ISSN: 2456-2912
VET 2024; SP-9(2): 70-73

www.veterinarypaper.com
Received: 02-01-2024
Accepted: 03-02-2024

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Optimizing nutrient utilization in layer chickens: The Impact of dietary metabolizable energy levels and feed particle size

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Abstract
This study investigated the effects of dietary metabolizable energy (ME) levels and feed particle size on the efficiency of nutrient utilization in Athulya layer chickens, aiming to optimize poultry diets for enhanced growth performance and economic viability. Utilizing a 3x3 factorial design, the research examined three ME levels (2600, 2400, 2200 kcal/kg) and three particle sizes (3.0, 5.0, 7.0 mm), resulting in nine distinct dietary treatments. Results revealed that increasing ME levels significantly improved the utilization of dry matter and gross energy, indicating the critical role of dietary energy in nutrient absorption efficiency. Although particle size showed less significant effects, finer particles tended to slightly enhance nutrient utilization, suggesting the importance of physical feed properties in digestive processes. This comprehensive study highlighted the intricate relationship between dietary ME levels, feed particle size, and nutrient utilization in layer chickens, providing valuable insights for formulating more effective and sustainable poultry diets.

Keywords: Nutrient utilization, metabolizable energy, feed particle size, layer chickens

Introduction

The efficiency of nutrient utilization in poultry is a critical factor influencing feed conversion ratios, growth performance, and overall economic viability of poultry production. Among various factors, dietary metabolizable energy (ME) levels and feed particle size are known to play pivotal roles in optimizing nutrient absorption and bird health. Metabolizable energy, a measure of the energy content of feed that is available for growth and maintenance, is a fundamental component of poultry diets. Adjusting ME levels in the diet can significantly affect the utilization of other nutrients, such as proteins, fats, and minerals, thereby impacting the productivity of layer chickens. Feed particle size, on the other hand, affects the mechanical processing of feed in the gastrointestinal tract, influencing digestion and nutrient absorption efficiency. While finer particles may enhance digestibility through increased surface area for enzyme action, coarser particles can stimulate gizzard activity, potentially improving gut health and nutrient utilization. However, the interplay between ME levels and particle size, and their combined effect on nutrient utilization, particularly in layer chickens, remains inadequately explored. This study aims to fill this gap by investigating the effects of varying dietary ME levels and feed particle size on the nutrient utilization efficiency of Athulya layer chickens. By elucidating these relationships, the research seeks to provide insights into dietary formulation strategies that optimize nutrient absorption, improve poultry performance, and contribute to the sustainability of poultry production systems.

Materials and Methods

The study employed a 3x3 factorial design within a completely randomized framework, focusing on two experimental factors: Metabolizable energy (ME) levels and feed particle sizes. Each factor comprised three levels: ME levels at 2600, 2400, and 2200 kcal/kg of diet, and particle sizes with sieve openings of 3.0, 5.0, and 7.0 mm. This setup resulted in nine distinct treatment combinations, labeled T_1 through T_9.

The experimental diets were formulated according to the BIS 1992 standards, with the highest ME level set at 2600 kcal/kg. Diets with reduced ME levels (2400 and 2200 kcal/kg) were designed to maintain the same calorie-to-protein ratio as the 2600 kcal/kg ME diet, ensuring nutritional consistency across treatments (Table 1). The adjustment of feed particle size was accomplished using a hammer mill (Precision Products, Ahmedabad, Gujarat, India) equipped with sieves of 3, 5, and 7 mm openings. The mill, boasting a capacity of 2 tonnes/hour and powered by a 15 hp motor, ensured uniform particle size reduction across the experimental diets.

Metabolism trial design

At 40 weeks, a metabolism trial was conducted on four randomly selected hens from each dietary group, housed in metabolism cages for precise monitoring of feed and water intake, and excreta collection. A three-day adaptation period preceded a three-day total collection phase, following Summers *et al*. (1976) [10] for accurate nutrient and mineral excretion assessment. Daily excreta were collected, weighed, homogenized, and stored at -20 ˚C in labeled polythene bags for subsequent chemical analysis, ensuring sample integrity. Chemical Analysis: Following AOAC (1990) [3] guidelines, the chemical composition of diets and excreta was analyzed. Fresh excreta samples were used for nitrogen content analysis, while dried samples were prepared for proximate and mineral content analysis. Calcium and phosphorus were measured volumetrically, and trace minerals (Mn, Zn, Cu) were quantified using Atomic Absorption Spectrophotometry after acid digestion. Gross energy of feed and excreta was determined using a bomb calorimeter, enabling the calculation of nutrient and mineral utilization rates, providing a comprehensive evaluation of dietary efficiency.

Table 1: Per cent ingredient composition of experimental diets

Ingredients	T_1, T_2, T_3	T_4, T_5, T_6	T_7, T_8, T_9
Maize	57.00	46.00	38.50
Soya Meal	30.00	22.50	17.00
Deoiled Rice Bran	3.00	18.50	18.50
Wheat Bran	-	3.00	16.00
Dicalcium Phosphate	1.50	1.50	1.50
Calcite	8.00	8.00	8.00
Salt	0.50	0.50	0.50
Feed Supplements (g per 100 kg feed)			
Merivite	0.012	0.012	0.012
Meriplex	0.012	0.012	0.012
DL-Methionine	0.100	0.100	0.100
Ultra TM	0.100	0.100	0.100
Tefroli	0.025	0.025	0.025
Choline Chloride	0.200	0.200	0.200
UTPP	0.100	0.100	0.100

Results and Discussion

Table 2: Influence of different levels of ME and particle size of feed on mean percent utilization of dry matter, gross energy, crude protein, crude fat, and total ash of athulya layer chicken

Factor	Dry Matter	Gross Energy	Crude Protein	Crude Fat	Total Ash
Metabolizable Energy, kcal/kg (E)					
2200	52.03 a±1.40	62.15 a ±0.48	44.10±2.24	76.54 ±2.04	37.46 ±2.26
2400	55.63 a±2.06	66.75 b ±0.58	44.97±2.97	72.99 ±1.81	38.71 ±2.42
2600	62.10 b±0.78	71.74 c±0.59	50.45±0.90	75.05 ±1.34	41.92 ±1.12
Particle Size, mm (P)					
3.0	57.78±1.28	67.23±1.02	45.70±2.42	75.20 ±1.71	40.49 ±1.40
5.0	57.70±2.24	66.84±1.54	47.67±2.77	73.40 ±1.83	40.58 ±2.20
7.0	54.29±2.04	66.58±1.29	46.15±1.76	75.99 ±1.78	37.02 ±2.37
P-Value					
E	0.000	0.000	0.117	0.367	0.296
P	0.198	0.671	0.811	0.568	0.386
ExP	0.707	0.059	0.396	0.311	0.519

Means within a column with one common superscript do not differ significantly ($p<0.05$)

Table 3: Influence of different levels of me and particle size of feed on mean percent utilization of calcium, phosphorus, zinc, copper, and manganese of athulya layer chicken

Factor	Calcium	Phosphorus	Zinc	Copper	Manganese
Metabolizable Energy, kcal/kg (E)					
2200	59.94 a±1.56	46.96±1.69	59.12 a±1.67	59.28±1.40	54.58 a±2.50
2400	64.88 b±2.14	48.35±2.66	60.43 a±2.00	59.73±1.84	54.33 a±2.01
2600	74.06 c±0.98	53.26±1.69	67.11 b±0.74	61.27±1.25	67.13 b±0.94
Particle Size, mm (P)					
3.0	69.36 b±1.55	49.82±2.07	63.37±1.33	61.56±1.33	57.24±2.71
5.0	66.69 ab±2.61	52.83±2.41	63.05±2.01	59.88±1.64	58.87±3.12
7.0	62.84 a±2.48	45.93±1.58	60.25±2.08	58.84±1.51	59.93±1.86
P-value					
E	0.000	0.074	0.003	0.655	0.000
P	0.016	0.059	0.331	0.487	0.624
ExP	0.606	0.472	0.663	0.849	0.391

Means within a column with one common superscript do not differ significantly ($p<0.05$)

Nutrient Utilization

The influence of dietary ME levels on nutrient utilization was profound (Table 2). Increasing the ME from 2200 to 2600 kcal/kg significantly ($p<0.05$) enhanced the utilization of dry matter and gross energy. Specifically, dry matter utilization escalated from 52.03% at the lowest ME level to 62.10% at 2600 kcal/kg, indicating that higher dietary energy content markedly improves nutrient absorption efficiency. This trend was mirrored in the gross energy utilization, which increased alongside the ME levels, highlighting the pivotal role of dietary energy in optimizing nutrient digestibility. These results echo previous findings (Bhanja & Verma, 2001; Enting *et al*., 2007) [4, 5], underscoring the detrimental impact of high levels of indigestible fiber from ingredients like deoiled rice bran (DORB) and wheat bran on nutrient absorption in low ME diets. A study by Aftab and Bedford (2018) [1] further supported this by demonstrating that the inclusion of exogenous enzymes in low-energy diets could mitigate the negative impact on digestibility of dry matter, crude protein, and fat.

The utilization of crude protein, crude fat, and total ash remained statistically consistent across different ME levels, suggesting these nutrients' absorption might be less influenced by variations in dietary energy content. However, a noticeable trend was the improved crude protein utilization with higher ME levels, attributed to the inclusion of high-digestible protein sources such as soybean meal in diets with higher energy content. This observation underscores the importance of formulating diets with not only adequate energy levels but also with consideration of protein source quality to ensure optimal nutrient utilization. Wu *et al*. (2019) [12] also reported that higher energy diets improved fat utilization and overall energy efficiency in layers, underscoring the importance of dietary energy in optimizing nutrient utilization.

The study also delved into the effects of feed particle size on nutrient utilization, revealing no significant differences for most nutrients. This finding aligns with Singh *et al*. (2014) [8] and Amerah *et al*. (2007) [2], who reported no significant impact of particle size on AME in poultry, suggesting that while feed physical form has a role in nutrient absorption, it may be less critical than the dietary ME content. However, a trend emerged where dry matter, gross energy, and total ash utilization improved as the particle size decreased, likely due to the increased surface area available for enzyme action in finely ground feeds. This is in line with findings by Thompson and Applegate (2020), who suggested that medium particle sizes (around 600 microns) offered an optimal utilization of DM, fiber, and CP in broilers.

Mineral Utilization

Mineral utilization, particularly for calcium, zinc, and manganese, was significantly (p<0.05) affected by dietary ME levels, with higher ME diets facilitating better mineral absorption (Table 3). This could be attributed to the reduced phytate content in higher ME diets, which otherwise binds with these minerals, reducing their bioavailability. Interestingly, Wu *et al*. (2019) [12] reported that higher energy diets significantly improved the absorption of minerals such as Ca and P, attributing this to the increased metabolic energy availability for active transport mechanisms. However, the utilization of phosphorus and copper did not vary significantly with ME levels or particle size, indicating that their absorption may be less sensitive to these dietary factors.

The enhanced calcium utilization with finer feed particle sizes (p<0.05) further highlights the influence of feed form on mineral absorption, possibly through improved enzymatic action due to a larger surface area. In accordance with our findings, Martins *et al*. (2021) [7] found that finer particles improved the bioavailability of trace minerals such as zinc and manganese in layers and there was a threshold beyond which further reduction in particle size could adversely affect gut health and nutrient absorption. Our findings contrast with studies by Kasim and Edwards (2000) [6] and Amerah *et al*. (2007) [2], who observed higher mineral utilization in broilers fed diets with coarser particle sizes, suggesting that the relationship between feed form and nutrient utilization may vary depending on the specific nutrient and poultry species. Singh *et al*. (2022) [9] underscored the importance of synergy between adequate energy levels and appropriate particle size in maximizing nutrient efficiency, particularly for minerals like Ca, P, zinc and Mn.

Conclusion

This study elucidates the significant impact of dietary metabolizable energy (ME) levels and feed particle size on nutrient utilization in layer chickens, revealing that higher ME levels markedly enhance the absorption efficiency of dry matter and gross energy, underscoring the pivotal role of dietary energy in optimizing nutrient digestibility. Although feed particle size showed less pronounced effects, finer particles slightly improved nutrient utilization, suggesting the importance of feed form alongside dietary energy content. By offering insights into optimizing nutrient absorption and bird health, this study provides valuable guidance for poultry diet formulation, aiming to improve poultry performance and contribute to the sustainability of poultry production systems.

Acknowledgements

This is a part of PhD thesis of the first author which has been completed under supervision of the second author. This work was supported by Kerala Veterinary and Animal Sciences University for which the authors are grateful.

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