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Nutritional and biochemical evaluation of rice distillers dried grains with solubles (RDDGS): Chemical composition, metabolizable energy estimation, and growth performance in broiler chickens

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Abstract

A controlled feeding experiment was undertaken at the Department of Poultry Science, Madras Veterinary College, Chennai, India, with the objective of evaluating the biochemical composition, metabolizable energy (ME), and feeding value of rice distillers dried grains with solubles (RDDGS) in broiler chicken diets. Eight representative RDDGS samples were subjected to laboratory analysis. The mean crude protein content was found to be $43.57 \pm 2.95\%$, whereas gross energy averaged 4091.63 ± 74.83 kcal/kg. Based on an ME:GE conversion coefficient of 0.72, the metabolizable energy was calculated to be 2946 kcal/kg. A total of 144 commercial broiler chicks were randomly allotted to four dietary treatments, each with three replicates of 12 birds. Experimental diets were formulated with RDDGS inclusion at 0% (T_1), 5% (T_2), 10% (T_3), and 15% (T_4), replacing soybean meal on an equivalent basis. The diets were maintained nearly isocaloric and isonitrogenous in accordance with BIS (2007) recommendations. Growth parameters such as body weight, body weight gain, feed intake, feed conversion ratio (FCR), and livability were recorded throughout the 42-day experimental period. Birds receiving 5% RDDGS showed growth performance comparable to the control group during later stages, while higher inclusion levels resulted in significant reductions ($p < 0.01$) in growth and feed efficiency. Feed intake declined consistently with increasing inclusion levels. Livability remained unaffected across all treatments. Feed cost per kilogram of feed as well as per kilogram of live weight showed a decreasing trend with increasing RDDGS inclusion. Based on the combined biological and economic responses, inclusion of RDDGS up to 5% can be recommended when diets are nutritionally balanced.

Keywords: RDDGS, metabolizable energy, dry matter, broiler performance, feed efficiency

Introduction

Poultry production systems are largely dependent on cereal grains and oilseed meals, and therefore, improving the efficiency of nutrient utilization from these ingredients is essential for sustaining production systems. Increasing emphasis is being placed on the utilization of agro-industrial coproducts, which are not directly suitable for human consumption but can be effectively converted into high-value animal protein through poultry. The rising cost and fluctuating availability of conventional protein sources, particularly soybean meal, have encouraged the exploration of alternative feed ingredients. Among these alternatives, distillers dried grains with solubles (DDGS) have gained prominence due to their relatively high protein content and consistent availability as by-products of ethanol production. During ethanol production, starch from cereal grains is converted into ethanol and carbon dioxide through fermentation. The residual fraction, which includes protein, fat, fiber, minerals, and vitamins, becomes concentrated and is recovered as DDGS (Luu *et al.*, 2009) [17]. Rice-based DDGS (RDDGS) has emerged as a potential feed ingredient, especially in rice-producing regions, due to its local availability and comparatively lower cost. Although RDDGS is rich in crude protein, its utilization in poultry feeding is influenced by variability in composition, reduced amino acid availability—particularly lysine—and increased fiber content, which may affect digestibility. These factors collectively influence its feeding value.

The present investigation was therefore undertaken to evaluate the chemical composition of RDDGS, estimate its metabolizable energy, examine its effect on broiler growth performance, and identify an appropriate inclusion level in practical feeding systems.

Materials and Methods

Ethical Approval

The experimental protocol involving broiler chickens was conducted in accordance with institutional guidelines for the care and use of animals in research. The study was reviewed and approved by the Institutional Animal Ethics Committee (IAEC), Madras Veterinary College, Chennai, India (IAEC No.: 17/SA/IAEC/2022). All procedures were carried out ensuring minimal stress and optimal welfare conditions for the birds.

Basis of Nutrient Expression

In the present study, all compositional and energy values of rice distillers dried grains with solubles (RDDGS) were expressed on a dry-matter (DM) basis to accurately represent intrinsic nutrient density and allow comparison with conventional feed ingredients. However, ingredient composition of experimental diets, calculated nutrient composition, and biological performance parameters were expressed on an as-fed basis, consistent with standard poultry feeding practices.

Sample Collection and Chemical Analysis

Eight RDDGS samples were collected from feed ingredient suppliers located in Telangana and Tamil Nadu. These samples were analyzed for chemical composition at the Animal Feed Analytical and Quality Assurance Laboratory (AFAQAL), Namakkal, following AOAC (2005) procedures. Amino acid profiling was carried out at SGS Laboratories, Ambattur, Chennai.

The following parameters were determined:

- Moisture content (oven drying method)
- Crude protein (Kjeldahl nitrogen $\times$ 6.25)
- Ether extract (Soxhlet extraction)
- Crude fiber (acid-alkali digestion)
- Total ash (muffle furnace combustion)
- Acid insoluble ash
- Calcium and phosphorus (titrimetric/spectrophotometric methods)
- Gross energy (bomb calorimetry)

The formulation batch used in diet preparation contained 16.71% moisture (83.29% DM). All nutrient values were converted to dry-matter basis.

Birds, Experimental Protocol, and Diet

Four experimental diets were formulated with RDDGS inclusion levels of 0%, 5%, 10%, and 15%, replacing soybean meal. All diets were designed to be nearly isocaloric and isonitrogenous in accordance with BIS (2007)^[2] recommendations. The ingredient composition and calculated nutrient values are presented in Tables 1 and 2. A total of 144 day-old straight-run commercial broiler chicks (Vencobb 400) were procured and randomly assigned to four treatment groups, each with three replicates of 12 birds. The experimental period lasted 42 days and was divided into three feeding phases: pre-starter (0-7 days),

starter (8-21 days), and finisher (22-42 days). Standard management practices were followed, and feed and water were provided ad libitum.

Data Collection

Body Weight (BW)

Body weight of birds was recorded:

At day-old

Weekly thereafter

Values were expressed in grams (g).

Body Weight Gain (BWG)

BWG = Final body weight – Initial body weight

Calculated weekly and cumulatively.

Feed Intake (FI)

Feed intake was measured daily and expressed as:

FI = Feed offered – Feed left over

Values were aggregated weekly.

Feed Conversion Ratio (FCR)

$$\text{FCR} = \frac{\text{Feed intake (g)}}{\text{Body weight gain (g)}}$$

Mortality-adjusted FCR was calculated where applicable

Economic Parameters

- Feed cost per kg feed
- Feed cost per kg live weight

These were calculated based on ingredient cost and feed intake.

Estimation of Metabolizable Energy

Metabolizable energy (ME) of rice distillers dried grains with solubles (RDDGS) was estimated from gross energy (GE) using an ingredient-specific conversion coefficient.

Gross energy was determined using a bomb calorimeter and expressed on an as-fed basis. Metabolizable energy was calculated as:

$$\text{ME} = \text{GE} \times 0.72$$

where:

ME = metabolizable energy (kcal/kg)

GE = gross energy (kcal/kg)

Using the mean GE value:

$$\text{ME} = 4091.63 \times 0.72 = 2946 \text{ kcal/kg (as-fed basis)}$$

For comparison of nutrient density, ME was also expressed on a dry-matter basis (DM = 82.86%), giving an estimated value of 3554 kcal/kg (DM basis). The use of a coefficient of 0.72 accounts for reduced energy availability in distillers coproducts due to higher fiber content and heat-induced reductions in nutrient digestibility (Rochell, 2018)^[20].

Results

Chemical Composition of RDDGS (Dry Matter Basis)

Chemical Composition of RDDGS are presented in Table 3.

The compositional analysis of rice distillers dried grains with solubles (RDDGS) indicated that the ingredient is

nutritionally concentrated, particularly when interpreted on a dry-matter basis. The mean crude protein content was recorded as 43.57%, which increased to approximately 52.54% when corrected for moisture content. The coefficient of variation for crude protein was relatively low (6.77%), suggesting consistency in protein concentration across samples. In contrast, crude fiber exhibited substantial variability, with a coefficient of variation exceeding 50%. This wide range reflects differences in raw material composition and processing conditions. Ether extract and total ash also showed moderate variation, indicating variability in lipid content and mineral fractions among samples. Gross energy values remained relatively stable, with a low coefficient of variation (1.83%), suggesting that the energy content of RDDGS is comparatively consistent despite variation in other proximate components. The estimated metabolizable energy, derived using an ME:GE coefficient of 0.72, followed a similar pattern of low variability.

Amino Acid Profile

Amino Acid Profile of RDDGS are presented in Table 4. The amino acid profile revealed that RDDGS protein is imbalanced, with relatively low lysine content compared to other essential amino acids. This limitation becomes more evident when expressed on a dry-matter basis, indicating that protein quality is constrained despite high crude protein levels.

Body Weight

Body weight data are presented in Table 5.

Body weight measurements did not differ significantly among treatments at the day-old stage ($p>0.05$), indicating uniformity in initial chick weight. During the first week, birds in the 5% inclusion group (T_2) maintained body weight comparable to the control group, whereas those in higher inclusion groups (T_3 and T_4) exhibited reduced weights. From the second week onwards, a progressive decline in body weight was observed with increasing levels of RDDGS inclusion. However, by the fifth and sixth weeks, birds in T_2 demonstrated body weights comparable to the control, suggesting that low-level inclusion did not adversely affect long-term growth. In contrast, birds in T_3 and T_4 continued to show significantly lower body weights ($p<0.01$).

Sex-wise Performance

Sex-wise analysis (Table 5A) showed no significant differences during early growth stages ($p>0.05$). However, significant differences were observed during weeks 5 and 6

($p<0.01$), with males exhibiting higher body weight and weight gain compared to females. These results indicate a main effect of sex on late growth performance.

Body Weight Gain

Weekly Body Weight Gain presented in Table 6.

The pattern of body weight gain mirrored the trends observed in body weight. Birds receiving 5% RDDGS showed gains comparable to the control group during later stages, whereas higher inclusion levels resulted in significantly reduced gains throughout the experimental period. The reduction in weight gain at higher inclusion levels suggests a limitation in effective nutrient utilization, despite the high crude protein content of the ingredient.

Feed Intake

Cumulative Feed Intake presented in Table 7.

Feed intake remained comparable between T_1 and T_2 during the later stages of the experiment. However, a noticeable decline in feed intake was recorded in T_3 and T_4 from the second week onwards. This reduction became more pronounced as the level of RDDGS increased. The decrease in feed intake indicates that factors such as increased dietary bulk or palatability may have influenced voluntary consumption.

Feed Conversion Ratio (FCR)

Cumulative Feed Conversion Ratio of Broilers Fed Different Levels of RDDGS in Table 8.

Feed conversion ratio (FCR) values varied across treatments. During the early phase, some variability was observed, likely due to low feed intake and small differences in initial growth. From the second week onwards, a consistent pattern emerged. Birds in T_2 maintained FCR values comparable to the control group, whereas those in T_4 consistently showed poorer FCR. Birds in T_3 exhibited intermediate values. The cumulative FCR at the end of the trial confirmed that feed efficiency was maintained at 5% inclusion but deteriorated at higher levels.

Economic Analysis

Feed Cost and Economic Efficiency of Broilers Fed Different Levels of RDDGS in Table 9.

Feed cost per kilogram of feed decreased progressively with increasing levels of RDDGS inclusion. Similarly, feed cost per kilogram of live weight gain showed a decreasing trend, with the lowest value observed in T_4 . However, when considered alongside growth performance, it became evident that the reduction in cost at higher inclusion levels was associated with compromised biological efficiency.

Table 1: Ingredient composition of experimental ration (as-fed basis)

Ingredients (%)	Pre-starter T ₁	Pre-starter T ₂	Pre-starter T ₃	Pre-starter T ₄	Starter T ₁	Starter T ₂	Starter T ₃	Starter T ₄	Finisher T ₁	Finisher T ₂	Finisher T ₃	Finisher T ₄
Maize	26.99	28.74	30.86	32.56	29.70	31.60	33.55	34.97	40.00	40.00	40.00	45.00
Broken rice	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	11.41	15.81	17.22	15.33
Soyabean meal	41.50	35.80	29.88	23.88	39.94	34.26	28.35	22.50	32.57	28.40	22.15	16.76
SFDOC	2.10	2.10	2.10	2.10	0.00	0.00	0.00	0.00	4.34	0.76	1.52	0.00
Calcite	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.08	0.05	0.06	0.03
DCP	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.50	1.11	1.20	1.20	1.30
MMP	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Palm oil	5.04	4.00	2.80	1.80	6.10	4.90	3.83	2.89	7.50	5.83	4.90	3.50
DL-Methionine	0.13	0.12	0.12	0.09	0.14	0.13	0.15	0.15	0.12	0.10	0.10	0.06
Lysine	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.17
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Rice DDGS	0.00	5.00	10.00	15.00	0.00	5.00	10.00	15.00	0.00	5.00	10.00	15.00
Ultravite M	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Perivac Plus	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.02	0.00	0.00	0.00	0.00
Cosmodot	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Oxinex	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.01	0.01	0.01	0.01
Choline	0.34	0.34	0.34	0.34	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Spectra DFM	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 2: Nutrient composition of experimental broiler feed (calculated values in the ration; as-fed basis)

Nutrient	Pre-starter T ₁	Pre-starter T ₂	Pre-starter T ₃	Pre-starter T ₄	Starter T ₁	Starter T ₂	Starter T ₃	Starter T ₄	Finisher T ₁	Finisher T ₂	Finisher T ₃	Finisher T ₄
CP (%)	23.00	23.05	23.05	23.05	21.99	22.02	22.09	22.07	20.00	20.00	20.00	20.00
ME (kcal/kg)	3000.0	2943.8	2880.6	2822.4	3103.0	3040.8	2986.6	2925.4	3200.0	3140.8	3081.6	3026.4
C:P ratio	130.45	130.29	130.15	130.15	141.08	140.79	140.55	140.58	160.00	160.00	160.00	160.00
Crude fiber (%)	4.01	3.97	3.93	3.87	3.39	3.34	3.30	3.24	4.19	3.30	3.43	3.01
Calcium (%)	1.01	1.01	1.00	1.08	1.01	1.00	0.99	1.05	1.00	1.00	1.00	1.00
Phosphorus (%)	0.48	0.47	0.46	0.46	0.47	0.46	0.45	0.49	0.45	0.45	0.45	0.45
Lysine (%)	1.55	1.45	1.33	1.34	1.49	1.38	1.28	1.21	1.27	1.16	1.01	1.00
Methionine (%)	0.51	0.51	0.52	0.54	0.51	0.52	0.51	0.55	0.45	0.45	0.48	0.45
Threonine (%)	0.76	0.67	0.59	0.53	0.72	0.64	0.56	0.47	0.65	0.61	0.56	0.51

Table 3: Chemical Composition, Energy Values, and Variability of RDDGS (As-fed Basis; n = 8 samples)

Parameters (%) / (kcal/kg)	Mean	Range	Standard deviation	Coefficient of variation (%)
Moisture (%)	17.14	14.02-19.16	1.76	10.27
Crude protein (%)	43.57	39.35-47.10	2.95	6.77
Crude fiber (%)	2.85	1.23-5.33	1.51	52.98
Ether extract (%)	4.69	3.19-7.67	1.43	30.49
Total ash (%)	4.51	1.18-6.84	1.69	37.47
Acid insoluble ash (%)	0.69	0.20-1.44	0.39	56.52
Calcium (%)	0.21	0.20-0.30	0.04	19.05
Phosphorus (%)	0.75	0.57-1.00	0.15	20.00
Salt (%)	0.35	0.16-0.58	0.14	40.00
Gross energy (kcal/kg)	4091.63	3980-4227	74.83	1.83
Metabolizable energy (kcal/kg)	2946.0	2866-3043	53.88	1.83

Table 4: Amino Acid Profile of RDDGS (g/100 g, As-Fed Basis)

Amino acid	Value	Amino acid	Value
Histidine	1.41	Methionine	1.19
Valine	2.08	Phenylalanine	2.29
Lysine	1.04	Threonine	0.74
Alanine	2.33	Cystine	0.34
Arginine	1.40	Glutamic acid	6.94
Aspartic acid	3.09	Glycine	3.52
Tryptophan	0.34	Proline	1.59
Isoleucine	1.27	Serine	2.29
Leucine	3.20	Tyrosine	1.58
Total	36.64	—	—

Table 5: Weekly Body Weight (g) of Broilers (Mean $\pm$ SE)

Age	T ₁ (0%)	T ₂ (5%)	T ₃ (10%)	T ₄ (15%)	F value
Day-old	43.50 $\pm$ 1.05	43.52 $\pm$ 1.05	44.09 $\pm$ 1.05	43.74 $\pm$ 1.05	0.07 NS
Week 1	151.83 ^a $\pm$ 4.08	143.55 ^{ab} $\pm$ 4.09	136.93 ^b $\pm$ 4.07	120.17 ^c $\pm$ 4.13	10.73**
Week 2	412.48 ^a $\pm$ 9.24	385.82 ^b $\pm$ 9.38	342.13 ^c $\pm$ 9.21	276.80 ^d $\pm$ 9.36	40.67**
Week 3	881.79 ^a $\pm$ 18.15	815.82 ^b $\pm$ 18.20	710.23 ^c $\pm$ 17.86	559.86 ^d $\pm$ 18.15	60.19**
Week 4	1400.52 ^a $\pm$ 26.91	1311.80 ^b $\pm$ 26.97	1152.42 ^c $\pm$ 26.47	923.66 ^d $\pm$ 26.91	60.78**
Week 5	1928.67 ^a $\pm$ 35.48	1838.30 ^a $\pm$ 35.57	1658.29 ^b $\pm$ 34.91	1365.29 ^c $\pm$ 35.48	49.27**
Week 6	2562.84 ^a $\pm$ 53.69	2460.54 ^a $\pm$ 53.82	2181.58 ^b $\pm$ 52.82	1855.64 ^c $\pm$ 53.69	35.05**

Means bearing different superscripts within a row differ significantly. * p <0.01; p <0.05; NS-Not significant. No of observations (n) = 36

Table 5A: Effect of Sex on Body Weight (g, Mean $\pm$ SE)

Sex	Day-old	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Male	43.59 $\pm$ 0.08	139.35 $\pm$ 3.08	351.15 $\pm$ 6.22	749.40 $\pm$ 13.54	1227.21 $\pm$ 20.07	1774.71 $\pm$ 26.47	2423.84 $\pm$ 40.05
Female	43.84 $\pm$ 0.70	136.89 $\pm$ 2.73	351.15 $\pm$ 6.98	734.45 $\pm$ 12.15	1166.99 $\pm$ 18.01	1620.55 $\pm$ 23.75	2106.46 $\pm$ 35.93
F value	0.06 NS	0.36 NS	0.50 NS	0.67 NS	4.97*	18.71**	34.64**

Main effect of sex significant at weeks 5-6; no interaction inferred unless tested

Table 6: Weekly Body Weight Gain (g, Mean $\pm$ SE)

Age	T ₁	T ₂	T ₃	T ₄	F value
Week 1	108.35 ^a $\pm$ 3.43	100.04 ^{ab} $\pm$ 3.45	92.85 ^b $\pm$ 3.45	76.15 ^c $\pm$ 3.49	15.67**
Week 2	368.99 ^a $\pm$ 8.74	342.21 ^b $\pm$ 8.88	298.01 ^c $\pm$ 8.71	232.77 ^d $\pm$ 8.86	45.77**
Week 3	838.61 ^a $\pm$ 17.68	772.21 ^b $\pm$ 17.72	666.12 ^c $\pm$ 17.39	515.89 ^d $\pm$ 17.68	63.74**
Week 4	1357.35 ^a $\pm$ 26.48	1268.19 ^b $\pm$ 26.55	1108.32 ^c $\pm$ 26.06	879.63 ^d $\pm$ 26.48	62.94**
Week 5	1885.45 ^a $\pm$ 35.14	1794.68 ^a $\pm$ 35.23	1614.19 ^b $\pm$ 34.57	1321.31 ^c $\pm$ 35.14	50.36**
Week 6	2519.55 ^a $\pm$ 53.37	2416.92 ^a $\pm$ 53.50	2137.47 ^b $\pm$ 52.51	1811.61 ^c $\pm$ 53.37	35.54**

Means bearing different superscripts within a row differ significantly. * p <0.01; p <0.05; NS-Not significant. No of observations (n) = 36

Table 7: Cumulative Feed Intake (g, Mean $\pm$ SE)

Age	T ₁	T ₂	T ₃	T ₄	F value
Week 1	101.94 $\pm$ 2.29	97.72 ^a $\pm$ 2.29	96.50 ^a $\pm$ 2.63	88.72 ^b $\pm$ 2.29	5.80*
Week 2	425.67 ^a $\pm$ 8.44	407.33 ^a $\pm$ 8.44	386.33 ^b $\pm$ 9.69	358.33 ^b $\pm$ 8.44	11.31**
Week 3	1075.80 ^a $\pm$ 18.04	1027.86 ^a $\pm$ 18.04	947.58 ^b $\pm$ 20.73	900.19 ^b $\pm$ 18.04	17.69*
Week 4	1998.22 ^a $\pm$ 34.10	1885.11 ^b $\pm$ 34.10	1720.00 ^c $\pm$ 39.18	1595.11 ^c $\pm$ 34.10	25.45**
Week 5	3105.03 ^a $\pm$ 69.95	2944.97 ^a $\pm$ 69.95	2717.25 ^b $\pm$ 80.37	2439.31 ^c $\pm$ 69.95	16.48*
Week 6	4323.50 ^a $\pm$ 97.90	4087.83 ^b $\pm$ 97.90	3872.50 ^b $\pm$ 112.48	3423.17 ^c $\pm$ 97.90	15.02*

Means bearing different superscripts within a row differ significantly. * p <0.01; p <0.05; NS-Not significant. No of observations (n) = 36

Table 8: Cumulative Feed Conversion Ratio (Mean $\pm$ SE) of Broilers Fed Different Levels of RDDGS

Age	T ₁ (Control)	T ₂ (5%)	T ₃ (10%)	T ₄ (15%)	F value
1st week	1.16 ^b $\pm$ 0.03	1.16 ^b $\pm$ 0.03	1.21 ^b $\pm$ 0.03	0.93 ^a $\pm$ 0.03	20.27*
2nd week	1.04 ^a $\pm$ 0.04	1.05 ^a $\pm$ 0.04	1.12 ^a $\pm$ 0.05	1.37 ^b $\pm$ 0.04	15.11*
3rd week	1.23 ^a $\pm$ 0.04	1.24 ^a $\pm$ 0.04	1.33 ^a $\pm$ 0.04	1.64 ^b $\pm$ 0.04	31.52*
4th week	1.44 ^a $\pm$ 0.03	1.43 ^a $\pm$ 0.03	1.47 ^a $\pm$ 0.03	1.75 ^b $\pm$ 0.03	27.16**
5th week	1.62 ^a $\pm$ 0.02	1.60 ^a $\pm$ 0.02	1.62 ^a $\pm$ 0.02	1.80 ^b $\pm$ 0.02	34.15**
6th week	1.71 ^a $\pm$ 0.04	1.67 ^a $\pm$ 0.04	1.76 ^a $\pm$ 0.04	1.86 ^b $\pm$ 0.04	5.79*

Means bearing different superscripts within a row differ significantly. * p <0.01; p <0.05; NS-Not significant. No of observations (n) = 36

Table 9: Feed Cost and Economic Efficiency of Broilers Fed Different Levels of RDDGS

Parameter	T ₁ (Control)	T ₂ (5%)	T ₃ (10%)	T ₄ (15%)	F value
Feed cost (Rs/kg feed)	50.83 ^a	48.25 ^b	45.33 ^c	42.41 ^d	52.93**
Feed cost per kg live weight (21-42 days) (Rs)	115.40 ^a	103.14 ^b	103.04 ^b	87.57 ^c	52.13**
Feed cost per kg live weight (0-42 days) (Rs)	85.70 ^a	82.90 ^{bc}	82.50 ^c	80.60 ^c	17.71**

Means bearing different superscripts within a row differ significantly. * p <0.01; p <0.05; NS-Not significant.

Discussion

Nutritional characteristics of RDDGS

The high crude protein content observed in RDDGS reflects the concentration effect resulting from starch removal during fermentation. Similar observations have been reported in distillers coproducts, where protein, fiber, and

lipid fractions become concentrated after ethanol extraction (Loar *et al.*, 2010) [16]. Despite this high protein concentration, the variability observed in fiber and ash content indicates that the ingredient is not compositionally uniform. Such variability has important implications for diet formulation and nutrient availability.

Amino acid limitation

Although crude protein levels were high, the biological performance results indicate that protein quality may be limiting. In particular, lysine availability is known to be reduced in distillers grains due to heat processing, which affects digestibility (Rochell, 2018) [20]. This limitation becomes more pronounced at higher inclusion levels, where the cumulative effect of amino acid imbalance likely contributes to reduced growth performance.

Growth response

The growth pattern observed in the present study suggests a threshold effect. Birds receiving 5% RDDGS were able to maintain growth performance comparable to the control, whereas higher inclusion levels resulted in reduced body weight and weight gain. This response is consistent with earlier findings that moderate inclusion of DDGS can be tolerated, but higher levels may impair performance if nutrient balance is not adequately maintained (Loar *et al.*, 2010) [16].

Feed intake

The reduction in feed intake observed at higher inclusion levels is likely associated with increased dietary fiber. Poultry have limited ability to utilize fiber, and increased fiber content may lead to reduced feed intake due to gut fill effects and slower passage rate (Rochell, 2018) [20]. Additionally, fermentation-derived compounds may influence palatability, further contributing to reduced consumption.

Feed Conversion Ratio

The deterioration in FCR at higher inclusion levels indicates reduced efficiency of nutrient utilization. This may be attributed to a combination of factors, including reduced digestibility, amino acid imbalance, and lower metabolizable energy availability. The maintenance of FCR at 5% inclusion suggests that the ingredient can be effectively utilized at lower levels without compromising feed efficiency.

Economic considerations

Although feed cost decreased with increasing RDDGS inclusion, the associated decline in growth performance at higher levels limits its economic advantage. The optimal inclusion level must therefore balance cost reduction with biological efficiency. In the present study, 5% inclusion provided the most favorable balance between these factors.

Conclusion

Rice distillers dried grains with solubles (RDDGS) is a nutritionally concentrated ingredient when evaluated on a dry-matter basis. However, its utilization in broiler diets is influenced by amino acid balance and fiber content. Inclusion at 5% did not adversely affect growth performance, feed intake, or feed conversion ratio, whereas higher inclusion levels resulted in reduced performance. From both biological and economic perspectives, RDDGS can be safely incorporated up to 5% in broiler diets when appropriate nutrient balancing is ensured.

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