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Article

Evaluation of Soybean Hulls as Replacement of Energy Concentrates: Effects on Intake, Growth Performance and Selected Blood Metabolites of Male Sahiwal Calves

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Abstract: The objective of this study was to evaluate the effects of replacing conventional energy sources (corn grain and wheat bran) with soyhulls on the growth performance of Sahiwal calves. Fifteen growing Sahiwal male calves weighing approximately 110 ± 2 kg were selected, blocked by body weight, and randomly assigned to one of three dietary treatments (5 calves/treatment) in a randomized complete block design. The treatments consisted of three concentrate diets: control (SH0, without soyhulls), SH18 (soyhulls replacing 30% of conventional energy sources), and SH36 (soyhulls replacing 60% of conventional energy sources). All diets were isonitrogenous with 13.5% crude protein (CP) and were fed as a total mixed ration (TMR) comprising 60% concentrate, 32% silage, and 8% Rhodes grass hay on a dry matter basis. Body weight was recorded weekly. Three animals per treatment were selected for an apparent digestibility trial using acid-insoluble ash as a marker. Results indicated a numerical increase in dry matter intake (DMI) with higher soyhull levels. Digestibility of NDF, ADF, DM, and OM increased linearly ($p \leq 0.05$) with increasing soyhulls in the diets. Total weight gain was 129 kg for SH0, 128 kg for SH18, and 133 kg for SH36. The average daily gain (ADG) was slightly more in the SH36 group (1.19 kg) than the SH0 group (1.15 kg). Cost per unit gain, blood glucose, and blood urea nitrogen (BUN) levels were similar ($p > 0.05$) among the treatments. In conclusion, the study demonstrated that soyhulls can be an effective alternative energy source to the corn grain and wheat bran, with similar growth performance and cost per unit gain with the additional benefits of greater dry matter intake and nutrient digestibility in male Sahiwal calves.

Keywords: soyhulls; energy source; calf performance

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1. Introduction

The livestock sector is a cornerstone of Pakistan's agriculture, contributing over 60.84% to the country's agricultural GDP [1]. Although Pakistan lacks specific beef breeds, male calves and yearlings play a significant role in the beef industry. In recent years, there has been a notable rise in calf fattening operations, a trend that continues to grow. To support these fattening practices, the use of both traditional and non-traditional feed resources offers a promising solution to address the country's ongoing livestock feed demands [2].

As livestock production expands, it is crucial to adopt alternative feeding strategies, such as incorporating total mixed rations (TMR) with cost-effective, non-conventional feed ingredients. Traditionally, corn grain and wheat bran have been the primary energy sources in beef cattle diets. However, recent research has shifted attention toward utilizing byproducts rich in digestible fiber and energy, particularly as the availability and cost of conventional feeds fluctuate. One such byproduct gaining popularity in Pakistan is soy hulls (SH), a fiber-rich byproduct of soybean oil extraction. Soy hulls have become more readily available at lower prices as the domestic oil industry has increased their capacity to process soybeans. Soy hulls can replace more expensive feed ingredients, such as hay or grain, in livestock diets [3]. Soy hulls, known for their high fiber and low protein content, have been widely utilized in dairy rations as a cost-effective feed ingredient [4]. Furthermore, replacing corn with soy hulls—up to 45% of dietary dry matter—can enhance microbial protein synthesis in the rumen, stabilize ruminal pH, and improve nitrogen digestibility throughout the gastrointestinal tract of ruminants [5, 6]. Animals fed with high levels of starch are prone to acidosis; therefore, low starch SH can reduce the risk of ruminal acidosis [6].

For a profitable and efficient beef production program, a cost-effective feeding protocol is essential, as the feeding regime accounts for approximately 65% of beef calf rearing costs [7]. High feed costs are one of the most significant limiting factors in the beef fattening sector [8]. Currently, the elevated cost of feeding remains a major challenge for the beef industry. To mitigate these expenses, farmers and nutritionists are increasingly turning to non-conventional feed resources.

Most studies on the inclusion of soy hulls have been conducted in temperate regions, and there is limited information on their effectiveness in replacing conventional energy sources within Pakistani conditions and local cattle breeds. Therefore, we hypothesize that maximizing the use of SH in the fattening diet of Sahiwal cattle can reduce the cost per unit gain without negatively impacting growth performance.

2. Materials and Methods

2.1. Experimental design, study animals, and management

The research trial was conducted at the Dairy Animals Training and Research Centre (DT&RC), University of Veterinary and Animal Sciences (UVAS), Ravi Campus, Pattoki. The total duration of the trial was 16 weeks, with two weeks for adaptation and 14 weeks for data collection. Fifteen growing Sahiwal male calves, weighing approximately 110 ± 2 kg, were selected. The animals were blocked based on their initial body weights. There were five blocks, each consisting of three animals, and within each block, the animals were randomly assigned to one of three dietary treatments (n = 5 calves/treatment) under a randomized complete block design.

2.2. Treatment diets

The treatments consisted of three concentrate diets: control SH0 (without sunflower hulls, SH), SH18 (with SH replacing 30% of conventional energy sources), and SH36 (with SH replacing 60% of conventional energy sources). The diets were isonitrogenous, containing 13.5% crude protein (CP), and were fed as total mixed rations (TMR) composed of 60% concentrate, 32% silage, and 8% Rhodes grass hay on a dry matter (DM) basis (Tables 1 and 2). The TMR was offered twice daily at 08:00 and 16:00 h ad libitum, and individual feed allowances were adjusted daily to ensure a 10% refusal rate. Refusals were recorded and weighed daily to calculate dry matter intake (DMI). The animals were fed individually, with free-choice access to fresh, clean water. Health management was followed in accordance with the farm protocols.

2.3. Feed Intake amd Growth Performance

Daily feed offerings, refusals, and intake were calculated on a DM basis. Samples were oven-dried at 72°C for 24 hours to determine DM content. The calves were weighed at the start of the trial and then on a weekly basis before the morning feeding. Average daily gain (ADG) was calculated weekly by subtracting the initial weight from the final weight and dividing it by seven.

Table 1. Composition of experimental TMR diets (DM basis).

Ingredients	Treatments [1]		
	SH0	SH18	SH36
Corn Silage	32.0	32.0	32.0
Rhodes Grass Hay	8.0	8.0	8.0
Ground Maize	22.8	15.9	9.1
Wheat Bran	13.8	9.6	5.5
Soy hulls[2]	0.0	10.9	21.9
Molasses	3.0	3.0	3.0
Soybean Meal	9.9	9.6	9.6
Maize Gluten 30%	8.7	9.0	9.0
Mineral Premix	0.6	0.6	0.6
Salt	0.3	0.3	0.3
Lime	0.9	0.9	0.9

[1] SH0 = Concentrate diet with ground corn and wheat bran as energy sources and 0% soybean hulls (SH). SH18 = Concentrate diet containing 18% SH, replacing 30% of the ground corn and wheat bran from the control diet (SH0). SH36 = Concentrate diet containing 36% SH, replacing 60% of the ground corn and wheat bran from the control diet (SH0).

Table 2. TMR chemical composition (DM Basis).

Nutrients	Treatments [1]			Silage	Soy Hulls	Rhodes grass hay
	SH0	SH18	SH36			
DM%	49.6	50.0	49.8	27.0	90.0	87.0
CP%	13.5	13.5	13.5	8.9	12	5.1
ME cal/kg DM[2]	2.7	2.6	2.5	2.5	2.74	1.9
FAT%	2.4	2.11	1.8	1.9	1.02	1.7
NDF%	39.5	43.5	47.4	49.7	59.45	69.2
ADF%	26.7	29.7	32.7	27.0	43.53	41.2
ASH%	7.0	7.34	7.5	8.6	4.57	7.8
Ca%	0.9	0.9	1.0	0.3	0.50	3.1
P%	0.6	0.6	0.6	0.2	0.16	2.6

[1] SH0 = Concentrate diet with ground corn and wheat bran as energy sources and 0% soybean hulls (SH). SH18 = Concentrate diet containing 18% SH, replacing 30% of the ground corn and wheat bran from the control diet (SH0). SH36 = Concentrate diet containing 36% SH, replacing 60% of the ground corn and wheat bran from the control diet (SH0).

2.4. Blood metabolites

Blood samples were collected from each animal 3 hours after the morning feeding, from the jugular vein into EDTA-coated tubes, on a weekly basis. The blood samples were centrifuged at 3000 × g for 10 minutes to obtain plasma. Plasma samples were stored in duplicate in Eppendorf tubes at -20°C until further analysis. Blood urea nitrogen (BUN) and blood glucose were analyzed using a colorimetric kit [9]. These analyses were performed in the Department of Physiology, UVAS, Lahore.

2.5. Chemical analysis

Feed samples were collected weekly, oven-dried at 72°C for 24 hours for DM determination, and ground to a 2 mm particle size using a Wiley mill (Model No. 2, Arthur H. Thomas Company, Philadelphia, USA). The ground feed samples were processed in the laboratory to determine DM, CP (using the Dumas method), crude fat (CF) using an Ankom fat extractor, and ash content [10]. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) analyses were performed using the filter bag technique according to Van

Soest et al. [11]. All feed analyses of the concentrate and TMR were carried out in the Central Laboratory Complex (CLC) of UVAS, Ravi Campus, Pattoki.

2.6. Economic analysis

The cost per unit gain for the animals was calculated, including the total cost of TMR consumed, divided by the total weight gain of the calves during the entire trial [12]. Structural measurements, including body length, heart girth, hip height, and wither height, were taken at the start and end of the trial. Body length and heart girth were measured using a measuring tape, while hip height and wither height were measured using a measuring rod [13].

2.7. Nutrient digestibility

Three animals from each treatment group were selected for the apparent digestibility experiment. The duration of the experiment was 5 days, with 2 days for adaptation and 3 days for data collection. Daily feed offered and refusals were recorded, and fecal samples were collected using the grab method. Composite samples of feed offered, refusals, and fecal material were prepared for each animal. These samples were analyzed for dry matter (DM), organic matter (OM), neutral detergent fiber (NDF), and acid detergent fiber (ADF) to evaluate digestibility coefficients. Acid-insoluble ash was used as a marker for the apparent digestibility study [14]. All digestibility analyses were performed at the CLC of UVAS, Ravi Campus, Pattoki.

2.8. Statistical analyses

Data were analyzed using the MIXED Procedure of SAS (SAS for Academics). Data for ADG, daily average DMI, BCS, blood glucose, and BUN were analyzed by repeated measures analysis of variance (ANOVA). Data for structural measurements, total weight gain, total feed intake, apparent digestibility, cost per unit gain, and feed efficiency were analyzed using one-way ANOVA. Animal block was considered a random effect, while diet was treated as a fixed effect. Results were considered statistically significant at $P \leq 0.05$. Means of significant results were compared using Tukey's post hoc multiple comparison test.

3. Results

3.1. Dry Matter Intake, Growth, and Feed Efficiency

The results for DMI, growth performance, and feed efficiency are presented in Table 3. There were no significant differences ($p > 0.05$) in total DMI and average daily DMI across the treatments.

Table 3. DMI, ADG, body weight gain and feed efficiency of Sahiwal bull calves fed different treatment rations.

Variables	Treatments [1]			SEM	*p* Value	
	SH0	SH18	SH36		Linear	Trt × wk
Average daily DMI, kg	4.521	4.603	4.637	0.72	0.894	0.0001
ADG, kg	1.152	1.146	1.195	0.37	0.966	0.001
Body weight, kg						
Initial	108.6	110.6	109.0	2.73	0.484	
Final	237.6	239.0	242.8	12.9	0.916	
Gain	129.0	128.4	133.8	11.4	0.959	
Feed Efficiency	0.260	0.254	0.258	0.02	0.695	
Total DMI	506.3	515.4	519.3	66.5	0.895	
Cost per kg	144.0	142.0	141.3	7.92	0.81	

[1] SH0 = Concentrate diet with ground corn and wheat bran as energy sources and 0% soybean hulls (SH). SH18 = Concentrate diet containing 18% SH, replacing 30% of the ground corn and wheat bran

from the control diet (SH0). SH36 = Concentrate diet containing 36% SH, replacing 60% of the ground corn and wheat bran from the control diet (SH0).

However, numerically, both total and average daily DMI were higher in the SH18 and SH36 groups compared to the control (SH0). No significant differences ($p > 0.05$) were observed in ADG, initial body weight, final body weight, or total body weight gain among the treatments. Despite this, calves in the SH36 group showed numerically higher final body weight and weight gain. Similarly, no effect of the dietary treatments on feed efficiency was observed ($p > 0.05$).

3.2 Blood Metabolites

Blood urea nitrogen and blood glucose concentrations were not affected ($p > 0.05$) by the dietary treatments. However, these values were the highest for SH0 and the lowest for SH36. Results are given in Table 4 as Means ± SEM.

Table 4. Effect of dietary treatments on blood urea nitrogen (BUN) and blood glucose.

Variables	Treatments[1]			SEM	*p* Value	
	SH0	SH18	SH36		Linear	Trt × wk
BUN, mg/d	18.772	18.355	17.613	1.564	0.483	0.067
Blood glucose, mg/dl	74.739	70.857	68.745	5.925	0.136	0.398

[1] SH0 = Concentrate diet with ground corn and wheat bran as energy sources and 0% soybean hulls (SH). SH18 = Concentrate diet containing 18% SH, replacing 30% of the ground corn and wheat bran from the control diet (SH0). SH36 = Concentrate diet containing 36% SH, replacing 60% of the ground corn and wheat bran from the control diet (SH0).

3.3 Apparent Digestibility

Apparent digestibility of NDF, ADF, DM and OM was affected ($p \leq 0.05$) by dietary treatments (Table 5). Digestibility of DM and OM increased ($p < 0.05$) linearly with increasing level of SH in the diet. Similarly, the NDF, ADF digestibility also increased linearly ($p < 0.05$) with increasing of SH in the concentrate diet.

Table 5. Effect of dietary treatments on apparent digestibility of NDF, ADF, DM and OM.

Variables [2]	Treatments [1]			-	*p* Value
	SH0	SH18	SH36	SEM	Linear
NDF	38.24^{b}	54.30^{ab}	57.35^{a}	3.42	0.003
ADF	37.50^{b}	55.61^{ab}	58.35^{a}	4.22	0.005
DM	74.16^{b}	77.64^{ab}	77.69^{a}	0.93	0.010
OM	52.97^{b}	67.19^{a}	65.77^{ab}	2.54	0.001

[1] SH0 = Concentrate diet with ground corn and wheat bran as energy sources and 0% soybean hulls (SH). SH18 = Concentrate diet containing 18% SH, replacing 30% of the ground corn and wheat bran from the control diet (SH0). SH36 = Concentrate diet containing 36% SH, replacing 60% of the ground corn and wheat bran from the control diet (SH0). [2] NDF: neutral detergent fiber; ADF: acid detergent fiber; DM: dry matter; OM: organic matter. $^{a–c}$ Values with different superscripts in a row are significantly different ($p \leq 0.05$).

4. Discussion

Replacement of conventional energy sources with SH up to 60% had effect on the chemical composition of the concentrate diets, as there was decrease in the metabolizable energy contents with the increasing level of SH. The ratio of replacement of corn grains to wheat bran remained same in all the treatments (1.65). However, NDF and ADF contents of concentrates diets increased because SH is rich in digestible fiber.

Overall, total DMI and average daily DMI did not differ significantly among treatments. However, the inclusion of SH in the fattening concentrate had a positive impact on

DMI, as evidenced by the numerical increase in DMI in calves fed the SH36% diet. Although the difference in DMI was small, the 2.5% higher intake in the SH36% group compared to the SH0% group suggests that replacing conventional energy sources with SH may enhance diet palatability.

Our findings align with those of others [15], who reported improved DMI when 25% or 50% of corn was replaced with SH in diets containing 35% or 60% forage. Similarly, Ferreira et al. [6] observed a linear increase in DMI with increasing SH levels (up to 45%) in high-concentrate diets (90% concentrate, 10% hay). This response may be linked to the lower dietary energy density when SH levels were increased. In current study, despite the SH36 diet having the highest NDF content, DMI was not limited. This could be attributed to the fact that the additional NDF from SH was highly digestible and not physically effective [16], allowing for an enhanced ruminal escape rate [17].

Initial body weight (BW), final BW, and BW gain were similar across treatments, with no significant differences. However, numerically, calves fed the SH36 diet had the highest final BW. The highest ADG was also recorded in the SH36 group compared to the SH0 group (1.19 kg vs. 1.15 kg). Bull calves on the SH36-based diet gained 3% more weight compared to those fed the SH0 diet. Over the course of the trial, weight gain was 129 kg for the SH0 group, while the SH18 and SH36 groups gained 128 kg and 133 kg, respectively.

The ADG observed in this experiment was higher than those previously reported for Sahiwal cattle. For example, the SH36 group recorded an ADG of 1.19 kg, whereas Jabbar et al. [12] documented an ADG of 0.849 kg/day in Sahiwal male calves. This suggests that with proper feeding management, it is possible to achieve ADG levels comparable to those of beef breeds. Our ADG findings are consistent with those of Bastos et al. [18], who reported no effect on growth rates when corn was replaced with SH in the diet. The numerically higher ADG in the SH36 group could be linked to increased DMI and improved digestibility of fiber components such as NDF and ADF. This is supported by [19], who found that the use of SH in receiving diets for feedlot steer calves promoted body weight gain similar to dry rolled corn, which is in line with the findings of this experiment.

No effect on feed efficiency was observed when corn and wheat bran were replaced with different levels of SH in the concentrate feed for bull calves. In contrast to our findings, Ferreira et al. [6] reported reduced feed efficiency when SH levels were increased up to 45% in the concentrate diets of feedlot lambs. Similarly, Bastos et al. [18] found that substituting corn with varying levels of SH in fattening diets led to a reduction in feed efficiency.

A key factor that may have contributed to maintaining animal performance in our study, despite the replacement of corn with SH, is the reduced risk of ruminal acidosis. As noted by Sarwar et al. [20], SH could minimize the negative effects associated with ruminal acidosis, which can occur with high levels of rapidly fermentable carbohydrates.

The cost per unit gain did not differ significantly among treatments. However, due to the higher cost of corn and wheat bran in the region, the cost per unit gain in the SH0 treatment was numerically slightly higher (144 Rs. /kg) compared to the SH18 and SH36 treatments (142 Rs. /Kg and 141 Rs. /Kg, respectively).

Blood glucose concentration and BUN levels were not significantly different among treatments, which is likely due to the similar energy values across all diets. Schmidt et al. [21] noted that blood glucose concentration in cattle is associated with energy intake, supporting the lack of variation in our results. The blood glucose values observed in this study are consistent with the findings of Kumar et al. [22], who reported a mean blood glucose concentration of 76.25 mg/dL in Sahiwal calves (0-1 year). Treatment diets have no effect on BUN concentration.

Similarly, our results align with those of Meng et al. [23], who observed that replacing wheat bran and corn grains with SH improved the digestibility of NDF and DM in cattle. Ferreira et al. [6] also reported increased NDF digestibility when SH replaced corn up to 45% in the concentrate diets of fattening lambs. Ludden et al. [24] found that including SH in the diet of crossbred steers, up to 60% of dietary DM, had a positive effect on NDF digestibility, which increased linearly with higher SH levels. However, they noted that DM digestibility decreased as SH fractions increased in the diet, which contrasts with our findings, likely due to the higher inclusion levels of SH in their study compared to ours.

5. Conclusions

In conclusion, this study demonstrated that replacing conventional energy sources (corn grain and wheat bran) with up to 36% soybean hulls (SH) in the concentrate diets of fattening Sahiwal bull calves can effectively support DMI, growth performance, and feed efficiency. The inclusion of SH slightly reduced feeding costs without negatively impacting production performance. Therefore, SH can be a viable and cost-effective alternative to traditional energy sources in the fattening diets of Sahiwal bull calves.

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