

Original Article : Open Access

Influence of rice DDGS and straw mixture on growth, intake, serum enzymes and thyroid hormones of dairy heifers

Manish Pandey*, S.V. Shah*, D. C. Patel**, P. R. Pandya***, K. N. Wadhvani**** and N. P. Sarvaiya**

*Department of Livestock Production Management, College of Veterinary Science and Animal Husbandry, Anand Agricultural University, Anand-388001, Gujarat, India

**Reproductive Biology Research Unit, College of Veterinary Science and Animal Husbandry, Anand Agricultural University, Anand-388001, Gujarat, India.

*** Animal Nutrition Research Station, College of Veterinary Science and Animal Husbandry, Anand Agricultural University, Anand-388001, Gujarat, India

**** Livestock Research Station, College of Veterinary Science and Animal Husbandry, Anand Agricultural University, Anand-388001, Gujarat, India

Article Info

Article history

Received 25 February 2025

Revised 12 April 2025

Accepted 13 April 2025

Published Online 30 June 2025

Keywords

DDGS

Groundnut straw

Heifers

Growth

Serum enzymes

Thyroid hormone profile

Abstract

The current research was conducted to assess the effects of incorporating rice distillers dried grains with solubles (RDDGS) into feed and using a mixture of groundnut straw and wheat straw on the performance of heifers. The main objectives were to determine the influence on growth performance, serum enzymes and thyroid hormone profile. Twenty-four (HF× Kankrej) heifers were randomly assigned to three treatment groups based on RDDGS inclusion levels: T1 (0% RDDGS), T2 (20% RDDGS) and T3 (40% RDDGS), respectively. Each treatment group was further divided into two subgroups based on the type of straw provided: R1 (wheat straw) and R2 (a mixture of wheat straw and groundnut straw). The experiment followed a randomised block design (factorial). Inclusion of RDDGS in the feed, particularly at 40% (T3), enhances body weight of crossbred heifers. The combination of groundnut and wheat straw (R2) further improves body weight, ADG and DMI. Serum enzymes and thyroid hormones levels were within normal physiological range. These findings suggest that RDDGS and a mixture of wheat and groundnut straw do not negatively impact normal growth and metabolism. Additionally, RDDGS and straw mixtures may play a crucial role in enhancing the nutritional management and performance of dairy heifers.

1. Introduction

The expense associated with traditional protein sources such as soybean cake and groundnut cake remains high, compounded by fluctuations due to seasonal availability. With constrained potential for expanding fodder cultivation areas, the imperative lies in exploring novel and alternative feed resources, coupled with optimizing existing ones, to ensure the sustainability of animal production. Rice is a staple food crop that sustains over 60% of India's population. India is the world's second-largest rice producer and exporter and plays a crucial role in global rice production and trade (Prakash *et al.*, 2025). During rice milling process, nearly 9% of paddy rice gets broken (Linscombe, 2006). Rice distillers dried grains with soluble (RDDGS) emerge as a significant by-product of distilleries, utilizing damaged, broken or low-grade rice for fermentation. RDDGS boasts a protein content exceeding 40%, have potential to substitute costly soybean meal (Yogi *et al.*, 2017; Dey *et al.*, 2019). Its availability is projected to rise with the increasing demand for ethanol in India, prompted by legislative measures such as the Clean Air Act Amendment of 1990,

advocating for reformulated gasoline to curb air pollutants (Chatterjee *et al.*, 2016). The inclusion of dead yeast cells enriches RDDGS protein with superior amino acid composition and nutritive value (Pecka-Kielb *et al.*, 2017). Moreover, RDDGS is devoid of anti-nutritional factors (Dey *et al.*, 2019) and can replace grains up to 40% in livestock diets (Klopfenstein *et al.*, 2008). Studies suggest that RDDGS can be incorporated into growing heifers' rations at levels up to 40% of dry matter intake (Kalscheur and Garcia, 2004). Dried distillers grains with soluble when incorporated in the dairy cow diet before calving improves colostrum quality, increases immunoglobulin levels and passive immunity in calves (Zachwieja *et al.*, 2025). Incorporating dried distillers grains with solubles in cattle diets does not increase CH₄ emissions, supporting sustainable livestock feeding practices (Mallik *et al.*, 2024).

Moreover, dairy animals predominantly consume cereal straws in India, with an annual availability exceeding a hundred million metric tons. Cereal straws contain low crude protein and essential minerals and possess low digestibility and voluntary intake, contributing to energy-protein malnutrition among livestock. India is the world's second-largest producer of groundnuts, yielding 10.24 million tonnes (MT) annually, following China. According to FAO data, approximately 5.96 million hectares of land in India were dedicated to groundnut cultivation in 2021 (Suthar *et al.*, 2024) underscoring

Corresponding author: Dr. Manish Pandey

Scientist, Division of Animal Science, Poultry and Fisheries, ICAR-Indian Agriculture Research Institute, Dhemaji-787035, Assam, India

E-mail: manish.pandey@icar.gov.in; manish1110222@gmail.com

Tel.: +91-7579013455

Copyright © 2025 Ukaaz Publications. All rights reserved.

Email: ukaaz@yahoo.com; Website: www.ukaazpublications.com

the potential of groundnut crop residues. Groundnut straw, a by-product of groundnut cultivation, presents itself as a viable supplement or sole feed (Etela and Dung, 2011). RDDGS, alongside legume straw, emerges as an excellent source of protein and energy, promising to address the nutritional deficiencies prevalent in livestock diets, particularly among developing replacement heifers. In light of these considerations, current study explores the utilization of rice distillery by-products and groundnut straw as sustainable alternatives in livestock nutrition, offering insights into their nutritional profiles, feeding strategies and implications for livestock health and production efficiency. The primary aim was to evaluate RDDGS and wheat and groundnut straw mixture effect on normal growth and metabolism of dairy heifers.

2. Materials and Methods

2.1 Experimental location, experimental animals and duration

The study was carried out at the Livestock Research Station, College of Veterinary Science and Animal Husbandry, Anand Agricultural University, Anand, Gujarat, involving twenty-four Holstein Frisian

and Kankrej cross (75:25) heifers with a mean body weight of 116.13 ± 4.74 kg and an average age of 281.92 ± 13.26 days. The main aim was to evaluate RDDGS and straw mixture effect on normal growth and metabolism of heifers. A 168-day feeding trial was conducted from 24th June 2020 until 9th December 2020. Prior approval was taken from CPCSEA/IAEC for carrying out the experiment (CPCSEA Reg. No: 486/GO/Re-S/ReBi-L/01/CPCSEA, dated 1/11/2021 and project No: 313/LPM/2019).

2.2 Experimental treatments and feeding regime

There were three main treatment groups T1, T2 and T3 groups based on concentrates type containing 0%, 20% and 40% RDDGS. Within each concentrate type, half of the heifers were provided with wheat straw (R1 group), while the other half received a mixture of groundnut straw and wheat straw as dry roughage (R2 group) (Table 1). The experiment followed a randomised block design (factorial). Ingredient (RDDGS) and Groundnut straw were procured from Daman, India rice grain distillery and Regional Research Station, Anand Agricultural University, Anand, Gujarat.

Table 1: Type of concentrate and straw mixture offered to experimental heifers

Groups		Number of heifers	Ingredients in ration		
			Concentrate	Dry roughage	
				Wheat straw	Groundnut straw
T1	R1	4	Concentrate-I 50%	50%	0%
	R2	4		25%	25%
T2	R1	4	Concentrate-II 50%	50%	0%
	R2	4		25%	25%
T3	R1	4	Concentrate-III 50%	50%	0%
	R2	4		25%	25%

* Concentrates (Types I, II, III) contain varying proportions of rice dried distillers grains with solubles (RDDGS): T1 (0%), T2 (20%), T3 (40%). Dry roughage includes wheat straw (R1) and a mixture of groundnut straw and wheat straw 1:1 (R2). Heifers were also offered with a preset 35 gm/head/d mineral mixture throughout the experiment.

Table 2: Proximate composition of various feed ingredients (% DM basis)

Particulars	Rice DDGS	Soya DOC	Amul dan	Groundnut straw	Wheat straw	Hybrid napier
OM	95.18	87.60	86.27	90.79	87.54	80.14
CP	44.67	43.15	18.8	10.67	2.63	10.60
EE	7.27	0.15	2.79	2.24	3.33	2.32
CF	2.04	8.93	16.26	30.37	39.26	28.18
Ash	4.82	12.45	13.73	9.21	12.46	19.87
NFE	41.2	35.32	48.42	47.51	42.32	39.03

*OM-Organic matter, CP-Crude protein, EE-Ether extract, CF-Crude fiber, NFE-Nitrogen free extract. Analysis was performed at Centre of Excellence for Animal Nutrition, AAU, Anand.

2.3 General management

All selected experimental heifers were de-wormed with Fenbendazole @ 7.5 mg/kg BW before the starting experimental trial. They were reared under iso-managerial conditions in ventilated, hygienic sheds, receiving calculated amounts of concentrate, roughage and green fodder as per the treatment schedule. Individual animals were tethered with neck chains in front of partitioned mangers for individual feeding.

2.4 Feeding management

Protein requirements were met as per ICAR (2013) feeding standards. Concentrate and roughage were offered twice daily between 9:00 to 9:30 h and 16:00 to 16:30 h. Experimental heifers also received fixed amounts of green hybrid napier based on body weight. Protein requirements were adjusted biweekly based on changes in body weight. Feed leftovers were weighed the following morning, with

additional wheat straw provided, if necessary to meet rumen fill requirements.

2.5 Analysis of feeds and fodder samples

Feed ingredients and concentrates were analysed for proximate principles according to AOAC (2000) standards at the Centre of Excellence for Animal Nutrition, Anand Agricultural University, Gujarat, India (Tables 2 and 3).

2.6 Observations recorded

- **Body weight:** Recorded fortnightly using an electronic weighing platform.
- **Feed intake:** Measured and recorded daily, with moisture content measured biweekly to calculate actual dry matter

consumption. Feeding trough was partitioned to ensure individual feeding.

- **Blood collection and serum enzyme analysis:** Blood samples were collected fortnightly from the jugular vein and analysed for serum creatinine by Jaffh's method, ALT and AST were analyzed using readymade diagnostic kits in Mindray BS-120 chemistry analyser as per the method described by Reitman and Frankel (1957).
- **Hormonal profile:** Serum samples collected at specified intervals (0, 28, 56, 84, 112, 140 and 168 day) were analysed for Triiodothyronine and Thyroxine levels using standard radioimmunoassay technique, kits were procured from Immunotech S.R.O., Radiova 1, 102 27 Prague 10, Czech Republic as described by Berson *et al.* (1964).

Table 3: Proximate composition of experimental concentrate mixtures, % DM basis

Particulars	Concentrate-I (0% RDDGS)	Concentrate-II (20% RDDGS)	Concentrate-III (40% RDDGS)
OM	86.58	88.18	89.77
CP	28.33	28.91	29.17
EE	1.70	3.05	4.42
CF	12.66	11.36	10.48
Ash	13.42	11.82	10.23
NFE	43.89	44.86	45.70

*OM-Organic matter, CP-Crude protein, EE-Ether extract, CF-Crude fiber, NFE-Nitrogen free extract. Analysis was performed at Centre of Excellence for Animal Nutrition, AAU, Anand.

Table 4: Body weight, average daily gain, dry matter intake of experimental heifers

Particulars	Group				
	T1	T2	T3	R1	R2
Body weight (kg)	177.54 ^A ± 4.63	178.99 ^A ± 4.35	182.32 ^B ± 4.60	177.25 ^a ± 3.59	181.98 ^b ± 3.79
CD		2.807			2.292
ADG (g/head/d)	703.9 ^A ± 21.0	723.2 ^A ± 22.4	779 ^B .9 ± 23.2	720.2 ± 18.6	751.1 ± 17.9
CD		52.56			NS
DMI (kg/head/d)	4.70 ± 0.07	4.65 ± 0.06	4.71 ± 0.06	4.57 ^a ± 0.05	4.81 ^b ± 0.05
CD		NS			0.055
DMI (kg/100 kg BW)	2.66 ^B ± 0.04	2.59 ^A ± 0.03	2.58 ^A ± 0.03	2.57 ^a ± 0.03	2.65 ^b ± 0.03
CD		0.035			0.029
DMI (kg/kg BW gain)	7.65 ± 0.53	7.17 ± 0.29	6.75 ± 0.30	7.33 ± 0.39	7.05 ± 0.22
CD		NS			NS

*Means with different superscripts in a row (A, B) differ significantly for concentrate and (a, b) differ significantly for roughage source ($p < 0.05$).

*CD-Critical Difference at 5% significance level.

2.7 Statistical analysis

The study utilized a factorial design within a randomised block design (RBD) framework. Data were analyzed using a two-way Analysis of Variance (ANOVA) conducted with in-house software, adhering to the methodological guidelines of Snedecor and Cochran (2002). Factor one was the concentrate levels (T1 = 0% RDDGS, T2 = 20% RDDGS, and T3 = 40% RDDGS), and factor two was the type of straw (R1 = wheat straw, R2 = a 1:1 mixture of groundnut straw and wheat straw). Results are written separately for factor one and factor two for simplified understanding.

3. Results

3.1 Effects of RDDGS on heifers' body weight, average daily gain (ADG) and dry matter intake (DMI)

The effects of different levels of RDDGS on body weight, ADG and DMI were evaluated fortnightly (Table 4). The average body weight of heifers in T1 (40% soya DOC) was 177.54 ± 4.63 kg, while in T2 (20% soya DOC + 20% RDDGS) it was 178.99 ± 4.35 kg. Heifers at T3 (40% RDDGS) showed significantly ($p < 0.05$) higher body weight of 182.32 ± 4.60 kg compared to T1 and T2 groups. The ADG (g/

head/d) of heifers in the T3 group (779.9 ± 23.2) receiving 40% RDDGS was significantly ($p < 0.05$) higher than that of T2 and T1 groups. Dry matter intake (DMI) (kg/head/d) of heifers did not change significantly with the inclusion of RDDGS in concentrate across all groups. However, DMI (kg/100 kg BW) showed a significant reduction ($p < 0.05$) with the replacement of soya DOC with RDDGS.

3.2 Effects of RDDGS on serum creatinine, ALT and AST levels of heifers

The serum creatinine level at different durations was evaluated (Figure 1). The average serum creatinine (mg/dl) of T1, T2 and T3 experimental heifers was 1.13 ± 0.02 , 1.02 ± 0.02 and 1.04 ± 0.02 , respectively. Serum creatinine was significantly ($p < 0.05$) lower in T2 and T3 heifers that received RDDGS compared to T1 heifers.

While serum ALT levels remained statistically similar across groups, AST levels increased linearly with RDDGS inclusion. T3 heifers showed significantly ($p < 0.05$) higher AST levels compared to T1 and T2.

3.3 Effects of RDDGS on thyroid hormone profiles of heifers

Serum tri-iodothyronine and serum thyroxine levels were assessed in heifers at different days (Figures 4 and 5). Average serum tri-iodothyronine (ng/ml) in T1, T2 and T3 group heifers was observed to be 2.69 ± 0.15 , 2.81 ± 0.16 and 2.94 ± 0.13 , respectively. Serum tri-iodothyronine levels were statistically similar among T1, T2 and T3 groups. Average serum thyroxine (ng/ml) in T1, T2 and T3 group heifers was found to be 52.20 ± 2.47 , 57.86 ± 4.09 and 52.30 ± 2.70 , respectively. Serum thyroxine concentrations also showed no significant differences between experimental groups.

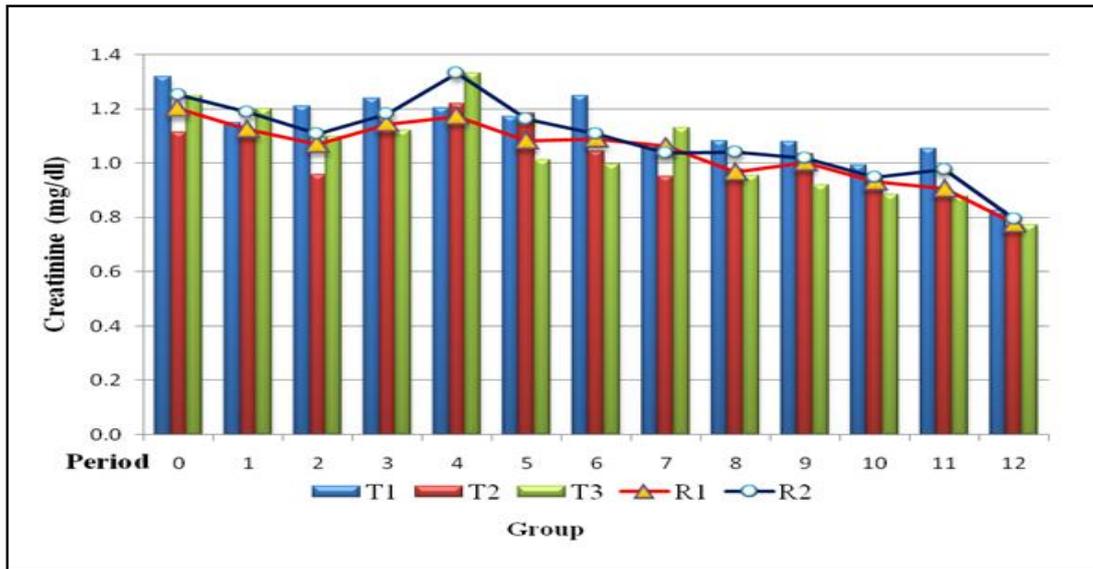


Figure 1: Serum creatinine (mg/dl) level of experimental heifers at start of experiment (0 day) then at every fortnightly interval. T1 (0% RDDGS), T2 (20% RDDGS), T3 (40% RDDGS), R1 (Wheat straw) and R2 (Wheat straw and groundnut straw in 1:1).

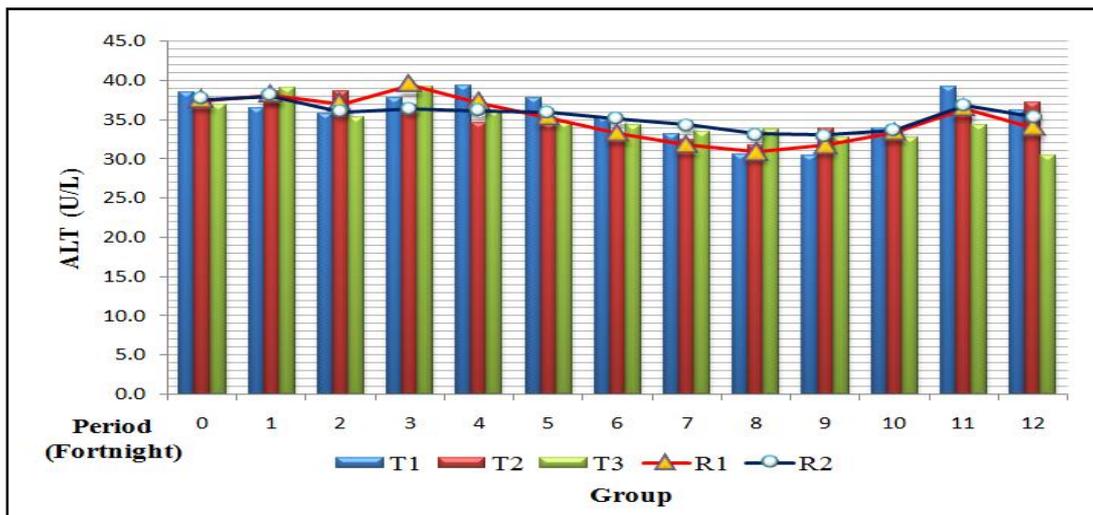


Figure 2: Serum ALT (U/L) of levels of experimental heifers at start of experiment (0 day) then at every fortnightly interval. T1 (0% RDDGS), T2 (20% RDDGS), T3 (40% RDDGS), R1 (Wheat straw) and R2 (Wheat straw and groundnut straw in 1:1).

3.4 Effects of groundnut straw and wheat straw mixture on body weight, ADG and DMI of heifers

The body weight, ADG and DMI of heifers fed wheat straw (R1) and a mixture of groundnut and wheat straw (R2) are presented in Table 4. Heifers in the R2 group had significantly ($p < 0.05$) higher body weight and DMI compared to R1. However, the increase in ADG for R2 was non-significant.

3.5 Effects of groundnut straw and wheat straw mixture on serum creatinine, ALT and AST levels

Serum creatinine, ALT and AST levels were evaluated in R1 and R2 group heifers (Figures 1, 2, and 3). Heifers in the R2 group had significantly ($p < 0.05$) higher serum creatinine and AST levels compared to R1, while ALT levels remained statistically similar between groups.

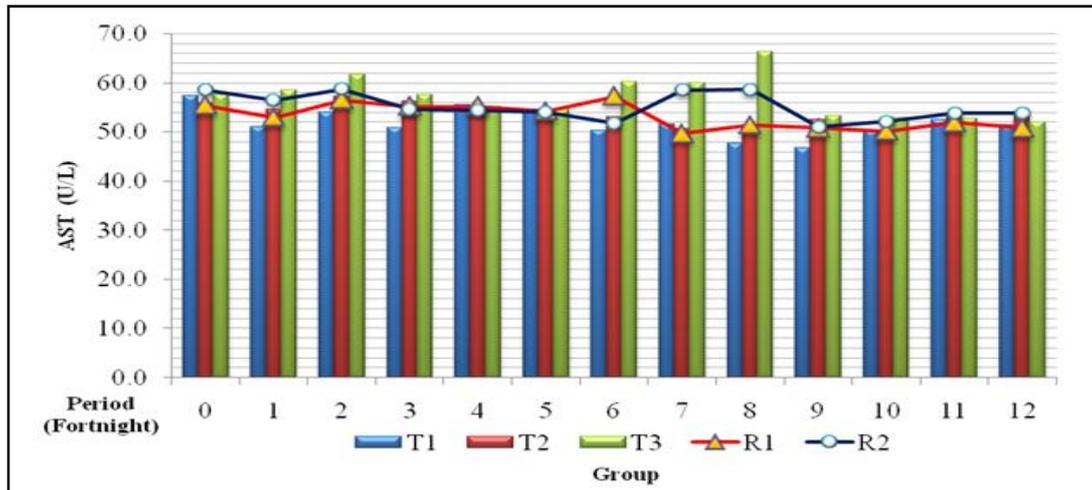


Figure 3: Serum AST (U/L) levels of experimental heifers at start of experiment (0 day) then at every fortnightly interval. T1 (0% RDDGS), T2 (20% RDDGS), T3 (40% RDDGS), R1 (Wheat straw) and R2 (Wheat straw and groundnut straw in 1:1).

3.6 Effects of groundnut straw and wheat straw mixture on thyroid hormone profiles of heifers

Serum tri-iodothyronine and thyroxine levels were assessed at different days (Figures 4 and 5). Average tri-iodothyronine (ng/ml) in R1 and R2 group heifers was found to be 2.60 ± 0.10 and $3.02 \pm$

0.13 , respectively. Serum triiodothyronine levels were significantly ($p < 0.05$) higher in R2 heifers. Average serum thyroxine (ng/ml) concentration in R1 and R2 group heifers was found to be 54.30 ± 2.16 and 53.94 ± 2.97 , respectively. Serum thyroxine levels remained statistically similar in R1 and R2 group heifers.

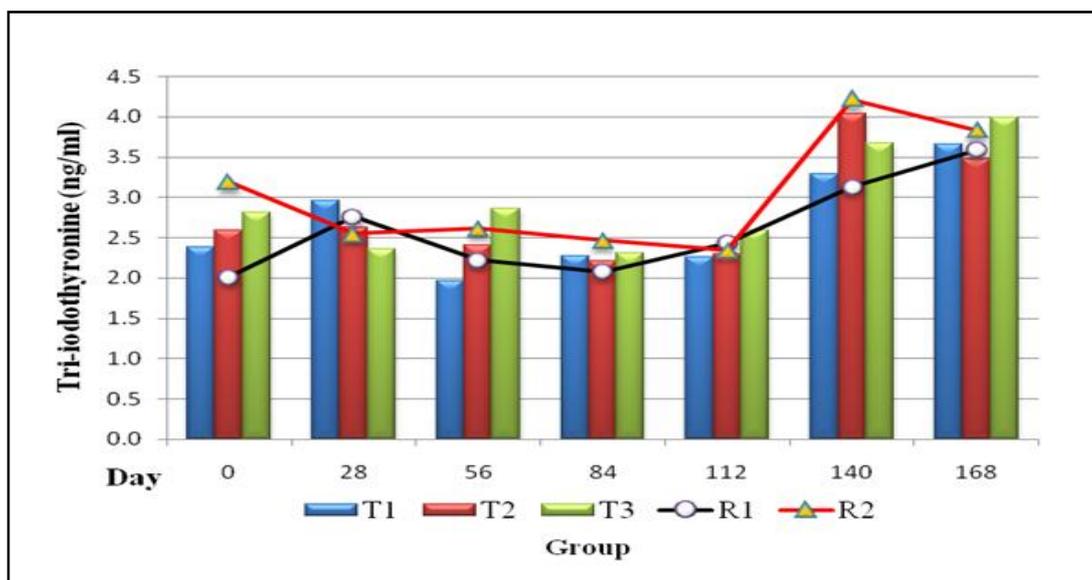


Figure 4: Serum tri-iodothyronine (ng/ml) levels of experimental heifers at start of experiment (0 day) then at 28, 56, 84, 112, 140 and 168 days. T1 (0% RDDGS), T2 (20% RDDGS) and T3 (40% RDDGS). R1 (Wheat straw) and R2 (Wheat straw and groundnut straw in 1:1).

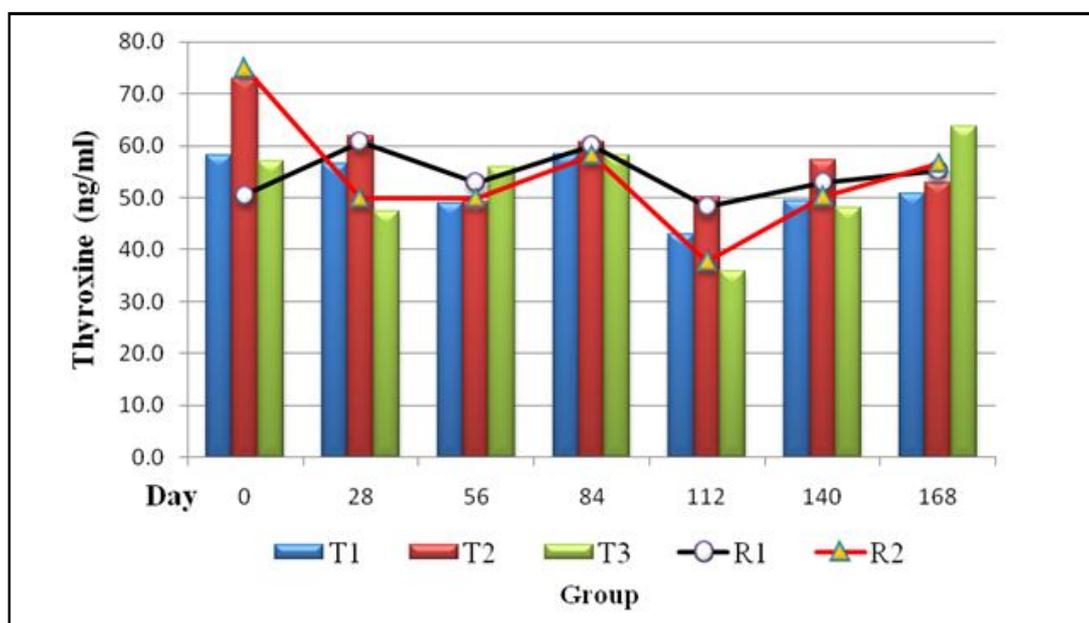


Figure 5: Serum thyroxine (ng/ml) levels of experimental heifers at start of experiment (0 day) then at 28, 56, 84, 112, 140 and 168 days. T1 (0% RDDGS), T2 (20% RDDGS), T3 (40% RDDGS), R1 (Wheat straw) and R2 (Wheat straw and groundnut straw in 1:1).

4. Discussion

Present research reported significantly ($p < 0.05$) higher body weight and ADG in heifers offered RDDGS, aligning with findings reported by Sousa *et al.* (2025) in feedlot cattle and Eun *et al.* (2009) in beef steers. However, Gibb *et al.* (2008) reported a non-significant linear increase in body weight on DDGS supplementation, while Manthey *et al.* (2016), Beretta *et al.* (2020) and Huang *et al.* (2020) in heifers, steers and buffaloes, respectively, found non-significant changes in body weight with DDGS feeding. Contrarily, Depenbusch *et al.* (2009) reported irregular changes ($p \leq 0.03$) in final body weight with higher levels DDGS. The inclusion of RDDGS did not significantly alter the dry matter intake (DMI) (kg/head/day) of heifers, consistent with previous research (Ranathunga *et al.*, 2018; Beretta *et al.*, 2020; Huang *et al.*, 2020; Fonseca *et al.*, 2021; Gullickson *et al.*, 2023; Ross *et al.*, 2024). Conversely, Gibb *et al.* (2008) reported a significant ($p < 0.05$) linear increase in DMI (kg/day) in feedlot cattle. Eun *et al.* (2009) found a significant ($p < 0.05$) decrease in DMI when feeding corn-DDGS to beef steers during both background and finishing periods. Garnsworthy *et al.* (2020) observed a linear decrease in DMI (23.1, 23.1, 22.9, and 22.3 kg/day) with a significant reduction at a 240 g/kg WDDGS level in dairy cows. Depenbusch *et al.* (2009) found an irregular pattern ($p < 0.03$) in DMI, with the highest intake observed at a 15% DGS diet. While DMI increased with up to 20% DDGS inclusion in dairy cow diets, higher levels potentially reduced intake due to high fat concentration (Council, U.G., 2012). Regarding gain-to-feed ratio, Gibb *et al.* (2008) found similar ratios during both background and finishing periods in heifers fed DDGS, consistent with Eun *et al.* (2009) in finishing beef steers. However, Gibb *et al.* (2008) reported a significant ($p < 0.05$) linear decrease in gain-to-feed ratio with increasing DDGS in heifer diets during the finishing period, while Eun *et al.* (2009) noted a linear increase with higher DDGS levels during the growing phase in beef steers. The serum creatinine levels in experimental heifers were within the normal range for cows

(0.5-2.2 mg/dl) as described by Khan and Line (2010). The serum ALT levels were within the usual range specified by Kaneko *et al.* (2008), while serum AST levels increased significantly with higher RDDGS inclusion. These findings align partially with Dey *et al.* (2019), who reported no significant change in ALT but varying AST levels based on dietary modifications. The serum triiodothyronine and thyroxine levels in this study were consistent with reference ranges established by Kaneko *et al.* (2008). While Pereira *et al.* (2008), Pauliková *et al.* (2011) and Baek *et al.* (2019) reported higher Serum thyroxine levels in heifers, breed and environmental conditions could explain these differences. This study indicates that concentrate composition, including RDDGS, did not significantly impact thyroid hormone profiles.

Crossbred heifers that received wheat straw and groundnut straw mixture as roughage showed significant ($p < 0.05$) increase in body weight, although there was only a numerical increase in ADG, consistent with Desai (2020), who observed similar results with mixed cereal and legume straw over sorghum hay. However, AAU (2019) reported only numerical improvements in body weight gain and a significant ($p < 0.05$) increase in ADG when feeding a mixture of cereal and legume straw over cereal straw alone. Feeding a mixture of wheat straw and groundnut straw significantly ($p < 0.05$) increased DMI (kg/head/day) in heifers, as observed by Desai (2020) in crossbred calves. However, AAU (2018) in crossbred calves and AAU (2019) in calves reported no significant changes in DMI, with a numerical increase observed in feeding legume and cereal straw mixture compared to cereal straw alone. DMI (kg/kg BW gain) did not significantly differ when a mixture of wheat straw and groundnut straw (R2) was offered to heifers compared to wheat straw alone (R1), although there was a numerical decrease in DMI (kg/kg BW gain) in the R2 group, similar to findings by Desai (2020) in crossbred calves. Serum creatinine and AST levels were influenced by roughage type, with higher levels observed in R2 heifers. These results align

with findings by Desai (2020), who noted variations in biochemical parameters based on roughage composition. The increase in triiodothyronine levels with groundnut straw inclusion suggests enhanced metabolic activity. These findings are consistent with Desai (2020), who reported similar hormonal responses with legume-based roughages. However, thyroxine levels remained unaffected, indicating that thyroid activity was not compromised.

5. Conclusion

This study concludes that replacing soya DOC with rice distillers dried grains with solubles (RDDGS) in the diet of crossbred heifers significantly improved growth performance and maintained normal physiological parameters. Heifers fed a higher level of RDDGS (40% in concentrate) exhibited superior body weight and average daily gain (ADG) compared to those fed soya DOC alone. Despite the inclusion of RDDGS, dry matter intake (DMI) remained consistent, while a reduction in DMI per kg body weight gain was observed with higher RDDGS levels. Serum biochemical parameters such as creatinine, ALT and AST generally stayed within normal reference ranges, though an increase in serum AST was noted with higher RDDGS levels, suggesting the need for further investigation. Additionally, the study found that the inclusion of groundnut straw with wheat straw in the roughage significantly elevated serum triiodothyronine levels, whereas serum thyroxine levels remained unaffected, indicating potential metabolic benefits. These findings highlight the effectiveness of RDDGS as a sustainable alternative to soya DOC and the benefits of mixed roughage strategies for improving metabolic efficiency in heifers. These insights underscore the potential of RDDGS and groundnut straw in enhancing sustainable livestock production practices.

Acknowledgements

The fund for the research was provided by the Director Research, Anand Agricultural University, Anand-388001, Gujarat, India. The first author is also a recipient of ICAR-JRF/SRF (F. No. EDN/1/25/2015) fellowship and hence acknowledges the Indian Council of Agricultural Research, India.

Conflict of interest

The authors declare no conflicts of interest relevant to this article.

References

- Anand Agricultural University (2018). Proceeding of 14th Meeting of Agricultural Research Subcommittee Animal Production and Fisheries subcommittee. AAU, Anand, Gujarat, India. Annual Progress Report.
- Anand Agricultural University (2019). Proceeding of 15th Meeting of Agricultural Research Subcommittee Animal Production and Fisheries subcommittee. AAU, Anand, Gujarat, India. Annual Progress Report.
- Association of Analytical Chemist (2000). Official methods of analysis (17thed). Washington, D.C.U.S.A.
- Baek, Y. C.; Kim M.; Jeong J. Y.; Oh Y. K.; Lee S. D.; Lee Y. K.; Ji S. Y. and Choi H. (2019). Effects of short-term acute heat stress on physiological responses and heat shock proteins of Hanwoo steer (Korean cattle). *J. Ani. Reprod. Biotech.*, **34**(3):173-182.
- Beretta V.; Simeone A.; Franco J.; Bentancur O.; Novac M.; Panizza, V. and Rodríguez M. V. (2020). Using sorghum dry distillers' grains plus solubles in sorghum-based finishing diets: Feed utilization, cattle performance and carcass traits. *Ani. F. Sci. Tech.*, **271**:114731.
- Berson, S. A.; Yalow, R. S.; Glick, S. M. and Roth, J. (1964). Immunoassay of protein and peptide hormones. *Metabolism*, **13**(10):1135-1153.
- Chatterjee A.; Dey D.; Mandal D. K.; Mohammad A. and Bhakat, C. (2016). Utilization of rice dried distillery grain with soluble as feed for ruminants. International Conference on Agriculture, Food Science, Natural Resource Management and Environmental Dynamics, **74**-77.
- Council U. G. (2012). A guide to distiller's dried grains with soluble (3rded.). U. S. Grain Council. http://www.ddgs.umn.edu/prod/groups/cfans/@pub/@cfans/@ansci/documents/ass_et/cfans_asset_417244.Pdf.
- Deppenbusch B. E.; Coleman C. M.; Higgins J. J. and Drouillard J. S. (2009). Effects of increasing levels of dried corn distillers grains with solubles on growth performance, carcass characteristics, and meat quality of yearling heifers. *J. Ani. Sci.*, **87**(8):2653-2663.
- Desai Y. A. (2020). Effect of Watering Frequency and Feed on Growth of Crossbred Calves. M.V.Sc. Thesis, College of Veterinary Science and Animal Husbandry, Anand Agricultural University, Anand, Gujarat.
- Dey D.; Sharma B.; Mohammad A.; Mandal D. K.; Bhakat C.; Dutta T. K. and Chatterjee A. (2019). Effect of feeding rice distillers dried grain with solubles as major protein source on nutrient digestibility and growth performance of Jersey crossbred calves. *Ind. J. Ani. Res.*, **54**(4):446-451.
- Etela I. and Dung D. D. (2011). Utilization of stover from six improved dual-purpose groundnut (*Arachis hypogaea* L.) cultivars by West African dwarf sheep. *Afr. J. Food Agri. Nutri. Develop.*, **11**(1):4538-4545.
- Eun J. S.; ZoBell D. R. and Wiedmeier R. D. (2009). Influence of replacing barley grain with corn-based dried distillers grains with solubles on production and carcass characteristics of growing and finishing beef steers. *Ani. Feed Sci. Tech.*, **152**(1-2):72-80.
- Fonseca, N. V. B.; Cardoso, A. D. S.; Hoffmann, A.; Leite, R. G.; Ferrari, A. C.; Fernandes, M. H. M. D. R. and Reis, R. A. (2021). Characterization and effects of DDG on the intake and digestibility of finishing bulls in feedlots. *Acta Scientiarum Ani. Sci.*, **43**, e51877.
- Garnsworthy P. C.; Marsden M.; Goodman J. R. and Saunders N. (2021). Inclusion of wheat dried distillers' grains with solubles from bioethanol plants in diets for dairy cows. *Animals*, **11**(1):70.
- Gibb D. J.; Hao X. and McAllister T. A. (2008). Effect of dried distillers' grains from wheat on diet digestibility and performance of feedlot cattle. *Canadian J. Ani. Sci.*, **88**(4):659-665.
- Gullickson, G. J.; Nichols, M.; Entzie, Y. L.; Hansen, L. E.; Underdahl, S. R.; Hanna, L. L.; Tobin, C. T.; Swanson, K. C. and Carlson, Z. E. (2023). Effects of replacing dried distillers grains with solubles with heat-treated soybean meal in forage-based growing cattle diets. North Dakota Livestock Research Report, pp:31.
- Huang J.; Wu T.; Sun X.; Zou C.; Yang Y.; Cao Y.; Yang Y.; Iqbal M. W. and Lin B. (2020). Effect of replacing conventional feeds with tropical agricultural by products on the growth performance, nutrient digestibility and ruminal microbiota of water buffaloes. *J. Ani. Physi. Ani. Nut.*, **104**(4):1034-1042.
- Indian Council of Agricultural Research (2013). Nutrients Requirements of Cattle and Buffalo. Official Publication. Nutrients requirement of Animals. ICAR, New Delhi, India.
- Kalscheur, K. F. and Garcia, A. D. (2004). Use of by-products in growing dairy heifer diets. *Extension Extra*, 4030:3.
- Kaneko J. J.; Harvey J. W. and Bruss M. L. (2008). Clinical biochemistry of domestic animals. Academic press.
- Khan, C. M. and Line S. (2010). The Merck veterinary manual. Whitehouse Station, NJ: Merck. & Co. pp:2584-2586.

- Klopfenstein T. J.; Erickson, G. E. and Bremer, V.R. (2008).** Board-invited review: Use of distillers by-products in the beef cattle feeding industry. *J. Ani. Sci.*, **86**(5):1223-1231.
- Linscombe, S. (2006).** Rice Quality Determines Payment. Available online at: https://www.lsuagcenter.com/portals/our_offices/research_stations/rice/features/publications/rice-quality-determines-payment.
- Malik, M. I.; Li, J.; Capucchio, M. T.; Hassan, T. and Sun, X. (2024).** Effects of distiller's dried grains with solubles on enteric methane emissions in dairy and beef cattle: A meta-analysis. *Front. Vet. Sci.*, **11**:1480682.
- Manthey, A. K.; Anderson J. L. and Perry, G.A. (2016).** Feeding distillers dried grains in replacement of forage in limit-fed dairy heifer rations: Effects on growth performance, rumen fermentation, and total-tract digestibility of nutrients. *J. Dairy Sci.*, **99**(9):7206-7215.
- Pandey, P. (2015).** Effect of elevated temperature and carbon-dioxide level on physiological and biochemical functions in zebu and crossbred cattle. (M.V.Sc. Thesis, ICAR-National Dairy Research Institute, Karnal, India). Retrieved from <https://krishikosh.egranth.ac.in>.
- Paulíková, I.; Seidel, H.; Nagy, O.; Tóthová, C. and Kováč, G. (2011).** Concentrations of thyroid hormones in various age categories of ruminants and swine. *Acta Veterinaria*, **61**(5-6):489-503.
- Pecka-Kielb, E.; Zachwieja A.; Mieta, D.; Zawadzki W. and Zielak-Steciwo A. (2017).** Use of Corn Dried Distillers Grains (DDGS) in Feeding of Ruminants. In *Frontiers in Bioenergy and Biofuels*. IntechOpen.
- Pereira, A. M.; Baccari F.; Titto E. A. and Almeida J. A. (2008).** Effect of thermal stress on physiological parameters, feed intake and plasma thyroid hormones concentration in Alentejana, Mertolenga, Frisian and Limousine cattle breeds. *Int. J. Biomet.*, **52**(3):199-208.
- Prakash, N. B.; Dhumgond, P.; Shruthi; Goiba, P. K. and Yogesh, G. S. (2025).** Enhancing yield and nutrient dynamics of rice through long term fertilization with slag-based and commercial gypsum in Southern India. *Sci. Rep.*, **15**(1):4990.
- Ranathunga, S. D.; Kalscheur K. F.; Anderson, J. L. and Herrick K. J. (2018).** Production of dairy cows fed distillers dried grains with solubles in low-and high-forage diets. *J. Dairy Sci.*, **101** (12):10886-10898.
- Reitman, S. and Frankel, S. (1957).** A colorimetric method for the determination of serum glutamic oxalacetic and glutamic pyruvic transaminases. *American J. Clin. Pathol.*, **28**(1):56-63.
- Ross, C. R.; Smith, Z. K.; Francis, F. L.; Menezes, A. C. B. and Rusche, W. C. (2024).** Increased dietary rumen degradable protein from soybean meal improved growth performance but increased liver abscess severity in finishing beef steers. *App. Ani. Sci.*, **40**(5):627-638.
- Snedecor, G. W. and Cochran W. G. (2002).** *Statistical methods* (7th ed.). The Iowa State University Press, Ames, Iowa, USA.
- Sousa, D. G.; McDermott, R. L.; Norman, M. M.; MacDonald, J. C.; Stock, R.; Mass, R. A. and Erickson, G. E. (2025).** Impact of Feeding Distillers Grains Compared to New Fractionated Distillers Grains (Solbran) on Feedlot Cattle Performance and Enteric Methane.
- Suthar, B.; Pundir, R. S.; Gundaniya, H. and Mishra, K. (2024).** Growth and instability analysis of area, production and yield of groundnut in selected states of India. *Env. Conservation J.*, **25**(1):192-198.
- Yogi, R. K.; Thakur S. S.; Mohini M., Singh S. K. and Malik, T. (2017).** *In vitro* evaluation of concentrate mixtures containing incremental level of rice dried distillers grain with solubles replacing oil cakes in concentrate mixture. *Ind. J. Ani. Nut.*, **34**(2):163-168.
- Zachwieja, A.; Pecka-Kielb, E.; Humienna, K.; Zielak-Steciwo, A.; Króliczewska, B.; Kaszuba, J.; Adamski, M.; Tumanowicz, J. and Wilk, M. (2025).** Dried Distillers' Grains with Solubles as a key feed ingredient in dairy cow diets: Implications for colostrum quality and calf immunity. *The Vet. J.*, **310**:106317.

Citation

Manish Pandey , S.V. Shah, D. C. Patel, P. R. Pandya, K. N. Wadhvani and N. P. Sarvaiya (2025). Influence of rice DDGS and straw mixture on growth, intake, serum enzymes and thyroid hormones of dairy heifers. *Ann. Phytomed.*, **14(1):1082-1089. <http://dx.doi.org/10.54085/ap.2025.14.1.108>.**