as individual agro-Industrial by-products (AIBPs) are generally insufficient to serve as a

Table 7: Post-acquisition processing, storage, and feeding strategies for CMS

Item	Frequency	Percentages
On-farm Processing of CMS (n*=18)		
Yes	18	94.7
No	1	5.3
Storage of CMS (n*=19)		
In sack	12	60.0
Under shade	7	35.0
In pits	0	0.0
In the open	0	0.0
Feeding of CMS (n*=18)		
As a mixture with different AIBP's	12	66.7
Only CMS	6	33.3
Frequency of Feeding (n*=19)		
Daily basis	18	94.0
Once a week	1	6.0

**Number of respondents*

basal diet. Although AIBPs can be formulated to meet specific caloric and protein requirements, a singular source typically lacks the essential amino acid profile and micronutrient density required for optimal physiological development (Zimmerman, 2000). Furthermore, the inherent fibrous fractions of many AIBPs can limit digestibility in non-ruminants, leading to diminished average daily gain (ADG) and gain-to-feed ratios when not balanced with complementary protein sources or enzymatic supplements (Parrini *et al*., 2023; Richli *et al*., 2023). Thus, while CMS is a critical cost-saving constituent, its role in a nutritionally precise regimen is as a component of a diversified ration rather than a standalone feedstuff.

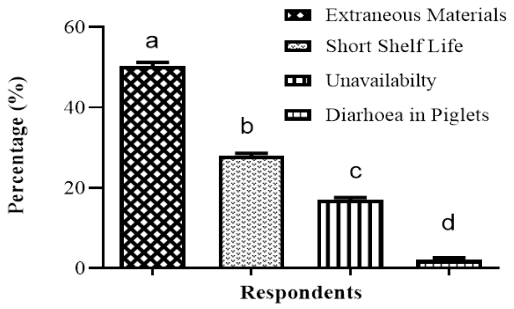


Figure 6: Categorical distribution of quality and logistical challenges associated with CMS utilization in smallholder swine production.

Logistical and Supply-Chain Constraints in CMS Utilization

The integration of corn mill sweepings (CMS) into swine nutritional regimens is impeded by a multifaceted matrix of logistical and qualitative constraints, with 100% of surveyed producers identifying systemic obstacles to efficient utilization. A systematic analysis of these impediments reveals a hierarchy of challenges ranging from supply-chain volatility to acute safety concerns. A critical threshold in CMS procurement is defined by biomass scarcity and intra-sectoral competition (Figure 6). While acute unavailability was cited by 17% of respondents, the underlying driver is a supply-demand disequilibrium exacerbated by the concentration of pig farms around a finite number of milling hubs. This scarcity is fundamentally temporal; CMS availability exhibits marked seasonality, peaking during periods of high grain processing, such as Muslim festive occasions (Boateng *et al*., 2015). Such seasonality creates significant supply gaps, undermining the consistency of nutritional regimens. These findings align with the framework proposed by MoFA (2013), which identifies high bulk density and geographical fragmentation as inherent barriers for agro-industrial by-products (AIBPs). The low value-to-volume ratio of CMS necessitates a localized utilization strategy, as the marginal cost of transport rapidly exceeds the feed's economic utility beyond immediate municipal boundaries, a phenomenon known as the "economic distance" threshold.

Qualitative challenges represent the most pervasive barrier, affecting 72% of the surveyed population. Among these, the presence of extraneous physical contaminants was identified as the primary concern by 52% of respondents. The influx of wooden debris, plastics, lithic fragments, and metallic shards, confirmed via physical examination in the first phase of this study, necessitates intensive manual sorting. This creates a significant labour constraint; indeed, some producers reported bypassing the sorting process due to high labour opportunity costs, despite the inherent risks to animal health. Such contamination is often an artifact of inefficient milling processes and the use of locally manufactured milling plates, which have been documented to introduce elemental iron and other pollutants into the biomass (Bahnasawy *et al*., 2015).

Rapid biological deterioration was identified as a major challenge by 29% of respondents, primarily attributed to the short shelf-life of CMS in its raw state. This observation is consistent with trends in other high-moisture AIBPs; for instance, Boateng *et al.* (2015) reported that 65% of pig farmers in the Afigya-Kwabre District faced similar spoilage issues with brewers' spent grains. In the current study, CMS deterioration is likely accelerated by high intrinsic moisture and suboptimal storage in synthetic sacks, which facilitates heat retention and microbial proliferation. Furthermore, 2% of farmers reported clinical diarrhea in piglets following CMS ingestion. This pathogenic response may be linked to mould infestation and potential aflatoxin contamination, which are prevalent in corn

-based by-products handled under inadequate drying and storage conditions (Hurburgh and Elmore, 2009; Dabbour *et al*., 2015).The systemic nature of these challenges suggests that the current CMS value chain lacks the technical interventions necessary for stabilization. Optimizing grinding parameters, such as grain moisture and sieve hole diameters, could enhance the initial quality of the product (Kwofie *et al*., 2011). Moreover, the adoption of stabilization techniques, such as solar drying or microbial fermentation, could extend the shelf-life and enhance the nutritional profile of CMS, transforming it from an erratic, low-quality waste stream into a standardized feed ingredient (Vukmirović *et al*., 2015; Rodrigues *et al*., 2014). Without such interventions, the "price-distance paradox" and qualitative risks will continue to limit the scalability of CMS in the smallholder sector.

Mitigation Strategies and Technical Interventions for CMS Valorization

The inherent limitations of corn mill sweepings (CMS) identified in this study, ranging from physical contamination and rapid oxidative rancidity to seasonal availability, require a systematic approach to quality assurance. To transition from the current "nutritional survivalism" toward a stabilized feed resource, several scientific and logistical remedies are proposed.

Firstly, a fundamental approach to overcoming the logistical bottlenecks of CMS is the establishment of centralized processing hubs. As suggested by Birhan (2014), localized processing plants can effectively manage ingredients that are traditionally challenging for individual smallholders to handle. For the pig farmers in Ejisu-Juaben, the formation of a specialized unit within their association could streamline the collection, dehydration, and distribution of CMS. This collective model would not only stabilize the supply but also ensure standardized quality control, potentially transforming a raw mill by-product into a reliable commercial feed ingredient.

Secondly, the substantial proportion of farmers surveyed (52.6%) reporting the presence of extraneous materials in CMS highlights the need for improved pre-collection handling and strengthened on-farm quality control measures. The removal of hazardous debris can be effectively achieved through a multi-stage physical separation process, involving manual sorting (hand-picking) to eliminate coarse contaminants, followed by sieving to remove finer particulate matter, and magnetic separation to extract ferrous metallic fragments. These procedures, as applied during the physical inspection phase of this study, are critical for minimizing the risk of internal injury and hardware-related disorders in swine. In addition, promoting the adoption of improved sweeping and handling practices among mill operators can reduce contamination at the source.

Thirdly, the high moisture content and rapid deterioration of CMS, reported by 31.6% of farmers, highlight a key concern for its long-term storage stability. Although Amoah *et al*. (2013) and El-Shafey *et al*. (2004) discussed preservation techniques in the context of brewers' spent grain (BSG), the underlying principles remain applicable to CMS. These include moisture reduction and anaerobic preservation through ensilage in high-density polyethylene (HDPE) sheets, which creates an oxygen-limited environment that suppresses aerobic spoilage organisms, as well as solar or mechanical drying, which reduces water activity to levels that inhibit microbial growth. In addition, blending wet CMS with dry fibrous carriers such as rice bran or wheat bran can facilitate drying by increasing surface area exposure and reducing overall moisture content, thereby improving shelf-life stability.

Lastly, to address health risks such as piglet diarrhea, CMS feeding protocols must be age-specific. Highly perishable or variable ingredients like CMS should be restricted to older, more robust animals with developed gastrointestinal tracts, as neonatal pigs are highly susceptible to the pathogenic loads often found in improperly stored by-products (Wyss, 1997). Furthermore, the inclusion of dietary additives, specifically mycotoxin binders and organic acids in CMS-based diets, could serve as an important risk mitigation strategy. These additives neutralize fungal toxins and lower the pH of the feed, reducing the incidence of enteric diseases and mitigating the biological effects of spoilage

(Crawshaw, 2003). Given that CMS availability is seasonal, farmers are encouraged to diversify their agro-industrial by-product (AIBP) portfolio to ensure nutritional continuity throughout the year**.**

CONCLUSION

This study demonstrates that corn mill sweepings (CMS) constitute a widely utilized agro-industrial by-product in pig feeding systems within the Ejisu-Juaben Municipality, reflecting its economic importance as a low-cost alternative feed resource. However, its utilization is constrained by notable quality challenges, including the presence of extraneous materials, high moisture content, and rapid deterioration, which collectively compromise storage stability, handling efficiency, and potential animal health outcomes. Despite these limitations, CMS remains a key component of pig diets, with most farmers incorporating it in combination with other agro-industrial by-products, although a minority rely on it exclusively due to feed scarcity and cost considerations. The findings further highlight that while CMS offers clear economic advantages, its inconsistent quality introduces hidden costs related to labour-intensive sorting and potential health risks to livestock. Improving the safety and nutritional reliability of CMS therefore requires targeted interventions along the value chain, particularly at the milling and handling stages. Strengthening hygiene practices, reducing contamination, and adopting simple preservation techniques could significantly enhance its feed value and safety. Overall, CMS holds strong potential as a sustainable feed ingredient, but its full benefits can only be realized through improved quality control and appropriate processing strategies.

REFERENCES

Aboh, A., Zoffoun, G., Djenontin, A., Babatoundé, S. and Mensah, G. (2013). Effect of graded levels of dry pineapple peel on digestibility and growth performance of rabbit. *Journal of Applied Biosciences* 67, 5271-5276.

Afari, A. D. (2012). The performance of University for Development Studies Meats Limited (UDSML) in relation to the pork value chain in Tamale Metropolitan area., 30pp. Available at: www.edepot.wur.nl/ 298084. Retrived on: 20/08/2025.

Alrahman, S. S. M. A. (2019). Animal welfare: Wrong approaches and mistreatment of some affected and diseased animals: *case reports*. Available at: https://www.semantic-scholar.org/paper/Animal-Welfare%3A-Wrong-Approaches-and-Mistreatment-Alrahman. Retrieved on 20/06/2025.

Amoah, K. O., Asiedu, P., Rhule, S. W. A., Wallace, P. and Bumbie, G. Z. (2013). Influence of preservation methods of brewers' spent grains on the growth and carcass characteristics of grower-finisher pigs. *Ghanaian Journal of Animal Science* 7 (2), 20-25.

Awunyo-Vitor, D. Bakang, J. and Cofie, S. (2013). Estimation of farm-level technical efficiency of small-scale cowpea production in Ghana. American-Eurasian Journal of Agriculture and Environmental Science, 13 (8): 1080-1087.

Balogu, T. V., Ibrahim, H. and Balogu, D. O. (2017). Nutritionally improved corn mill Waste (chaff) with microbial protein: an economic alternative for poultry feed. Advances in Applied Sciences, 2(2): 18-22. doi:10.11648/j.aas.20170202.11.

Biagi, G., Vecchiato, C. G. and Pinna, C. (2017). The utilization of prebiotics, probiotics, organic acids and antibiotics in monogastric animals. Kne Life Sciences, 2(6), 55. https://doi.org/10.18502/kls.v2i6.1019.

Bijay, P. and Singh, A. (2013). Viability of Using Cassava as Feedstock for Bioethanol Production in Fiji. In Climate-Smart Technologies, Springer Berlin Heidelberg, 459-472

Birhan, M. (2014). Assessment of Agro-Industrial by-Products for Animal Feed Supply in North Gondar Zone, Ethiopia. *Journal of Animal Production Advances* 1 (4), 342-347.

Boateng, M. Atuahene, P.Y. Amoah, K.O. Frimpong, Y.O. Okai, D.B. (2020). Assessment of the production, nutrient composition, and some mineral elements levels in

corn-mill sweepings (cms) from various sources in the Kumasi metropolis. *Ghanaian Journal of Animal Science*, Vol. 11 No.1, 2020. pp 27 – 37.

Boateng, M., Okai, D. B., Frimpong, Y. O. and Asumang-Owusu, A. (2014). Problems associated with the use of wet brewers‟ spent grains (WBSG) and brewers‟ spent yeast (WBSY), and possible solutions: A case study of some Afigya-Kwabre pig farmers, Ashanti Region, *Ghanaian of Journal Animal Science*, 8 (1): 45-51.

Boateng, M., Okai, D. B., Frimpong, Y. O. and Zeebone, Y. Y. (2015). Wet brewers' spent grains and wet brewers' spent yeast: problems associated with their usage and suggested solutions: a case study of the Ejisu-Juaben Municipality of Ghana. *Livestock Research for Rural Development,* 27 (1), Article No. 5. Available at: http://www.lrrd.org/lrrd 27/1/boat27005.htm. Retrived on: 20/08/2025.

Boateng, M., Okai, D., Baah, J. and Donkoh, A. (2008). Palm kernel cake extraction and utilisation in pig and poultry diets in Ghana. *Livestock research for rural development* 20 (7), 2008.

Bregendahl, K., and Zimmerman, D. R. (2001). Comparison of hydrolyzed intestinal by-products. *Iowa State University Animal Industry Report*, 1(1). Avaialble at: https://www.iastatedigitalpress.com/air/article/id/7758/. Retrieved on: 20/08/2025.

Crawshaw, R. (2003). Co-product feeds: animal feeds from the food and drinks industries, Nottingham University Press, Nottingham. *Journal of the Science of Food and Agriculture* 83 (4), 362-362.

Dabbour, M., Bahnasawy, A. H., Ali, S. A. and El-Haddad, Z. (2015). Grinding parameters and their effects on the quality of corn for feed processing. *Journal of Food Processing and Technology*, 6(9), 1–7. https://doi.org/10.4172/2157-7110.1000482.

Darkwa, S., Okai, D. B., Boateng, M. and Amoah, K. O. (2013). Responses of growing rats and pigs to diets containing varying levels of dried brewers' spent grains supplemented with Bergazym—an exogenous enzyme complex. *Journal of Animal Science Advances*, 3(6), 286–290.

Davies, P. (2013). Pigs and MRSA: What are the human health risks and to whom, The Food Policy Center, University of Minnesota, 3pp

Devendra, C. and Leng, R. (2011). Feed resources for animals in Asia: Issues, strategies for use, intensification, and integration for increased productivity. *Asian-Australasian Journal of Animal Sciences* 24 (3), 303-321.

Dramaretska, K. and Zorhach, A. (2023). Logistics management of agricultural enterprises. *Ukrainian Journal of Applied Economics and Technology*, 8(1), 248–253. https://doi.org/10.36887/2415-8453-2023-1-36.

El-Shafey, E. I., Gameiro, M. L. F., Correia, P. F. M., and de Carvalho, J. M. R. (2004). Dewatering of brewer's spent grain using a membrane filter press: A pilot plant study. *Separation Science and Technology*, 39, 3237–3261. https://doi.org/10.1081/SS-200028775.

Erukainure, O. L., Oke, O. V., Daramola, A. O., Adenekan, S. O. and Umanhonlen, E. E. (2010). Improvement of the biochemical properties of watermelon rinds subjected to Saccharomyces cerevisiae solid media fermentation. P*akistan Journal of Nutrition*, 9 (8), 806–809.

Frimpong, Y. O. (2010). Feed ingredients and their usage in the Ashanti Region of Ghana: A case study in the Ejisu-Juaben District. B.Sc. Thesis, Department of Animal Science, KNUST, Kumasi, 50pp.

Gebresenbet, G., and Oodally, G. (2006). Review and analysis of rural agricultural transport and logistics in developing countries: *Technical Guidelines Report. Switzerland: University of Agricultural Sciences.*

Georganas, A., Giamouri, E., Pappas, A. C., Zoidis, E., Goliomytis, M. and Simitzis, P. (2023). Utilization of agro-industrial by-products for sustainable poultry production.

Sustainability, 15(4), 3679. https://doi.org/10.3390/su15043679.

Herawati, M. M., Rastosari, A. and Wati, N. E. (2019). The productivity of pigs at PT. Adhi Farm, Solo. Journal of Physics Conference Series, 1155, 012082. https://doi.org/10.1088/1742-6596/1155/1/012082.

Hurburgh, C. R., & Elmore, R. W. (2009). 2009 Corn Quality Issues. Available at: https://lib.dr.iastate.edu/cropnews/528/. Retrieved on: 23/08/2025.

Hutjens, M. F. (2007). Facing the diminishing corn supply: dairy alternatives. Available at: https://www.txanc.org/Proceedings/2007/Hutjens-manuscript-final-2007.pdf. Retrived on: 23.08/2025.

Idowu, A.O. Ambali, O. I. and Otunaiya, A. O. (2012). Microfinance and small-scale pig business in Osun State, Nigeria. Available at: https://www.cabidigitallibrary.org/doi/full/10.5555/20123376437. Retrived on: 16/08/2025.

Ifende, V. I., Weka, R., Muwanika, V. B., Gukut, M. Y., Luka, P. D., Masembe, C. and Chenais, E. (2025). Knowledge, perception, and practices concerning African swine fever in smallholder pig value chain in North Central Nigeria. Transboundary and Emerging Diseases. Available at: https://doi.org/10.1155/tbed/5582374. Retrieved 21/08/2025.

Kokov, A. C., Grigoryan, A. N. and Bikmetov, R. R. (2022). Development of transport and logistics infrastructure in agrarian business. *The European Proceedings of Social and Behavioural Sciences*, 128, 364–370. https://doi.org/10.15405/epsbs.2022.11.51

Kwofie, S., Andrews, A. and Mensah, E. (2011). The quality of locally-manufactured corn-mill grinding plates. Journal of Science and Technology (Ghana), 31(1). https://doi.org/10.4314/just.v31i1.64903.

Llop, C. S. (2016). Utilization of agro-industrial by-products in liquid feeding for fattening pigs (Doctoral dissertation). *Universitat Autònoma de Barcelona*. Avaulable at: https://www.ciap.org.ar/Sitio/Archivos/UAB.pdf. Retrieved on: 21/08/2025.

Martens, B. J., Scheibe, K. P. and Bergey, P. (2012). Supply chains in Sub-Saharan Africa: A decision support system for small-scale seed entrepreneurs. *Decision Sciences*, 43(5), 737–759. https://doi.org/10.1111/j.1540-5915.2012.00370.x

Mercer, D. G. (2013). Limited financial resources and poor infrastructure among barriers to development of African agri-food industries. Avaialble at: https://atrium.lib.uoguelph.ca/server/api/core/bitstreams. Retrived on: 24/08/2025.

Ministry of Food and Agriculture (MoFA) (2013). Ejisu-Juaben. Available at: http://mofa. gov.gh/site/?page_id=6032. Retrieved on: 21/08/2025.

Mohammed T (2010). Waste management practices adopted by swine producers in the Ashanti Region of Ghana: A case study of the Ejisu-Juaben Municipality. B.*Sc. Thesis, Department of Animal Science*, 66pp.

Okai, D. and Boateng, M. (2007). Pig nutrition research in Ghana, some achievements, prospects and challenges. *Ghanaian Journal of Animal Science* 23 (1), 19-25.

Parrini, S., Aquilani, C., Pugliese, C., Bozzi, R. and Sirtori, F. (2023). Soybean replacement by alternative protein sources in pig nutrition and its effect on meat quality. *Animals*, 13(3), 494. https://doi.org/10.3390/ani13030494.

Pierer, M., Amon, B. and Winiwarter, W. (2016). Adapting feeding methods for less nitrogen pollution from pig and dairy cattle farming. Nutrient Cycling in Agroecosystems, 104(2), 201–220. Avaialble at: https://doi.org/10.1007/s10705-016-9767-0. Retrie-ved on: 23/08/2025.

Rekwot, P., Abubakar, Y. and Jegede, J. O. (2005). Swine production characteristics and management systems of smallholder piggeries in Kaduna and Benue States. *Nigerian Veterinary Journal*, 24(2). https://doi.org/10.4314/nvj.v24i2.3452.

Richli, M. M., Weinlaender, F., Wallner, M., Pöllinger-Zierler, B., Kern, J. and Scheeder, M. R. L. (2023). Effect of feeding Alphitobius diaperinus meal on fattening

performance and meat quality of pigs. *Journal of Applied Animal Research*, 51(1), 204–211. https://doi.org/10.1080/09712119.2023.2176311.

Rodrigues, S., Stringhini, J. H., Ribeiro, A., Pontalti, G., McManus, C. and McManus, C. (2014). Quality assessment of corn batches received at a feed mill in the Brazilian Cerrado. *Brazilian Journal of Poultry Science*, 16(3), 233–240. https://doi.org/10.1590/1516-635X1603233-240.

Statistical Package for Social Sciences (2007). Statistical Package for Social Sciences SPSS, Version 16.0.0. Polar Engineering and Consulting. Available at:www. winwrap.com. Retrieved on: 20/06/2025.

Trostle, R. (2008). Global agricultural supply and demand: factors contributing to the recent increase in food commodity prices (No. WRS--0801). US Department of Energy (USDOE), Washington, DC (United States). Office of Energy Efficiency and Renewable Energy (EERE), *Bioenergy Technologies Office*. Avaible at: https://www.osti.gov/servlets/purl/1218372. Retrieved on: 24/08/2025.

Vukmirović, Đ., Lević, J., Fišteš, A., Čolović, R., Brlek, T., Čolović, D. and Đuragić, O. (2015). Influence of grinding method and intensity of corn on pellet quality. *Hemijska Industrija*, 70(1), 67–72. https://doi. org/10.2298/HEMIND141114012V

Wajszczuk, K. (2005). Logistics costs analysis as an assisting tool to achieve competitive advantage for agricultural enterprises. Available at: https://doi.org/10.22004/ag.econ.24562. Retrieved on: 28/08/2025.

Wyss, U. (1997). Ensiling of brewers' grains: high effluent production and good fermentation quality. *Agrarforschung*, 4(3): 105-108.

Zimmerman, D. R. (2000). Effect of inedible egg product on growth performance of weanling pigs. *Iowa State University Animal Industry Report*, 1(1). Available at: https://www.iastatedigitalpress.com/air/article/id/7671/. Retrieved 23/08/2025.