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Research Article

CHEMICAL AND NUTRITIONAL COMPOSITION OF RICE DISTILLER DRIED GRAIN WITH SOLUBLES FOR LIVESTOCK AND POULTRY

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ABSTRACT: A research study was carried out to assess the gross energy, nutrient composition, fiber fraction, macro- and micro-mineral status, amino acid, and fatty acid profile of Rice Distiller Dried Grain with Solubles (rDDGS), a by-product of the ethanol manufacturing process. Sixteen (16) samples were procured from various manufacturing batches of the ethanol industry. There was a higher gross energy (GE) of 4104.75 kcal/kg than in the original grains. Total ash (TA), nitrogen-free extract (NFE), ether extract (EE), crude protein (CP), crude fiber (CF), dry matter (DM), and acid insoluble ash (AIA) had respective mean values of 90.87, 40.24, 6.26, 7.67, 31.53, 5.15, and 1.45%, respectively. The percentages of neutral detergent fiber (NDF) and acid detergent fiber (ADF) were 37.84% and 14.33%, respectively. The percentages of phosphorus and calcium were 1.20 and 0.57%, respectively. Similarly, trace minerals like iron, copper, zinc, cobalt, and manganese were found to be 67, 14, 34, 16, and 68 ppm, respectively. The glutamic acid (6.65), leucine (3.34), and aspartic acid (6.34) were the most abundant amino acids found in rDDGS, while cystine (0.88) and tryptophan (0.41) were the amino acids with the lowest values, respectively. The rDDGS fat has a high amount of linoleic acid (omega-6) with a value of 36.41% and 37.4% of oleic acid. The samples presented a value of 19.68% of palmitic acid, being the highest among saturated fatty acids.

Keywords: : Distillers by product, Nutritional value, Rice distiller dried grain with solubles.

INTRODUCTION

The most rapidly expanding segments of India's agricultural industry include livestock and poultry farming, which has seen a substantial increase in production due to advancements in nutrition and genetics. The primary component of livestock production is feed, which contributes 60-70% of all recurring expenses, and its cost has sharply increased, primarily driven by the price of protein sources. There is an enormous gap between the availability and demand for conventional protein sources (oilseed cakes), resulting in a never-ending hunt for affordable novel feed ingredients. Nowadays, the conventional cost of feed ingredients has increased manyfold. Say, for example, due to feed manufacturers' dependency on imported soybean meal, the limited supply of soybean meal has raised feed prices. Hence, feed manufacturers are in a crisis because of the increased price of conventional feed ingredients. Mill owners are constantly searching for unconventional feed resources with high nutritive value.

Distiller's dried grains with solubles (DDGS) may be an unconventional protein source for livestock and poultry feeding. Distiller's dried grains with solubles (DDGS) are the nutrient-rich dried residues obtained after the fermentation of cereals by selected enzymes and yeasts [1]. Carbon dioxide and ethanol are produced from the rice grain's starch during the fermentation process. The remaining components of rice grains-protein, fats, fiber, minerals, and vitamins-are concentrated, however, chemically unaltered. The leftover components are altogether known as distillers

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dried grains with solubles (DDGS), a byproduct. DDGS is a significant partial replacement for the costly ingredients used in livestock and poultry feed due to its high energy, protein, and phosphorus content. The nutritional variability of DDGS, which may differ based on grain sources and manufacturing techniques, is an important consideration when it comes to its use in feed. Additionally, the nutrient levels of DDGS vary from one production plant to another or even from batch to batch.

Most of the research work done is limited to corn and wheat DDGS, whereas very scant information is accessible in the literature regarding the nutritional assessment of rDDGS. So, it is utmost necessary to investigate its nutritive and feeding value due to its increased availability as a low-cost alternate feed ingredient. Thus, the objective of the research study was to assess the gross energy, nutrient composition, fiber fraction, macro- and micro-mineral status, amino acid, and fatty acid profile of rDDGS, which is predominantly available in India and used as the protein source in livestock and poultry feed formulation.

MATERIALS AND METHODS

The 16 samples of rDDGS produced during different production batches are procured from the ethanol industry producing genuine DDGS from rice crops only. To perform chemical analysis, the samples were ground and oven-dried using a Willey mill for fitting through a 2 mm screen. The samples were analyzed for proximate constituent and AIA [2] and fiber fraction [3]. The major minerals, calcium [4] and phosphorus [2], were analyzed as per the method described. Using an atomic absorption spectrophotometer, the trace minerals (cobalt, copper, manganese, zinc, and ferrous) were quantified [5]. The gross energy was estimated by an automatic ballistic Bomb Calorimeter.

High-performance liquid chromatography examined the amino acid profile (HPLC). In a vacuum-sealed glass tube, hydrolysis of the samples was first carried out for 24 hours at 110 ± 20 °C using phenol containing 6N HCl. Performic acid oxidation was done before acid hydrolysis to profile methionine and cysteine amino acids. Following post-column derivatization, the amino acids in the hydrolysate were subsequently identified by HPLC. The fatty acids were estimated by gas chromatography (GC). The fatty acid methyl ester (FAME) was prepared directly from samples as per the direct transesterification method [6]. The FAME was analyzed using gas chromatograph-mass spectrometry (GCMS).

RESULTS AND DISCUSSION

Gross energy

The gross energy of rDDGS was estimated to be 4104 (Kcal/kg) (Table 1), which is higher than the GE value of 3660 of rice grain [7]. Our present findings corroborated with research findings [8] of 4097 kcal/kg gross energy of rDDGS. In contrast, a slightly higher gross energy value (4513 kcal/kg) of rice DDGS has also been reported [9], which might be due to the use of rice grain along with bran in DDGS production. The GE value of maize-DDGS ranged from 4895 to 5540 Kcal/kg in different studies [10, 11, 12], which were higher than our finding of GE value, which might be due to less crude fat content in rice than corn. Previous researchers also observed that rice DDGS has a lower crude fat content than corn DDGS [17].

Proximate composition and fiber fraction

The proximate composition (% dry matter) in terms of organic matter (OM), crude protein (CP), ether extract (EE), crude fiber (CF), nitrogen-free extract (NFE), and total ash (TA) was 94.85, 40.24, 7.69, 6.26, 31.53, and 5.15%, respectively (Table 1). The acid-insoluble ash (AIA) content was 1.45 percent. The moisture content as estimated by different authors [8, 13, 14] was a little bit higher (ranged between 7 to 11%) than the present

Table 1. Chemical composition, fiber component and mineral composition of rDDGS.

S.No.	Nutrient	Mean	SE
1	Gross energy (kcal/kg)	4104.75	9.14
Proximate nutrient and silica (%)			
2	Dry matter	90.87	0.41
3	Organic matter	94.85	0.13
4	Ash	5.15	0.13
5	Crude protein	40.24	0.66
6	Ether extract	7.67	0.60
7	Crude fiber	6.26	0.16
8	NFE	31.53	1.35
9	AIA	1.45	0.10
Fiber fraction (%)			
10	NDF	37.84	0.30
11	ADF	14.33	0.14
Major mineral (%)			
12	Calcium	0.57	0.02
13	Phosphorous	1.20	0.04
Trace mineral (ppm)			
14	Iron	67	4.23
15	Copper	14	0.48
16	Zinc	34	2.07
17	Cobalt	16	0.27
18	Manganese	68	2.29

Table 2. Nutrient composition of rice DDGS as analyzed by various researchers.

Chemical composition	Gupta *et al.* [8]	Ranjan *et al.* [13]	Dinani *et al.* [14]	Xue *et al.* [9]	Talasani *et al.* [19]
Moisture (%)	8.28	7.56	8.65	-	-
Dry matter (%)	91.72	92.44	91.35	-	92.81
Crude protein (%)	45	61.41	44.68	28.55	45
Ether extract (%)	4.49	2.24	6.47	6.44	7.93
Crude fibre (%)	4.89	5.71	9.12	10.85	6.71
Total ash (%)	10.22	6.09	4.01	-	13.31
Acid insoluble ash (%)	4.28	2.67	1.27	-	1 .96
Calcium (%)	0.73	-	0.62	0.75	0.07
Phosphorus (%)	0.77	-	0.83	0.41	0.7
Gross energy (kcal/kg)	4097	4739.73	4232	4513	-
Metabolizable energy (calculated)	-	-	2880	-	3500

Table 3. Composition of amino acid in rDDGS.

S.No.	Amino acid	(%)	SE
1	Alanine	2.42	0.12
2	Arginine	2.63	0.16
3	Aspartic acid	3.31	0.23
4	Cystine	0.88	0.14
5	Glutamic acid	6.65	0.55
6	Glycine	1.72	0.36
7	Proline	2.17	0.08
8	Serine	1.95	0.20
9	Tyrosine	1.08	0.08
10	Histidine	1.07	0.08
11	Isoleucine	1.62	0.06
12	Leucine	3.64	0.14
13	Methionine	1.03	0.07
14	Phenylalanine	2.07	0.46
15	Threonine	1.43	0.27
16	Tryptophan	0.41	0.03
17	Valine	2.27	0.45
18	Lysine	1.19	0.06

Table 4. Amino acid profile of rDDGS as analyzed by various researchers.

Amino acid (%)	Luu *et* [24]	Xue *et al.* [9]	Gupta *al.* [8]
Arginine	1.42	1.47	3.06
Histidine	-	1.01	1.04
Isoleucine	1.12	0.93	1.89
Leucine	2.02	2.94	3.60
Lysine	0.99	0.64	1.23
Methionine	0.52	0.61	1.19
Phenylalanine	1.35	1.28	2.32
Threonine	1.24	0.92	1.67
Tryptophan	-	0.24	-
Valine	1.53	1.39	2.64
Alanine	1.81	1.84	2.56
Aspartic acid	2.26	1.94	3.91
Cysteine	0.61	0.62	0.98
Glutamic acid	4.52	4.08	7.48
Glycine	1.23	1.10	1.92
Proline	1.22	1.86	2.10
Serine	1.21	1.34	2.20
Tyrosine	-	1.08	-
Crude protein	23.1	28.55	45.0

study (5.15%), whereas one author observed the moisture content of rDDGS varying between 14 to 19% [15]. The findings showed that rDDGS has a reasonable amount of crude fiber and is a decent source of protein. The results were in line with the previous workers [16, 17, 18], except for crude protein content. The crude protein content of rDDGS found in this study was slightly lower when compared with the findings of some authors [14, 19, 18] who reported 42.60 to 48.43% in rDDGS. The probable reason for lower crude protein content may be due to the variability of rice grain used and/or the rate of soluble addition during rDDGS production. Another study [9] reported 28.5% CP in Chinese rDDGS produced from the fermentation of rice along with bran, whereas rDDGS with a high crude protein level of 61.41% has also been revealed [13]. According to previous researchers, the crude protein level of corn DDGS was between 29 and 30 percent, which is lower than our present findings [20, 21], and it might be due to different grain compositions. The neutral detergent fiber (NDF) and acid detergent fiber (ADF) of fiber fraction constitute 37.84% and 14.33% (% DM),

Table 5. Composition of fatty acid in rDDGS.

Sl.No.	Fatty acid			
	Lipid Number	Common Name	g/100 g fat	SE
1	C12:0	Lauric acid	0.2	0.01
2	C14:0	Myristic acid	0.31	0.02
3	C16:0	Palmetic acid	19.68	1.37
4	C16:1	Palmitoleic acid	0.37	0.06
5	C18:0	Stearic acid	1.94	0.16
6	C18:1	Oleic acid	37.4	3.38
7	C18:2	Linoleic acid	36.41	1.41
8	C18:3	Linolenic acid	1.37	0.14
9	C18:3n3	alpha linolenic acid	0.79	0.06
10	C20:0	Arachidic acid	0.8	0.06
11	C20:1	Gadoleic acid	0.96	0.04
12	C20:2	Eicosadienoic acid	0.04	0.00
13	C22:0	Behenic acid	0.02	0.00
14	Saturated fatty acid (SFA)		22.41	1.14
15	Monounsaturated fatty acid (MUFA)		39.67	1.57
16	Polyunsaturated fatty acid (PUFA)		40.01	0.96
17	Unsaturated fatty acid (UFA)		79.40	1.67

respectively. These findings are corroborated as reported [18] that the neutral detergent fiber (NDF) and acid detergent fiber (ADF) of rDDGS were 36.74% and 14.47%, respectively. In contrast, slightly higher neutral detergent fiber (40-44%) and acid detergent fiber (16-17.4%) have also been reported [16, 17, 9]. Several studies also reported the range of ether extract (2.24 to 8.90%) and crude fiber content (4.89 to 10.85%) [14, 13, 19]. The variation in the crude fiber and ether extract concentration of rDDGS may be due to differences in the nutrient content of DDGS produced from different grain sources, as well as differences in the ethanol processing and drying process of DDGS [22].

Mineral composition

Major minerals, mainly calcium (Ca) and total phosphorus (%), were 0.57 and 1.20, respectively, which shows its potential as the phosphorus source. The result of the current study could not support the findings of previous researchers (Table 2), as they have reported that calcium content was 0.07-0.09% [9, 17], which was comparatively sixfold lower than our findings; however, a high amount of calcium (1.13%) was noticed in rDDGS [16]. Similarly, the phosphorus percentage of rDDGS varied from 0.41 to 0.95% as reported in the above-cited studies, which were also lower than our findings (Table 2).

The trace minerals content, *viz.*, copper (Cu), zinc (Zn), manganese (Mn), iron (Fe), and cobalt (Co), were 14, 34, 68, 67, and 16 ppm, respectively. Similar to macrominerals, these findings are inconsistent with previously reported values. In one study, it was observed that iron, zinc, copper, and manganese content were 350, 54, 6.92, and 76.70 ppm, respectively [9]. Similar findings were also reported in another study where the values of iron, zinc, copper, and manganese were noticed as 349, 55, 7.06, and 76.35 ppm, respectively [17]. In contrast, a wide range of variability in DDGS was also observed [23], where iron content varied from 73 to 325 ppm and manganese content varied from 15 to 48 ppm. This variability might be due to various factors that involve grain source, level of inorganic fertilizer used in grain production, differences in the proportion of grain and soluble in DDGS, and extra addition of mineral compound processing technique among ethanol plants.

Amino acid composition

The amino acid content was estimated by HPLC methods. On a dry basis, the amino acids, *viz.*, alanine, arginine, aspartic acid, cystine, glutamic acid, glycine, proline, serine, tyrosine, histidine, isoleucine, leucine, methionine, phenylalanine, threonine, tryptophan, valine, and lysine, were 2.42, 2.63, 3.31, 0.88, 6.65, 1.72, 2.17, 1.95, 1.08, 1.07, 1.62, 3.64, 1.03, 2.07, 1.43, 0.41, 2.27, and 1.19 percent, respectively (Table 3).

The amino acid contents are higher in rDDGS as compared to the rice grain. The amino acid profile indicated that it is rich in both essential as well as nonessential amino acids. The lysine content in the present study was slightly higher than the earlier works [9, 24], which was probably due to a lesser crude protein level (28.55% and 23.1%, respectively), and the quantity of all amino acids (Table 4) decreased. Similarly, the lysine content in the present study was slightly lower than the earlier work [8], which is probably due to the crude protein level (45%); the quantity of all amino acids increased. The methionine content in the present study was slightly higher than the earlier works [9, 24], which was probably due to a lesser crude protein level (28.55% and 23.1%, respectively), and the quantity of all amino acids decreased. Similarly, the methionine content in the present study was slightly lower than the earlier worker [8], which is probably due to the crude protein level (45%), the quantity of all amino acids increased.

Lysine was the amino acid that varied the most among the sources of DDGS's amino acid composition [25]. Similarly, one study reported that the lysine content of DDGS varied from 0.48-0.76%, whereas the crude protein variation was between 27.0-29.8% only [26]. The amino acid content and variability are also affected by the color of DDGS because higher drying temperatures produce dark color, resulting in lower amino acid values (due to the Maillard reaction). When the amino acid profile of soy protein is compared, its inconsistency in profile may be caused by differences in the amino acid composition of the source grains that are used to produce ethanol [27]. The drying process, the improper mixing of the condensed distiller's solubles (CDS) and distiller's wet grains (DWG) during the drying process (which may alter the nutrient consistency in DDGS), and the high temperature (which may lower the protein quality) are all factors that contribute to the variation in the nutrient content [28].

Fatty acid composition

Gas chromatography analysis of the fatty acid profile reveals that unsaturated fatty acids make up the majority of the fat in rDDGS. The profile (Table 5) shows that linoleic and oleic are the most abundant fatty acids with values of 36.41% and 37.4%, respectively. A similar observation was also reported in maize DDGS [29], however, the values were lower than in the current study. The crop that is used to produce DDGS also has an impact on the fatty acid profile. Unsaturated fatty acids were predominant in rice lipids [30]. The rDDGS presented a value of 19.68% of palmitic acid, the highest among saturated fatty acids.

CONCLUSION

The study concluded that rice DDGS are a rich source of crude protein, fat, fiber, and minerals. The amino acid profile is complementary with the traditional protein source for livestock and poultry. The fat of rice DDGS is rich in omega-6 linoleic acid. In terms of gross energy, crude protein and amino acid composition, crude fiber, total ash, and fatty acid composition, rice DDGS is a highly suitable feed ingredient for both livestock and poultry.

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