Research Article

DOI: 10.48165/ijar.2021.42.2.7

The Indian Journal of Animal Reproduction

The official journal of the Indian Society for Study of Animal Reproduction

Year 2021, Volume-42, Issue-2 (Dec)

ACS Publisher www.acspublisher.com

ISSN 0970-2997 ***(Print)***

Effect of Feeding DDGS on Body Weight Gain, Steroid Hormones Profile, Age at Puberty and its Economics in Crossbred Heifers

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ABSTRACT

The study was undertaken on HF x Kankrej heifers (n=24) from average 8 months till 19 months of age. The aim was to evaluate the effect of feeding distillers dried grains with soluble (DDGS) and Soy DOC alone or in combination with cereal and/or leguminous straws as TMR on their body weight gain, serum steroid hormones profile, ovarian changes, age at puberty/sexual maturity and its economic benefits. Monthly gain in body weight, and serum P_4 and E_2 levels increased progressively with advancing age. Ovarian activity in terms of follicles and corpus luteal (CL) was noticed from 14 months of age onwards with pregnancy in more than 60% heifers by 19 months and 100% by 23 months of age. Higher body weight gain (BWG) was observed in DDGS and legume straw fed groups as compared to soy DOC and cereal straw fed groups. Average age at onset of puberty and sexual maturity/conception were 552.21±10.72 and 616.79±15.67 days, respectively, with mean number of AIs per conception as 2.83±0.40. Overall, supplementation of DDGS and legume gotar in ration did not influence the reproductive hormone parameters and age at maturity. Though daily feed cost (₹ / head) remained the same, the feed costs per kg BW gain (₹) were reduced significantly (P<0.01) in heifers fed half and full soy DOC replacement with DDGS (135.83±2.42, and 122.42±2.34 vs 148.00±2.96). So it can be concluded that feeding TMR consisting of DDGS in place of soy DOC in concentrate mixture and a mixture of legume straw and cereal straw (groundnut gotar and wheat straw) to growing crossbred heifers is superior with respect to body weight gain, steroid hormone profile and improved reproductive efficiency.

Key words: Body weight gain, DDGS, HF x Kankrej heifers, Ovarian function, Puberty, Gonadal hormones.

How to cite: Dhami, A., Shah, S., Chaudhari, D., Lunagaria, P., Chaudhary, M., & Sarvaiya, N. (2021) Effect of Feeding Ddgs on Body Weight Gain, Steroid Hormones Profile, Age at Puberty and its Economics in Crossbred Heifers. *The Indian Journal of Animal Reproduction, 42*(2), 39–47. https://doi.org/10.48165/ijar.2021.42.2.7

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Received 26-12-2022; Accepted 26-01-2023

INTRODUCTION

Optimizing growth rate through proper and cost-effective ration in growing heifers is the first step to reduce age at puberty and calving for economic benefits. Distillers dried grains with soluble (DDGS) is one of the residual co-produced from the production of ethanol from grain after fermentation of starch and is rich in protein, fat, vitamins and minerals (Youssef *et al*., 2013). Distillers' grains have been reported to be good source of rumen undegradable protein (RUP) and energy for ruminants. Yeast present in decoction not only improves the composition of amino acids in its protein but also the taste. Protein is extremely important in the diet of growing heifers to ensure adequate frame size, growth and onset of cyclicity. Replacing protein from soybean feeds with DDGS is cost effective and does not affect production in dairy cows (Ranathunga *et al*., 2018). It can be added to ration of growing heifers up to 40% of DMI to achieve improved growth rate and FCR (Kalscheur and Garcia, 2004). Legume straws contain 40-100 % more DCP than cereal straws and can meet production requirement of livestock to certain extent. Intensification of ethanol industry has increased availability of DDGS, a potential source, to replace conventional protein sources and generating favorable economic output. Only few researches have been conducted on feeding alternate protein sources to replacement heifers. DDGS can be an excellent source of bypass protein and energy, and legume straw can supply more protein than cereal straw for growing replacement heifers. Hence, this study was planned on crossbred heifers to study the effect of feeding DDGS, Soya DOC and roughage on growth and reproduction, and to evaluate its cost-benefit ratio.

MATERIALS AND METHODS

This work was carried out on 24 HF × Kankrej heifers of initial average 8 months of age at Livestock Research Station, AAU, Anand. Selected heifers were divided randomly on the basis of body weight and age into following six treatment groups (3 concentrate, 2 roughage; 4 animals/replicates in each) under factorial RBD and were fed accordingly with 50% concentrate and 50% roughage as TMR till all heifers evinced puberty, and conceived through AI.

Concentrate (50%)	Roughage (50%)
T1: 60% Amul Dan + 40% Soy DOC	R1, 50% Cereal straw
	R2, 25% each Cereal & Legume straw
T2: 60% Amul Dan +20% Soy DOC + 20 % rice DDGS	R1, 50% Cereal straw
	R2, 25% each Cereal & Legume straw
T3: 60% Amul Dan + 40% DDGS	R1, 50% Cereal straw
	R2, 25% each Cereal & Legume straw

All the experimental heifers were de-wormed and kept tied under iso-managerial condition in well ventilated hygienic shed and fed individually. The heifers were left loose for 2 hrs in the morning and in the evening, and closely observed for heat/estrus signs. Measured quantity of ration as TMR and clean wholesome drinking water was provided to the animals 3-4 times a day. Representative samples of concentrate mixtures and TMR offered were analyzed for proximate principles (AOAC, 2000), and the results were as shown in Table 1 and 2.

Table 1: Proximate composition of concentrate mixture with RDDGS (% 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

Table 2: Proximate composition of different TMR offered to heifers (% DM basis)

Particulars	TMR-1	TMR-2	TMR-3	TMR-4	TMR-5	TMR-6
OM	86.94	88.38	87.73	88.76	88.58	89.38
CP	15.46	17.35	15.68	17.72	15.86	17.85
EE	2.52	2.18	3.23	2.86	3.71	3.54
CF	25.90	23.48	24.86	22.43	24.68	22.36
Ash	13.06	11.69	12.27	11.24	11.42	10.62
NFE	43.06	45.30	43.96	45.75	44.33	

Observations taken include daily/monthly feed intake and monthly body weight gain from 8 months of age, and monthly USG and P/R monitoring of uterine/ovarian growth and functional structures from 14 months of age including serum profile of estradiol, progesterone and cortisol using RIA technique. Age at puberty and sexual maturity was recorded as age at first observed heat/AI, and fertile estrus confirmed by P/R examination, respectively. AI was done only at body weight more than or equal to 285 kg and pregnancy was confirmed 45-60 days post-AI. Cost of feeding was calculated considering daily feed intake, gain in body weight, and procurement cost of feed and fodder used. Feed cost per kg body weight gain was worked out for the different treatments. Data was analyzed using factorial RBD and CD tests (Snedecor and Cochran, 2002).

RESULTS AND DISCUSSION

Body weight

Initial and final body weights of heifers at 8 and 19 months of age were 116.13±4.56 and 354.16±5.98 kg, respectively. Body weight of heifers recorded during the study period was significantly higher in 40% DDGs fed group (T3) and also in legume-cereal mixed roughage (R2) group as compared to other contemporary groups (Table 3, Figure 1). Monthly gain in body weight was also correspondingly better in these groups.

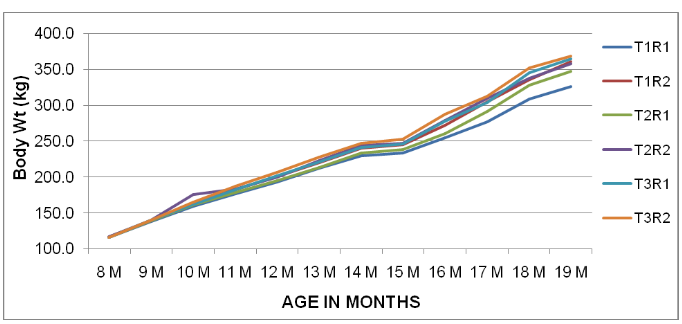

Fig. 1: Effect of concentrate x roughage interactions on body weight of CB heifers

Eun *et al. (*2009) reported significant ($p<0.05$) improvement in body weight of beef steer fed corn-DDGS during the growing phase. Gibb *et al.* (2008) and Dey *et al.* (2019) observed a non-significant but linear increase in body weight when British crossbred heifers and calves received a diet replacing soybean meal with 0, 20 and 40% of DDGS on DM basis. While no change in body weight was found on feeding DDGS in dairy heifers (Manthey *et al.*, 2016), steers (Beretta *et al.*, 2020) and in water buffaloes (Huang *et al.*, 2020). Increase in body weight of crossbred heifers that received a mixture of wheat straw and groundnut gotar (R2) was in agreement with the findings in Gaolao (Misal, 2017) and Sahiwal (Mahalle *et al.*, 2019) heifers. Further, Desai (2020) observed significant ($p<0.05$) improvement in body weight, when crossbred calves were offered a mixture of wheat and soybean straw over jowar hay.

Reproductive hormones and cyclicity

Serum profile of reproductive hormones progesterone, estradiol and cortisol monitored along with USG and P/R palpation for uterine growth and ovarian changes of animals from 14 months of age onwards are presented in Table 4 to 6 with few sonograms of different progressive reproductive stages in Figure 2. Ovarian activity in terms of follicles and CL was noticed from 14 months of age onwards with pregnancy in more than 60% heifers by 19 months of age and 100% by 23 months of age with better results in DDGS and legume gotar fed groups. Comparable findings were also reported by Dhami *et al.* (2019) in HF x K crossbred heifers fed high plane of nutrition over routine feeding from early age of 8 months till 18 months.

Table 3: Body weight of experimental crossbred heifers fed Soy DOC, Rice DDGS and legume, non-legume straws from 8 months to 19 months of age

Average body weight (kg) in Groups						Overall	
T1		T2		T3		R1	R2
R1	R2	R1	R2	R1	R2		
218.63 ±10.18	231.77 ±11.44	225.16 ±10.44	233.46 ±11.72	233.43 ±11.45	238.64 ±11.81	225.74^{X} ±6.16	235.63^{Y} ±6.56
225.20^{A}±7.65		229.31^{AB}±7.78		236.03^{B}±8.19		230.54±4.54	

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

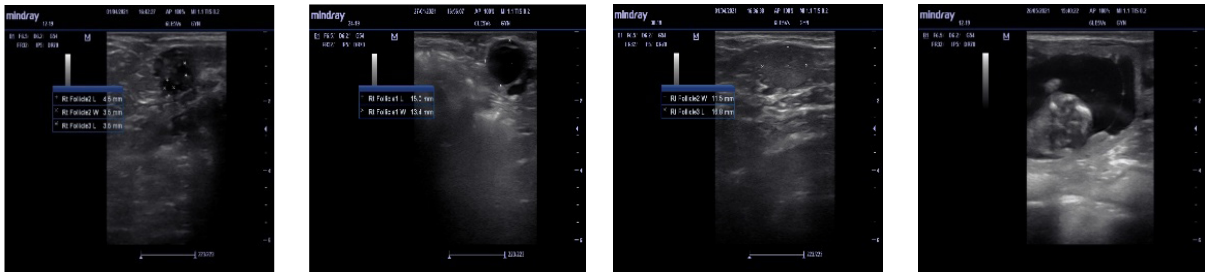

Fig. 2: Sonograms of heifers showing progressive follicular growth, CL and early pregnancy

Serum estradiol concentration varied significantly between periods/ months studied from 17.55±1.95 to 27.83±2.86 pg/ml. and it fluctuated as per the ovarian cycle in different groups at different time intervals reflecting presence of anovulatory follicles as reflected by monthly USG in some of the animals. However, the effect of concentrate or roughage alone did not influence the serum estradiol levels, although the interaction of PxTxR was significant (Table 4). Dhami *et al.* (2019) recorded similar findings in HFxK crossbred heifers fed high plane of nutrition over routine feeding from early age of 8 months have been recorded (Dhami et al., 2019).

The overall mean serum progesterone concentrations from 14 to 19 month of age recorded were 0.54±0.18, 0.62±0.15, 1.23±0.32, 3.75±0.73, 4.99±0.75 and 5.66±0.73 ng/ml, respectively, with gradual and significant rise with advancing age due to increasing number of animals conceived in each group. It also varied significantly due to TxR interaction, the values being higher in T3R1 group, and in T1R2 and T2R2 groups than counter parts. However, the effect of concentrate or roughage alone, ignoring the counterpart, did not influence the serum progesterone profile significantly (Table 5, Fig. 3). Dhami *et al.* (2019), found similar results in HFxK crossbred heifers fed high plane of nutrition over routine feeding from early age of 8 months till 18 months and opined that ovarian dynamics begins around 14-15 months of age with silent ovulation in HFxK crossbred heifers.

Table 4: Monthly mean (±SE) serum E_2 concentration of experimental HF x K heifers under different treatment groups from 14 months to 19 months of age at LRS, Anand.

Group		Age in month						Overall pooled
		14.0	15.0	16.0	17.0	18.0	19.0	
T1	R1	14.00±2.71	28.50±7.50	26.50±2.99	21.75±5.89	17.25±4.00	23.50±5.06	**21.92±2.08**
	R2	23.50±4.99	32.75±5.02	22.50±5.07	15.25±1.89	20.25±8.09	23.25±4.89	**22.92±2.20**
	Pooled	**18.75±3.18**	**30.63±4.25**	**24.50±2.83**	**18.50±3.12**	**18.75±4.21**	**23.38±3.25**	**22.42±1.50**
T2	R1	18.50±4.03	17.00±3.39	26.75±4.11	22.75±6.34	23.75±6.14	23.00±5.45	**21.96±1.94**
	R2	15.50±2.75	20.50±4.29	31.25±5.65	21.25±4.70	15.00±4.36	31.88±2.99	**22.56±2.08**
	Pooled	**17.00±2.33**	**18.75±2.62**	**29.00±3.34**	**22.00±3.66**	**19.38±3.86**	**27.44±3.33**	**22.26±1.41**
T3	R1	18.75±6.50	32.25±7.59	46.50±9.64	15.75±3.61	13.30±1.67	19.18±3.05	**24.29±3.25**
	R2	17.75±2.66	28.00±2.45	13.50±1.26	24.50±5.72	15.75±3.07	21.63±4.06	**20.19±1.64**
	Pooled	**18.25±3.25**	**30.13±3.77**	**30.00±7.69**	**20.13±3.54**	**14.53±1.68**	**20.40±2.39**	**22.24±1.83**
Over-all	R1	17.08±2.54	25.92±3.91	33.25±4.34	20.08±2.98	18.10±2.62	21.89±2.52	**22.72±1.43**
	R2	18.92±2.15	27.08±2.62	22.42±3.19	20.33±2.58	17.00±3.01	25.58±2.49	**21.89±1.14**
	Pooled	**18.00±1.64**	**26.50±2.30**	**27.83±2.86**	**20.21±1.93**	**17.55±1.95**	**23.74±1.77**	**22.30±0.91**

Period effect and Period x Treatment x Roughage interaction were significant at $P<0.01$.

Table 5: Monthly mean (±SE) serum P_4 concentration of experimental HF x K heifers under different treatment groups from 14 months to 19 months of age at LRS, Anand

Group		Age in month						Overall pooled
		14.0	15.0	16.0	17.0	18.0	19.0	
T1	R1	1.05±0.68	0.66±0.24	0.95±0.63	1.88±1.19	3.73±1.90	4.86±2.26	**2.19±0.59**
	R2	0.52±0.22	0.88±0.13	1.38±0.85	6.86±2.61	5.92±1.77	7.10±1.34	**3.78±0.80**
	Pooled	**0.79±0.35**	**0.77±0.13**	**1.17±0.49**	**4.37±1.63**	**4.82±1.27**	**5.98±1.29**	**2.96±0.50**
T2	R1	0.23±0.09	0.58±0.35	0.45±0.19	2.48±1.32	3.76±1.63	2.89±1.54	**1.73±0.48**
	R2	1.01±0.83	1.17±0.74	1.99±0.87	5.64±1.92	4.55±1.98	6.30±1.84	**3.39±0.70**
	Pooled	**0.62±0.41**	**0.87±0.39**	**1.07±0.47**	**4.06±1.25**	**4.15±1.20**	**4.59±1.28**	**2.56±0.44**
T3	R1	0.14±0.02	0.33±0.13	2.49±1.28	8.40±1.47	8.40±1.47	8.68±1.49	**3.96±0.82**
	R2	0.30±0.17	0.10±0.00	0.41±0.16	1.96±1.42	3.56±2.14	4.17±1.52	**1.75±0.56**
	Pooled	**0.22±0.08**	**0.22±0.08**	**1.45±0.72**	**2.83±0.88**	**5.98±1.51**	**6.42±1.30**	**2.85±0.52**
Over-all	R1	0.47±0.24	0.52±0.14	1.30±0.51	2.69±0.67	5.29±1.10	5.47±1.19	**2.62±0.39**
	R2	0.61±0.28	0.71±0.26	1.16±0.40	4.82±1.25	4.68±1.07	5.86±0.91	**2.97±0.41**
	Pooled	**0.54±0.18**	**0.62±0.15**	**1.23±0.32**	**3.75±0.73**	**4.99±0.75**	**5.66±0.73**	**2.80±0.28**

Period effect and Treatment x Roughage interaction were significant at *P*<0.01.

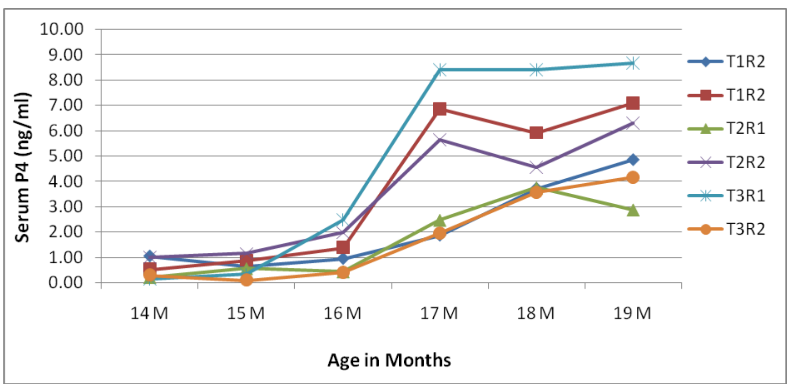

Fig. 3: Monthly mean serum P_4 concentration of experimental HF x K heifers under different treatment groups from 14 months to 19 months of age

Table 6: Monthly mean (±SE) serum Cortisol concentration of experimental HF x K heifers under different treatment groups from 14 months to 19 months of age at LRS, Anand

Group		Age in month						Overall pooled
		14.0	15.0	16.0	17.0	18.0	19.0	
T1	R1	11.83±3.86	8.79±2.12	8.60±3.08	13.00±5.63	14.59±5.04	8.93±4.33	**10.96±1.58**
	R2	12.92±0.82	7.74±1.71	9.73±3.29	9.69±1.47	10.79±2.41	13.06±2.55	**10.66±0.88**
	Pooled	**12.38±1.84**	**8.26±1.27**	**9.16±2.10**	**11.34±2.76**	**12.69±2.68**	**11.00±2.45**	**10.81±0.90**
T2	R1	14.53±3.43	9.73±2.15	15.29±2.84	16.46±3.07	21.88±4.07	24.30±2.92	**17.03 1.51**
	R2	14.06±3.02	12.41±2.61	18.20±3.67	17.40±2.73	15.72±1.32	14.63±1.75	**15.40±1.04**
	Pooled	**14.29±2.12**	**11.07±1.64**	**16.75±2.22**	**16.93±1.91**	**18.80±2.29**	**19.46±2.41**	**16.22±0.91**
T3	R1	15.43±2.84	13.77±0.86	23.10±2.91	21.01±1.91	17.13±3.85	24.09±5.25	**19.09±1.42**
	R2	12.62±3.14	18.95±3.40	19.83±5.10	15.41±2.90	16.28±1.43	26.41±3.18	**18.25±1.52**
	Pooled	**14.03±2.03**	**16.36±1.89**	**21.46±2.79**	**18.21±1.92**	**16.70±1.91**	**25.25±2.87**	**18.67±1.03**
Over-all	R1	13.93±1.84	10.76±1.15	15.66±2.36	16.82±2.25	17.86±2.45	19.11±3.12	**15.69±0.95**
	R2	13.20±1.35	13.03±1.97	15.92±2.52	14.17±1.62	14.27±1.19	18.03±2.24	**17.77±0.77**
	Pooled	**13.57±1.12**	**11.90±1.14**	**15.79±1.69**	**15.49±1.38**	**16.06±1.38**	**18.57±1.88**	**15.23±0.68**

Only the Period and Treatment effect were significant at *P<0.01.*

Serum cortisol levels increased with advancing age and it was also higher in T2 and T3 than T1 treatment, irrespective of roughage source, with overall mean values of 10.81±0.90, 16.22±0.91 and 18.67±1.03 ng/ml, in T1, T2 and T3 treatment, respectively. This may be due to effect of DDGS on stress receptors, however, roughage quality did not influence this hormone profile (Table 6).

Hypothalamic-pituitary axis is hypersensitive to the negative feedback of estradiol, which in turn limits secretion of LH prior to the onset of puberty. As the time of puberty approaches, dominant ovarian follicles of greater diameter develop in heifers. This increase allows for the greater secretion of estradiol by these follicles, which would result from the decreased negative feedback of estradiol on secretion of LH prior to puberty (Wolfe *et al.,* 1991). Prepubertal decline in negative feedback of estradiol on secretion of LH is followed by a period of positive feedback post-puberty and subsequent increase in frequency of LH pulses (Bergfeld *et al.,* 1994). Present findings indicate that continuous increase of ovarian size occurred until heifers reached puberty. When heifers were classified according to pubertal status, pubertal heifers had a larger follicle diameter than non-pubertal heifers which were in accordance with previous reports (Ferreira *et al.,* 1999; Holm *et al.,* 2009 and Monterio *et al.,* 2013).

Circulating concentrations of estradiol are low initially but increases with age as the prepubertal heifer matures, particularly over the last 12 weeks before first ovulation (Evans *et al.,* 1994; Melvin *et al,,* 1999). First ovulation in heifers is often not associated with estrus, and the subsequent corpus luteum is smaller than in a normal cycle and may be short-lived (Evans *et al.,* 1994). This short cycle is followed by estrus and a normal, full-length luteal phase. Increased estrogen secretion eventually causes a preovulatory LH surge and first ovulation. Estradiol appears to be the prominent negative feedback agent on LH secretion, operating indirectly through other neuronal systems.

Age at puberty and sexual maturity/conception

Data on group-wise mean age at puberty and sexual maturity and No. of AIs required per conception in CBHF heifers under study are presented in Table 7. The mean age at onset of puberty and sexual maturity/conception recorded in experimental heifers were 552.21±10.72 and 616.79±15.67 days, respectively, with mean No. of AIs per conception as 2.83±0.40. Overall, the supplementation of concentrate with 40% DDGS and roughage with legume straw in ration did not influence significantly these parameters. Dhami *et al.* (2019), however, recorded shortened age at puberty and sexual maturity by nearly two months in HFxK crossbred heifers fed high plane of nutrition over routine feeding from early age of 8 months.

Post-weaning nutrition plays a key role in the determination of age at puberty (Thallman *et al.,* 1999; Dhami *et al.,* 2019). According to some researchers (Romano *et al.,* 2007; Roberts *et al.,* 2009 and Monteiro *et al.,* 2013), age at puberty is more affected by the growth rate and body weight gain, heifers that consumed more energy and had a higher daily weight gain rate reached puberty at younger age. In

Table 7: Effect of feeding Soy DOC and DDGS without and with legume straws on Age at Puberty and Sexual maturity in CBHF heifers at LRS

Concentrate Group	Roughage group	Age in Days		
		Puberty	Sexual Maturity	No. of AIs/ Conception
	R1	554.50 ±25.58	617.00 ± 48.45	3.00 ± 1.35
T1	R2	545.25 ±17.53	593.50 ±30.00	2.75 ±1.11
	Pooled	**549.88 ±14.45**	**605.25 ±26.74**	**2.88 ±0.81**
	R1	574.25 ±28.40	590.25 ±35.73	3.00 ±1.22
T2	R2	574.25 ±28.40	611.50 ±36.39	2.25 ±0.63
	Pooled	**554.50 ±21.13**	**600.88 ±23.93**	**2.63 ±0.65**
	R1	529.75 ±40.68	627.00 ±63.08	3.25 ±1.25
T3	R2	574.75 ±15.11	661.50 ±18.64	2.75 ±0.75
	Pooled	**552.25 ±21.80**	**644.25 ±31.12**	**3.00 ±0.68**
	R1	539.67 ±17.71	611.42 ±26.73	3.08 ±0.67
Overall	R2	564.75 ±11.82	622.17 ±17.60	2.58 ±0.45
	Pooled	**552.21 ±10.72**	**616.79 ±15.67**	**2.83 ±0.40**

Treatment, Roughage and TxR interaction did not differ on all 3 parameters.

Table 8: Cost of feeding Soy DOC and DDGS without and with legume straws from 8 to 19 months of age in CBHF heifers at LRS

Concentrate Group	Roughage group	Average daily cost of feeding per animal (₹/head/d)	Total cost of feeding per animal (₹/head)	Feed cost/kg BW gain (₹/kg BW gain)
T1	R1	97.16±1.74	32062.47±573.87	152.68±2.73
	R2	106.72±1.09	35216.87±360.05	143.98±1.47
	Pooled	**101.94^{b}±2.04**	**33639.67±673.59**	**148.00^{c}±2.96**
T2	R1	93.09±0.95	30718.92±314.35	132.95±1.36
	R2	101.49±1.17	33491.35±385.07	138.58±1.59
	Pooled	**97.29^{ab}±1.73**	**32105.14±572.24**	**135.83^{b}±2.42**
T3	R1	88.58±1.07	29231.58±354.03	117.78±1.43
	R2	97.24±1.06	32088.50±348.45	126.98±1.38
	Pooled	**92.91^{a}±1.78**	**30660.04±586.83**	**122.42^{a}±2.34**
Overall	**R1**	**92.94^{A}±1.26**	**30670.99±414.54**	**133.50±1.80**
	R2	**101.81^{B}±1.30**	**33598.91±430.25**	**136.39±1.75**
	Pooled	**97.38±1.28**	**32134.95±422.54**	**135.00±1.77**

Means bearing different superscripts within the column differ significantly (P<0.05).

the present study also, the pubertal heifers were heavier and younger than non-pubertal animals.

Economics of feeding DDGS in heifers

Daily cost of feeding heifers (Rs. per head) under different treatments calculated from the records of daily feed consumption considering the procurement cost of feed and fodder was significantly lower in heifers fed concentrate with 40% DDGS as compared to 40% Soy DOC, and similar were the findings for the feed cost per kg BW gain worked out for the different treatments. However the differences in total feed cost/animal between treatments were statistically non-significant. Average daily feed cost was significantly higher, and feeding cost per kg BW gain was non-significantly higher in legume fed groups. Cost of feeding per kg BW gain was significantly higher with T1 (40% Soy DOC), followed by T2 (20% Soy DOC, 20% DDGS), and the least in T3 (40% DDGS) fed groups (Table 8), suggesting beneficial effect of feeding rice DDGS over soy DOC to growing heifers.

Tangendjaja (2013) and Dey *et al.* (2019) reported similar reduced daily feed cost of dairy cows fed concentrate supplemented with DDGS. Further, the cost of feeding mixture of wheat straw and groundnut gotar was significantly higher, which concurred with the results in Gaolao heifers (Misdal, 2017) and in Crossbred calves (Desai, 2020). Huang *et al.* (2020) in water buffaloes found a significant (p<0.05) reduction in feed cost (₹ /kg BW gain) by using DDGS in feed (2.24 *vs.*2.46 $/kg).

CONCLUSIONS

Present findings of the study on HF x Kankrej heifers (n=24) revealed feeding of DDGS in place of soy DOC in concentrate and feeding a mixture of legume straw and cereal straw (groundnut gotar and wheat straw) superior with respect to higher body weight gain, lower feed cost per kg gain, normal hormonal profile and improved reproductive efficiency without adverse effect on health.

ACKNOWLEDGEMENTS

We thank the Dean of Veterinary College, and authorities of AAU, Anand for the encouragement and permission granted to take up work on animals of LRS. The financial support received through 'AICRP on Nutritional and Physiological Interventions for Enhancement of Reproductive Performance in Animals' by the ICAR-NIANP, Bangalore to Dr. A.J. Dhami, PI and HoD, Veterinary Gynaecology, is also gratefully acknowledged.

CONFLICT OF INTEREST

All authors declare that they have no conflict of interest.

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