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Diversifying Energy and Protein Sources for Poultry Feeds in Kenya

Ann Wachira[1], Michael Mwangi[1], Damaris Nyingi[2], Eunice Minyattah[1], Waiguru Muriuki[3, *]

[1]Kenya Agricultural and Livestock Research Organization (KALRO) Non Ruminant Research Institute, Kakamega, Kenya
[2]Veterinary and Animal Production Solutions, (VETANP), Nairobi, Kenya
[3]Centers for Research and Data Technologies (CRDT), Nairobi, Kenya

Email address:
annmumbi@gmail.com (Ann Wachira), mwangimichael04@gmail.com (Michael Mwangi), nyingidamaris@gmail.com (Damaris Nyingi), minyattah@gmail.com (Eunice Minyattah), waigurusamuel@gmail.com (Waiguru Muriuki)
[*]Corresponding author

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Abstract: This study explores the utilization of alternative and locally available energy and protein sources in laying chicken feed formulations, aiming to reduce costs, enhance availability, and promote climate-smart approaches. The experiment included five dietary groups, each with specific energy and protein sources. Significant results emerged: average live weights displayed statistical significance ($p < 0.0001$), with hens on diet A3 containing fish meal (omena) exhibiting a moderate weight increase. Weekly egg collection demonstrated significance ($p < 0.0002$), with diet A3 yielding the highest collection, while A5 (positive control) produced the lowest. These trends mirrored the percentage lay, emphasizing diet's role in egg production. The incorporation of fish meal in diet A3 stood out, influencing growth rates and egg production due to its nutrient density and balanced amino acids. The impact of diets on egg weights was significant ($p<0.0001$), and feed consumption varied ($p<0.0001$), influenced by factors such as palatability and nutritional balance. The Feed Conversion Ratio (FCR) analysis highlighted diet differences in feed efficiency. Overall, the study highlights the intricate interplay between dietary compositions, poultry performance, and production metrics, emphasizing the importance of well-balanced, diverse, and climate-smart feed formulations in achieving sustainable and efficient chicken production.

Keywords: Alternative Feed Sources, Local Energy and Protein Sources, Climate-Smart Feed Formulations, FEED Efficiency, Egg Production

1. Introduction

Fishmeal and maize are conventional feed ingredients utilized as the main components in poultry nutrition due to their excellent nutrient profiles. However, these essential feed sources face significant demand from other livestock (fishmeal) and human consumption (maize). Predictions suggest that by the year 2050, the global population could reach 9.1 billion, resulting in an escalated demand for food resources [4, 5]. Developing nations are experiencing a notable surge in the consumption of poultry products such as eggs and meat. This surge necessitates a corresponding increase in the demand for poultry feed. This escalating demand for poultry feed introduces an element of competition in terms of availability. Consequently, the existing balance of feed resources may be disrupted, thereby potentially compromising national food security. Currently, there are concerted efforts to investigate alternative feed options that can effectively replace maize in poultry diets [14]. The push behind this phenomenon arises from the escalated costs associated with conventional raw materials, compelling the search for substitutes aimed at cost reduction. In this framework, cassava and sorghum stand out as prominent contenders among staple crops owing to their significant energy profiles, while the potential for omena substitution with soybeans as a protein source also comes into play.

These non-conventional energy ingredients (cassava and sorghum) show potential to entirely supplement maize as the primary energy source in poultry diets [15]. After maize, wheat, and rice, sorghum stands as the fourth most notable cereal crop in the world [1]. Sorghum farming constitutes a significant agricultural endeavor in Kenya, with cultivation spanning across the western, northern, eastern, and central provinces in an area covering 197,403-ha. The crop's popularity in Kenya's arid areas stems from its impressive drought tolerance. In 2022, the nation had produced 135,000 metric tons of sorghum (Safiorganics Guide: Sorghum Farming Guide, 2023). This is low when compared to other nations' output, such as Nigeria and Ethiopia. Nigeria is Africa's top sorghum producer, with a total output of 6,725,000 metric tons.

Concurrently, cassava *(Manihot esculenta Crantz*) is a drought-tolerant root crop grown in the Western, Coast, and Eastern zones of Kenya. Cassava is grown on approximately 61,201 ha, with a production rate of 11 metric tons per hectar [3, 7]. Cassava root serves as a valuable energy source for chicken; however, it comes with constraints such as inadequate protein and amino acid balance. Despite this, its energy content remains notably high, comparable to conventional sources like maize, with a range of 3000 to 3200 Kcal/kg.

In regard to protein sources, the sun-dried and ground product of the silver cyprinid, known as *omena*, produces fish meal, a highly digestible protein source extensively used in chicken feeds across Kenya [9]. Omena fishmeal contains elevated levels of crude protein, omega-3 fatty acids, calcium, and phosphorus. However, integrating fishmeal into chicken diets poses a challenge due to the conflict between human consumption and animal feed production. Moreover, the relentless exploitation of marine resources leads to a decline in the population of small pelagic forage fish essential for fish meal production. Additional limitations stem from its restricted incorporation, which is capped at a maximum level of 10% in both egg and meat production chicken feeds. Given these complexities, relying solely on fishmeal or omena as the primary protein source in feed production is no longer a sustainable or prudent option.

The possibility of wholly replacing fishmeal with soybeans as a protein source presents an intriguing opportunity in Kenyan poultry nutrition. Soybean meal holds a central role as the primary protein supplement in chicken diets globally, serving as the standard against which alternative protein sources are evaluated. Chicken have the option of being nourished with whole or full-fat soybeans, as well as soybean meal—a by-product of oil extraction [8]. The notable protein content of soybeans compared to other plant-based sources, along with their advantageous amino acid profile, makes soybean meal a preferred choice for balancing dietary amino acid levels with cereal grains and their derivatives in chicken feeds. Although the global availability of suitable land for soybean cultivation is diminishing, soybean cultivation is widely underexploited in Kenya [12].

This scarcity of conventional resources such as maize and fishmeal has driven a significant increase in prices, with these ingredients now constituting 70% of total feed production costs [15]. The main objective of this study was to investigate the utilization of alternative and locally available energy and protein sources while reducing costs, increasing availability, and also promoting climate-smart feed formulations for laying chicken.

2. Materials and Methods

Study Location: The research took place at the Non-Ruminant Research Institute, Kakamega, which is part of the Kenya Agricultural & Livestock Research Organization. This institute is situated in Kakamega County, located in the western region of Kenya, with geographical coordinates of 0.2777 N and 34.76 E. The climate of Kakamega features an annual average rainfall of 1395 mm, and the daily temperature ranges from a minimum of 16°C to a maximum of 28°C during the day. The humidity level remains around 74% throughout the year.

Experimental Birds: The study utilized the KALRO Improved Indigenous Chicken KC1 breed, recognized for its dual-purpose attributes of meat and egg production. This breed is distinguished by its accelerated maturity, quick attainment of market weight, and enhanced egg-laying capacity. A total of one hundred and fifty (150) laying hens, aged 25 weeks, were randomly assigned to five distinct treatment diets: A1, A2, A3, A4, and a positive control diet denoted as A5.

To ensure their optimal performance, the birds were placed in an open house with appropriate lighting, temperature, and ventilation. Throughout the study duration, adherence to standard management protocols was maintained, with unrestricted access to both feed and clean water.

Experimental Setup: The study employed a Completely Randomized Design, wherein each of the five test diets was assigned randomly to three separate pens, for a total of 15 pens, each housing 10 layers. Throughout the 10-week experimental period, data was collected on a weekly basis, covering a variety of parameters such as feed intake, live weight, and egg numbers, all relevant to hen performance and feed conversion ratio.

Experimental Diets: The study used five distinct dietary groups, with each formulation designed to maintain consistent levels of nitrogen and energy. Furthermore, all diets adhered to a minimum energy requirement of 2300 kcal/kg and a crude protein content of 16%, specifically tailored for the KALRO improved indigneous layers. These diets used diverse sources of energy and protein: A1 had cassava as the primary energy source; A2 contained sorghum as the key energy source; A3 had omena as the main protein source up to the maximum inclusion level of 10%; A4 integrated soybean as the principal protein component up to an inclusion level of 12%; and lastly, A5, designed as the positive control, represented the standard commercial layer mash diet against which others were compared as presented in Table 1.

Feed Consumption: The feed consumption of each diet group was carefully measured on a weekly basis using an electronic weighing scale, enabling an analysis of dietary intake patterns. Weekly evaluations involved measuring both the feed provided and the remaining leftovers, which allowed for the calculation of daily feed intake. By subtracting the total allocated feed from the total leftover feed, the exact overall feed consumption for each group was determined. This method ensured a comprehensive grasp of consumption patterns and the efficiency of feed utilization.

Egg Production: Daily egg collection involved placing the eggs on sanitized trays with the pointed ends facing downward. Weekly recordings were conducted to document the egg count for each diet group. This approach allowed for an assessment of how dietary interventions influenced egg production and, subsequently, the laying percentage.

Egg Weight: Weekly measurements were conducted to determine the weight of eggs laid by hens in each dietary treatment group. These measurements offered insights into potential variations in egg weight attributed to the dietary treatments.

Body Weight: Weekly assessments of the hens body weight were conducted in each diet group using an electronic weighing scale. This approach facilitated the tracking of weight changes throughout the study duration.

*Feed Conversion Ratio: T*he feed conversion ratio (FCR) played a pivotal role in evaluating the efficiency of each diet in converting feed into eggs. To calculate the FCR, the total feed consumed was divided by the total number of eggs produced within each diet group. This approach allowed for a precise comparison of feed utilization efficiency.

Statistical analysis:

Data were subjected to statistical analysis using the Statistical Analysis Software (SAS software). A one-way analysis of variance (ANOVA) was employed to assess the significance of differences among the dietary treatment groups on repeated measures through the 10 week trial period. Post hoc tests, including Tukey's least significant difference (LSD) test, were used to identify specific differences between the treatments and the coefficients of their variations.

3. Results

Table 1. *Effects of energy and protein sources on chicken performance.*

Diet	WEIGHT OF BIRD	EGGS COLLECTED	EGG WEIGHT (g)	PERCENT LAY	CONSUMPTION	FCR FEED2EGG
A1 Cassava-1	1874.12 ab	60.095 ab	50.0265 ab	85.850 ab	125.562 b	14.6790 b
A2 Sorghum-2	1850.67 b	58.143 ab	51.1588 a	83.061 ab	126.086 b	15.2810 b
A3 Omena-3	1909.79 a	60.905 a	50.9391 a	87.007 a	126.590 ab	14.6079 b
A4 Soya 4	1875.40 ab	57.190 b	48.5145 b	81.701 bc	124.629 b	15.4299 b
A5 Control	1732.64 c	53.238 c	50.1281 ab	78.216 c	129.446 a	17.2508 a
Pr	<.0001	0.0002	<.0001	0.0030	<.0001	<.0001
Mean	1848.523	57.91429	50.15338	83.16704	126.4626	15.44972
LSD	35.951	3.0934	1.7001	4.2884	2.9855	0.9688
CV%	3.173126	8.714469	5.530706	8.412769	3.851708	10.23102

Note: Means with the same letter in a column are not significantly different at 5% level using Tukey /LSD mean separation test

The average live weights exhibited a high level of statistical significance ($p<0.0001$), supported by a least significant difference (LSD) of 35.951g. Among the diets, hens fed with diet A3 exhibited an average weight of 1909.79g, reflecting a moderate increase from their initial weight of 1790.83g. Conversely, no significant differences in the live weights were observed among birds fed diets A1, A2, and A4. Interestingly, diet A5 led to the smallest weight gain compared to the initial weight over the course of the 10-week period.

The weekly egg collection count demonstrated a significance of $p<0.0002$, wherein hens consuming diets A1, A2, and A3 exhibited no significant differences. Notably, diet A3 yielded a weekly collection of 61 eggs, while A1 and A2 achieved collections of 60 and 58 eggs, respectively. Diet A4 resulted in 57 eggs, differing significantly from A3 but not from A1 and A2. Birds on diet A5, the positive control, produced the lowest egg collection at 53 eggs. These variations in collection were driven by a minimum of 3 eggs. Furthermore, the egg collection data mirrored the percentage lay, with hens on diet A3 displaying the highest collection, thereby reflecting the most significant laying percentage. This trend extended across diets A1, A2, A4, and A5, showcasing a remarkable minimum variance of 4.2884% and underscoring statistical significance with a $p<0.003$.

The A3 diet incorporated fish meal as its primary protein source, differentiating it from the remaining diets. Fish meal is characterized by its rich nutrient density and well-balanced composition of crucial amino acids, some of which might be deficient in alternative protein sources [11]. The availability of these amino acids from fish meal can support optimal growth rates and egg production. Furthermore, fish meal boasts high digestibility, ensuring optimal absorption of its nutrient content within the chicken's digestive system. This attribute results in heightened utilization of protein and other essential nutrients, translating to improved growth, weight gain, and egg production [10].

The impact of the diets on egg weights also displayed a considerable effect, underscored by a high level of significance at 0.0001. Among these diets, A2 exhibited the most substantial weight at 51.1588g, representing a least significant difference of 1.7001g. This weight was statistically insignificant from A1, A3, and A5; however, A4 deviated slightly with a weight of 48.5145g. Notably, the mean egg weight of 50.15338g fell within the established standard range. The weight of eggs is subject to various influences, encompassing genetic factors, environmental conditions, age, management practices, and nutritional factors. Given that the birds shared identical environmental conditions, breed, and age, and that the diets were designed to meet identical minimal compositional standards, the absence of discernible variation in egg weight across the different diets can be attributed to these consistent factors.

Feed consumption within the various diets exhibited a notable significance at 0.0001. Among these diets, A5 emerged with the highest consumption, with each bird ingesting 129.446g per day. Conversely, diets A1, A2, A3, and A4 exhibited no substantial differences in consumption between them, with a least significant difference of 2.9855g. The quantity of feed consumed by birds is influenced by a range of factors, including their physiological requirements, management practices, health status, and environmental conditions. Birds tend to consume more when their nutritional needs are not adequately met. The palatability and nutritional balance of the diet play a vital role in promoting increased consumption. Diets rich in dense energy content might lead to reduced feed intake as birds fulfill their energy requirements with smaller amounts of feed. Notably, ensuring sufficient protein levels is crucial for optimal growth and production. Insufficient protein in diets can lead to heightened feed consumption as birds attempt to compensate for the deficiency [13].

The Feed Conversion Ratio (FCR) was calculated to assess the quantity of feed consumed by a bird to produce a single egg. The feed conversion ratio (FCR) is subject to a range of influences, including genetics, age, health conditions, and nutrition. A lack of proper nutritional balance, which could involve an increase in protein content or energy levels, can profoundly impact efficiency and FCR [2]. Among the diets, A5 displayed the highest FCR value at 17.2508, while A3 showcased the lowest ratio at 14.6079. This conveys that a layer fed with A5 required 17.2508 grams of feed to produce an egg, whereas a layer on A3 needed only 14.6079 grams for the same purpose. With a least significant difference of 0.9688, diets A1, A2, A3, and A4 did not exhibit significant discrepancies in FCR values, whereas A5 stood out distinctly.

The overall mean FCR, calculated at 15.44972 grams, indicated that on average, a layer consumes 15 grams of feed to produce one egg. The A3 diet, containing fish meal, demonstrated lower efficiency in feed conversion, aligning closely with other diets that employed soybean meal as the protein source. The control diet A5 displayed the lowest feed efficiency.

4. Discussions

Table 2. *Diet composition.*

Ingredients	Diet composition (percentage inclusion levels)			
	A1	**A2**	**A3**	**A4**
Maize	-	-	51.00	47.00
Cassava	51.00	-	-	-
Sorghum	-	55.00	-	-
Threonine	2.00	2.00	1.50	3.00
DL Methionine	2.00	2.00	1.50	3.00
Lysine	2.00	2.00	1.50	3.00
Omena/ fishmeal	9.00	5.00	10.00	-
Sunflower SC	7.00	6.00	7.00	9.00
Soya Full fat	11.00	8.00	-	12.00
W. bran	6.00	10.00	16.00	12.00
Lime	7.00	7.00	8.00	8.00
DCP	3.00	2.00	2.00	2.00
Premix	1.00	1.00	1.00	1.00
Salt	0.30	0.30	0.30	0.30
Enzyme	0.03	0.03	0.03	0.03

Table 3. *Diet Nutrient composition.*

	A1	**A2**	**A3**	**A4**
CP (%)	17.4	18.1	16.9	18.4
ME (Kcal)	2604	2719.3	2421.6	2482.4
Crude Fiber (%)	7.5	3.9	3.9	4.8
Crude Fat (%)	4.2	4.8	4.6	5.5
Lysine (%)	2.3	2.2	1.9	2.9
M+C (%)	2.4	2.5	2.1	3.4
Calcium (%)	3.6	3.1	3.7	3.2
Phosphorus (%)	0.5	0.8	1	0.7
Cost/kg (in KES)	105.8	93.4	115.6	121.4
Consumption (grams per day)	125.562	126.086	126.590	124.629
Cost of feed consumed (KES per day)	13.284	11.776	14.633	15.130
Production (%)	85.850	83.061	87.007	81.701

In the context of climate change and the imperative to embrace climate-smart practices, the study's outcomes offer a promising pathway forward. The results strongly suggest that maize can be replaced with climate-smart crops like cassava or sorghum in chicken feed formulations without compromising the feed conversion ratio. This realization is not only a significant stride towards sustainable chicken production but also aligns with the pressing need to adapt to changing agricultural landscapes and address the challenges posed by climate change.

Cassava and sorghum, both considered climate-smart crops, emerge as compelling alternatives to maize due to their adaptability to various regional contexts. These crops, prominently available in western Kenya and arid regions such as lower Eastern and the Coast, present an opportunity to diversify feed ingredient sources and reduce the ecological footprint of feed production. By incorporating these locally available crops, the poultry industry can actively contribute to climate resilience and sustainable resource utilization, thereby aligning with broader environmental goals.

However, in the face of increasing population growth, the competition for essential resources, notably maize and omena, has intensified. Maize's status as a staple crop renders it an essential dietary component for millions, amplifying demand as the locall population surges. This dual demand for maize, both for human consumption and animal feed, creates a complex web of challenges surrounding availability, affordability, and sustainability. Similarly, omena, a crucial protein source, is caught in the midst of this competition. Widely consumed by humans, particularly in regions with limited alternatives, omena faces increased demand for both human consumption and as a critical animal feed ingredient.

Amidst this intricate landscape, the study's innovative approach offers a potential resolution. By validating the efficacy of cassava and sorghum in poultry feed, the study addresses the resource competition conundrum. These alternative ingredients not only offer feed efficiency but also contribute to reducing the demand on maize and omena. This finding aligns with the need for holistic and sustainable solutions in the face of population growth, competition for resources, and climate challenges.

In conclusion, the study's multifaceted implications span the economic, environmental, and nutritional realms. It underscores the feasibility of transitioning towards climate-smart crops in poultry feed while acknowledging the competition between human and animal feed for key ingredients. By embracing alternative feed sources, the poultry industry can contribute to sustainable food systems, mitigate climate impacts, and alleviate resource pressures, all of which are crucial in navigating the complexities of a changing world.

The disparities in daily feed consumption costs present notable fluctuations, warranting an evaluation encompassing both production expenditures and incurred costs. Against the backdrop of the prevailing egg market prices standing at KES 15, diet A2 distinctly emerges as a remarkably lucrative alternative, prominently showcasing an exceptional laying rate of 83%. This translates to a substantial profit margin of KES 4.00 per each egg sold. As a result, a standard tray of 30 eggs demonstrates the potential to yield a profit of KES 120.00, subsequent to accounting for the associated production outlays.

Drawing upon the latest Census 2019 statistics by the Kenya National Bureau of Statistics (KNBS), it's evident that the mean Kenyan household consists of four individuals, sustaining an average monthly income of KES 20,123.00. This translates to an approximate daily budget of KES 670.77. To achieve the dual objectives of ensuring food security through chicken production and surpassing the poverty threshold, a household would necessitate a per-tray egg profit of KES 120.00, a feat attainable through the implementation of diet A2. Consequently, to attain this financial target, a household must generate a daily output of 6 egg trays, culminating in a profit of KES 720.00. This calculation underscores that the typical household would need to manage a poultry enterprise encompassing 200–250 birds, achieving an egg production rate mirroring the observed 83% in this study, or alternatively maintaining an average rate of 75% to achieve a break-even point.

5. Conclusion

In conclusion, this comprehensive study offers a multifaceted insight into the dynamic landscape of poultry nutrition, profitability, and sustainability within the context of climate change and evolving market conditions. The findings underscore the potential for substituting conventional feed ingredients with locally available and climate-smart alternatives, notably cassava and sorghum, without compromising critical performance metrics such as feed conversion ratio and egg production. This paradigm shift in feed formulation not only addresses the economic challenges posed by volatile feed ingredient markets but also aligns with the imperative of adapting agriculture to changing environmental conditions.

The research serves as a clarion call for the poultry industry to adopt innovative strategies that not only enhance economic viability but also contribute to resilience in the face of climate-induced uncertainties. The confirmation of cassava and sorghum as effective feed ingredients not only augments resource efficiency but also positions poultry production as a driver of sustainable agricultural practices. Furthermore, the study's insights on feed efficiency, egg production, and weight gain provide a robust foundation for evidence-based decision-making in feed formulation, thereby contributing to improved poultry management practices.

In the backdrop of mounting challenges due to population growth and resource competition, the study's implications extend beyond the realm of poultry production. By promoting alternatives to maize and omena, which face dual demands for human and animal consumption, the research embodies a crucial step towards reconciling the needs of both sectors. This is particularly pertinent as the global population continues to expand, intensifying the competition for essential resources. The study's findings, rooted in economic, environmental, and nutritional considerations, spotlight a pathway that promises a harmonious coexistence between poultry and human food systems.

As a whole, this study encapsulates the interplay of economic viability, sustainable practices, and climate resilience within the poultry industry. By embracing alternative feed ingredients, considering changing market dynamics, and factoring in climate-smart principles, the research not only paves the way for a more efficient and profitable poultry sector but also serves as a blueprint for a more adaptable and sustainable agricultural landscape in the face of evolving challenges. Ultimately, the study's outcomes underscore the imperative of marrying innovation, sustainability, and economic prosperity in shaping the future trajectory of poultry production in the context of a changing world.

6. Recommendations

Several actionable recommendations emerge that can guide the chicken industry, policymakers, and stakeholders towards more sustainable, efficient, and resilient poultry production practices:

1) Diversify Feed Ingredients: Encourage the incorporation of locally available and climate-smart crops like cassava and sorghum into poultry feed formulations. This diversification not only reduces dependency on resource-intensive crops like maize but also contributes to climate resilience by promoting crops adapted to changing weather patterns.
2) Promote Feed Efficiency: Emphasize the importance of feed efficiency in poultry management practices. Provide education and resources to chicken farmers on balanced feed formulations that optimize feed conversion ratios, enabling better utilization of resources and lowering production costs.
3) Support Research and Innovation: Foster ongoing research initiatives focused on identifying alternative feed sources and their impact on performance. Investment in innovation can lead to the discovery of more cost-effective, sustainable, and nutritionally balanced feed options.
4) Enhance Climate Adaptation: Recognize the role of climate-smart crops in enhancing climate adaptation strategies. Encourage breeding and cultivation of crops that withstand environmental stresses, contributing to a more resilient agricultural system.
5) Financial Literacy for chicken Farmers: Provide farmers with financial education and tools to better understand profit margins, break-even points, and cost-benefit analyses. This knowledge equips them to make informed decisions that enhance profitability while considering resource constraints.
6) Policy Support: Collaborate with policymakers to develop supportive regulations and incentives that encourage the adoption of alternative feed ingredients. Tax incentives, subsidies, or grants for research and development of climate-smart crops can incentivize sustainable practices.
7) Capacity Building: Offer training and workshops to chicken farmers on sustainable practices and efficient resource utilization. Equipping farmers with the skills to manage their operations more effectively can lead to better overall performance and reduced environmental impacts.
8) Industry Collaboration: Foster partnerships between the poultry industry, research institutions, and government agencies. This collaboration can facilitate knowledge exchange, technology transfer, and the implementation of best practices across the sector.
9) Market Diversification: Explore opportunities to diversify product offerings beyond conventional chicken products, such as organic or specialty eggs, which may command premium prices in niche markets.
10) Long-Term Planning: Encourage long-term planning that considers market trends, resource availability, and climate impacts. By adopting a forward-thinking approach, poultry producers can anticipate challenges and adjust their strategies accordingly.

In essence, the study's outcomes emphasize a paradigm shift towards sustainability, efficiency, and adaptability in chicken production. By embracing alternative feed sources, optimizing resource utilization, and aligning practices with climate-smart principles, the industry can navigate the complex web of challenges posed by population growth, resource competition, and climate change. Through concerted efforts across stakeholders, the recommendations outlined above can drive a more resilient, profitable, and sustainable future for chicken production.

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