



Research Article

Effects of Dietary Bypass Fat Supplementation and Varying NDF Levels on Growth Performance, Feed Efficiency, Blood Metabolites and Nutrients Digestibility in Beetal Goat Bucks

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Abstract | The objective of current study was to evaluate the effects of bypass fat supplementation with ration of varying levels of NDF on growth performance, blood metabolites and nutrient digestibility in Beetal goat bucks. A total of thirty-two Beetal goat bucks of 10±1 months of age with an average body weight of 42±7 kg was selected and randomly distributed among 4 dietary treatments and structured as 2 × 2 factorial arrangements. The dietary treatments; (T1) low NDF (30%) without supplementation of bypass fat, (T2) low NDF (30%) with bypass fat supplementation (40gm), (T3) high NDF (40%) without bypass fat supplementation, (T4) high NDF (40%) with bypass fat supplementation (40gm) for 60 days. Results showed the improved ($P < 0.05$) average daily gain, feed conversion ratio, body condition score, and nutrient digestibility, including dry matter and NDF in T4. Triglyceride levels were also higher ($P < 0.05$) in the high NDF and bypass fat supplemented group (T4), though blood glucose levels remained unaffected. It is concluded that bypass fat supplementation (40gm) with a high NDF (40%) diet, positively influenced growth performance, nutrient digestibility and economic efficiency in Beetal goat bucks.

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Introduction

Goats are rapidly growing ruminants in the world, including Pakistan. According to the Economic Survey of Pakistan (Anonymous, 2023-

24), the country is blessed with 82.5 million goats, predominantly owned by rural farmers. The global demand for goats and sheep for meat and milk is increasing, driven by increasing human population and urbanization as well as evolving customer

preferences (Kosgey and Okey, 2007). To meet this increasing demand, it is essential to optimize the nutritional strategies to ensure healthy growth and high productivity. A nutritionally balanced diet is crucial for proper growth and development. Fiber plays an important role in maintaining rumen health and supporting efficient digestion and nutrient absorption.

Roughages are the main source of fiber. To meet the sufficient fiber intake, it is recommended to add 70% forage in the diet. Fiber is essential for rumen function and microbial growth. The neutral detergent fiber (NDF), a major component of fiber, is particularly important as it affects rumen fermentation and nutrient utilization (Renhuang *et al.*, 2023). Adequate NDF levels in goat feeding not only maintain a healthy rumen environment but also prevent acidosis and other health issues. The high NDF diets, however, affect the intake, ultimately limiting the energy uptake and affecting the optimal growth rate. To boost the energy density of feedlot diets, bypass fat may be provided in place of traditional dietary fat sources (Fluhart and Loerch, 1997). The bypass fat is typically rich in a highly digestible saturated fatty acid (Singh *et al.*, 2014). The rumen bypass fats are concentrated sources of energy; they bypass the rumen, digested and absorbed in the intestines and deliver a concentrated energy source. The rumen bypass fats can improve the energy density of ruminant diets without compromising fiber content. The bypass fat reduces the risk of metabolic acidosis and is somewhat resistant to biohydrogenation by rumen bacteria (Naik *et al.*, 2009). The bypass fat resists the microbial breakdown of fats in the rumen, thus preventing the negative effects of unsaturated fats on fiber digestion (Drackley, 2007). The bypass fat, usually given as calcium salts, is less likely to go through biohydrogenation. Because bypass fat reduces the bio-hydrogenation of fatty acids (FA) in the rumen and increases the amount of unsaturated fats available for post-ruminal absorption (Zinn *et al.*, 2000; Huang *et al.*, 2009). The supplementation of bypass fat not only helps to meet the high energy requirements of growing animals but also improves nutrient utilization, thereby improving overall feed efficiency. This helps to keep higher levels of unsaturated fatty acids available for absorption (Zinn *et al.*, 2000; Huang *et al.*, 2009). Studies have shown that the addition of bypass fat to the ruminant diets can improve body condition scores, increase average

daily gain (ADG), and improve carcass quality (Bhatt *et al.*, 2009; Naik *et al.*, 2009).

In addition to supplementing with bypass fat, use of optimal levels of NDF in the diet is a necessity. It is crucial, therefore, to investigate various aspects of goat's fibrous diet and their optimal utilization for maximum meat output. As NDF influences feed intake, rumen fermentation, and nutrient utilization, it is an essential component of the digestive process in animals raised for food (Renhuang *et al.*, 2023). The NDF adequacy may be beneficial for rumen health but can limit the uptake of energy due to their bulky nature. The bypass fat can be added to the diet to increase energy density without increasing the bulk, thereby complementing the high NDF content. Regarding the optimum NDF at a certain level of bypass fat supplementation for growing goats, very little information is available from previous studies. In light of these facts, the goal of the current study is to assess the ideal NDF level in goats and how it interacts with the bypass fat supplementation.

Materials and Methods

Experimental design, management, and diets

The research was conducted at the Small Ruminant Research and Training Centre, University of Veterinary and Animal Sciences, Ravi campus, Pattoki, Pakistan. All the methods used in this experiment were under the recommendations of the ethical review committee, UVAS, vide letter no DR/176. The duration of the study was 74 days, including 14 days of dietary adaptation. Prior to the deworming protocol, as guided by the farm veterinarian, bucks were vaccinated against prevalent diseases. With an average age of 10 ± 1 months and a live body weight of 42 ± 7 kg, 32 Beetal goat bucks were randomly distributed into the 4 treatment groups ($n = 8/\text{treatment}$) and structured under a 2×2 factorial arrangement. The dietary treatments were (T1) low NDF (30%) without supplementation of bypass fat, (T2) low NDF (30%) with bypass fat supplementation (40gm), (T3) high NDF (40%) without bypass fat supplementation, (T4) high NDF (40%) with bypass fat supplementation (40gm). The bucks were offered feed two times in a day at 6:00 am and 6:00 pm. Clean and fresh water was provided on *ad libitum* basis to the animals throughout the trial. Animals were fed at individual stalls. Feeds were prepared to meet the nutrient requirements of goats

as recommended by nutrient requirements of small ruminants (NRC, 2007). Feed ingredients used in the TMR and the chemical composition are presented in Table 1.

Feed intake, growth performance, blood metabolites and nutrient digestibility

Feed offering and refusal were measured daily. The collectedorts were estimated for DM and the DMI was estimated on an individual basis. Average daily gain was noted on a fortnightly basis. The body condition score (BCS) was measured at the start and at the end of study at 1-5 scale, as described by Abdel-Mageed (2002).

The five animals from each group were selected for blood sampling, blood glucose and triglyceride were determined at the start and end of the trial. The blood was collected from a jugular vein puncture in a tube containing EDTA and centrifuged at 3000 rpm for 15 minutes and stored at -20 °C for further analysis. The blood glucose and blood triglyceride were analyzed in the university diagnostic laboratory (UDL) using commercially available kits.

The DM, CP, acid detergent fiber (ADF) and NDF digestibility were determined using total tract digestibility by the total collection method (Yudithia *et al.*, 2022) at the end of the trial for 5 consecutive days. The animals were placed in individual feeding stalls; every day, the total amount of feed intake and fecal output were weighed and noted, and 100 g of the total day to day feces for five days were collected and stored at -20 °C till further analysis (Blanco *et al.*, 2014). The apparent nutrient digestibility was determined using the following formula:

$$\text{Nutrient digestibility} = \frac{\text{Nutrient intake} - \text{Nutrient excreted}}{\text{Nutrient intake}}$$

Chemical analysis

Feed and fecal samples of the experiment were analyzed for DM (AOAC, 2023) using method no 945.15, EE (AOAC, 2023) using method no 920.29, and CP (AOAC, 2023) using method no 984.13. The CP content was measured by multiplying the nitrogen percentage with a factor of 6.25. The NDF content of the feed and fecal samples was determined by the method of AOAC (2023).

Table 1: Ingredients and chemical composition of experimental TMR fed to Beetal goat bucks.

Ingredients %	T ₁ (Low NDF 0gm By pass fat)	T ₂ (Low NDF 40 gm By pass fat)	T ₃ (High NDF 0 gm By pass fat)	T ₄ (High NDF 40 gm By pass fat)
Corn silage	23	23	23	23
Maize grain	39	20.8	24	22
Wheat straw	0	0	12	13
Rice polishing	3	2	5.2	3
Wheat bran	9	21	4.8	4.8
Molasses	6	12	5	7
Corn gluten 30%	11	11	17	17
Canola meal	5	5	5	5
Urea	1	1	1	1
Mineral mixture	2	2	2	2
Soda Bicarb	1	1	1	1
By pass Fat (gm) supplementation	0	40	0	40
Total	100	100	100	100
Chemical composition				
DM%	74.87	74.87	68.43	68.43
CP%	15.5	15.4	15.6	15.6
Energy MCal/kg	2.50	2.52	2.51	2.52
NDF%	30.0	30.0	40.00	40.00
NFC%	45.10	45.10	39.62	39.5
Ca%	0.6	0.6	0.6	0.6
P%	0.3	0.3	0.3	0.3

Low NDF means 30% NDF, High NDF means 40% NDF. DM, dry matter; CP, crude protein; NDF, neutral detergent fiber; NFC, non-fibrous carbohydrates; Ca, calcium; P, phosphorus.

Statistical analysis

Data were evaluated using the MIXED procedure of SAS (version 9.4; SAS Institute Inc.). Treatments were structured as 2 × 2 factorial arrangements with 2 levels of NDF (30% and 40%) and 2 levels of bypass fat supplementation (0 or 40 g/head/day). Significant differences were declared at $P \leq 0.05$ and the trend at $P \leq 0.10$. Means of significant results were compared by Tukey's post hoc multiple comparison test (Steel *et al.*, 1997).

Results and Discussion

Growth performance

The performance assessment of Beetal goat bucks under varying dietary treatments revealed significant differences across parameters presented in Table 2. Highest DMI was recorded in treatment T4 with high NDF (40%) and 40 g bypass fat supplementation head/day at 1.39 ± 0.03 kg compared to others. The same treatment of T4 also had the highest ADG at 0.18 ± 0.05 kg besides having the lowest FCR value that was 7.56 ± 0.20 and the highest BCS score recorded to be 3.45 ± 0.10 . Meanwhile, the bucks with low NDF (30%) without bypass fat supplementation have lowest ADG at 0.13 ± 0.05 kg, the highest FCR at 10.38 ± 0.15 , and the lowest BCS at 3.02 ± 0.10 . The statistical analysis of the treatment effect showed that NDF contents and bypass fat supplementation affected ADG, FCR, and BCS, respectively ($p = 0.04$ and $p = 0.03$; $p = 0.05$ and $p = 0.01$; and $p = 0.02$ and $p = 0.01$, respectively). Overall and significant interaction effect between NDF and bypass fat supplementation is seen for ADG ($p = 0.02$), FCR ($p = 0.005$) and BCS ($p = 0.015$); hence, it indicated synergy in high NDF diet supplemented with bypass fat, enhanced the growth performance as well as body condition score for Beetal goat bucks.

Blood metabolites

The analysis of blood metabolites in Beetal goat bucks across different treatment groups showed significant differences in triglyceride concentrations as affected by NDF and fat supplementation presented in Table 3. The highest triglyceride concentration was observed in bucks fed with a high NDF diet supplemented with 40 g of fat per individual daily, at 75.60 ± 1.89 mg/dl, while the lowest triglyceride concentrations were observed in bucks fed with a low NDF diet without any fat supplementation at 64.83 ± 1.76 mg/dl. However, the glucose levels did not expose an

important difference among groups, although, it was a close range of values from 84.76 ± 1.67 to 87.08 ± 2.53 mg/dl. Statistical analysis showed that the triglyceride level had strong significance from the NDF level ($p = 0.005$) and fat supplementation ($p = 0.002$). However, the interaction of NDF with fat supplementation affected triglycerides largely ($p = 0.004$), and it might be that mixed dietary factors enhance the levels of triglycerides in Beetal goat bucks. Glucose levels were not affected to any significant extent over any of the treatment variables.

Table 2: Performance assessment of Beetal goat bucks fed total mixed ration with varying levels of NDF and bypass fat.

NDF	Fat supplementation	DMI (kg)	ADG (kg)	FCR	BCS
Low NDF	0 g/head/d	1.35 ± 0.03	$0.13^c \pm 0.05$	$10.38^c \pm 0.15$	$3.02^c \pm 0.10$
	40 g/head/d	1.37 ± 0.03	$0.15^b \pm 0.04$	$9.13^b \pm 0.14$	$3.32^b \pm 0.10$
High NDF	0 g/head/d	1.34 ± 0.03	$0.14^b \pm 0.06$	$9.57^b \pm 0.18$	$3.20^b \pm 0.12$
	40 g/head/d	1.39 ± 0.03	$0.18^a \pm 0.05$	$7.56^a \pm 0.20$	$3.45^a \pm 0.10$
P-value					
NDF		0.3	0.04	0.05	0.02
Fat supplementation		0.25	0.03	0.01	0.01
Interaction		0.2	0.02	0.005	0.015

Low NDF means 30% NDF, High NDF means 40% NDF

Table 3: Blood metabolites of Beetal goat bucks fed total mixed ration with varying levels of NDF and bypass fat.

NDF	Fat supplementation	Glucose (mg/dl)	Triglyceride (mg/dl)
Low NDF	0 g/head/d	85.08 ± 2.51	$64.83^c \pm 1.76$
	40 g/head/d	84.76 ± 1.67	$68.33^b \pm 1.92$
High NDF	0 g/head/d	87.08 ± 2.53	$70.50^b \pm 1.77$
	40 g/head/d	86.76 ± 1.73	$75.60^a \pm 1.89$
P-value			
NDF		0.467	0.005
Fat supplementation		0.597	0.002
Interaction		0.737	0.004

Superscripts on different meant within column differ significantly at $P \leq 0.05$.

Nutrient digestibility

The nutrient digestibility of Beetal goat bucks included an investigation on the effects of three treatments involving NDF levels and bypass fat

supplementation, presented in Table 4. Highest digestibility of the nutrients assessed was observed in a Beetal goat bucks, which were fed a diet with 40 grams of fat supplemented per day. Observed digestibility's were as follows: Digestibility for DM was found to be 46.45 ± 2.05 % and digestibility values for CP and NDF reached 70.25 ± 0.78 %, 52.75 ± 0.78 %, ADF digestibility was valued at 28.85 ± 0.47 %. On the contrary, bucks fed with low NDF diet without fat supplementation had the lowest digestibility percentages of these nutrients (DM: 34.02 ± 1.52 %, CP: 67.40 ± 0.72 %, NDF: 46.86 ± 0.57 %, and ADF: 26.73 ± 0.55 %). Statistical analysis revealed that NDF and fat supplementation have independent effects on digestibility of all nutrients (DM, CP, NDF, and ADF) since p-values were between <0.0001 to 0.045 . There was a significant interaction between NDF levels and fat supplementation for all digestibility parameters, with p-values <0.0001 for DM, 0.0112 for CP, 0.0025 for NDF, and 0.008 for ADF. This suggests that there is a synergistic effect of higher NDF levels and fat supplementation in improving nutrient digestibility in Beetal goat bucks.

Economics

The cost of meat production was calculated by dividing net cost of meat production divided by average live weight gain per animal. There was significant difference ($P \leq 0.05$) observed in the profit calculations of each treatment group. The maximum profit obtained is in T4 group and the minimum was in T1 group as presented in Figure 1.

The present study evaluated the effects of dietary bypass fat supplementation with varying NDF levels on growth performance, feed efficiency, blood metabolites, and nutrient digestibility in Beetal goat bucks. It was hypothesized that dietary

supplementation of bypass fat may have beneficial effects on the above-mentioned parameters in Beetal goat bucks with high NDF with 40 g/head/d more beneficial. The significant interaction between NDF level and bypass fat supplementation resulted in improved ADG, FCR, and BCS in bucks fed a high NDF diet with bypass fat supplementation. The reported improved growth performance in bucks fed diets high in NDF aligns with Schulze *et al.* (2014), who observed a decrease in DMI due to the rumen fill effect. In the current study, the bucks fed high-NDF diets with bypass fat supplementation exhibited significantly better feed efficiency, likely due to the fiber's effect on rumen health, buffering, and improved nutrient absorption. Khurshid *et al.* (2023) also reported similar improvements in ADG in goats fed high-NDF diets, highlighting the importance of dietary fiber in improving growth during the feed transition phase. Some studies, in contrast, reported that high NDF and bypass fat did not affect the DMI, ADG, and FCR in bucks (Behan *et al.*, 2019; Nitin *et al.*, 2010).

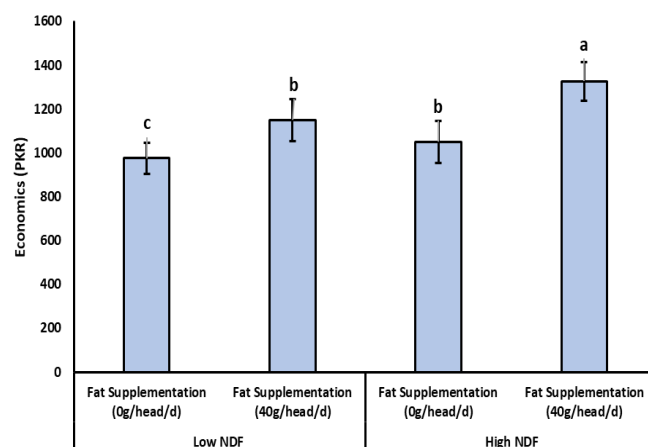


Figure 1: Economics of Beetal goat bucks fed total mixed ration with varying levels of NDF and bypass fat.

Table 4: Nutrient digestibility of Beetal goat bucks fed total mixed ration with varying levels of NDF and bypass fat.

NDF	Fat supplementation	DM %	CP %	NDF %	ADF %
Low NDF	0 g/head/d	$34.02^c \pm 1.52$	$67.40^c \pm 0.72$	$46.86^c \pm 0.57$	$26.73^b \pm 0.55$
	40 g/head/d	$37.38^b \pm 2.40$	$69.50^b \pm 0.68$	$48.50^b \pm 0.67$	$27.20^b \pm 0.63$
High NDF	0 g/head/d	$43.09^b \pm 2.68$	$66.83^c \pm 0.59$	$50.30^a \pm 0.68$	$28.10^a \pm 0.40$
	40 g/head/d	$46.45^a \pm 2.05$	$70.25^a \pm 0.78$	$52.75^a \pm 0.78$	$28.85^a \pm 0.47$
P-value					
NDF		0.017	0.045	0.0015	0.0102
Fat supplementation		<0.0001	0.0308	0.005	0.0205
Interaction		<0.0001	0.0112	0.0025	0.008

Superscripts on different meant within column differ significantly at $P \leq 0.05$.

Bucks fed high NDF diets supplemented with bypass fat had improved triglyceride levels. The findings are consistent with Kumar and Thakur (2007), who reported increased blood triglycerides in buffalo calves supplemented with bypass fat. Increased triglyceride levels in this study may be related to better absorption and metabolism of dietary fats, as suggested by Grewal *et al.* (2014). The strong interaction between varying NDF levels and bypass supplementation on triglyceride concentrations highlights the importance of supplementing with bypass fat in high-fiber diets to regulate lipid metabolism. However, both NDF levels and bypass fat supplementation did not impact blood glucose levels. These findings align with Hammon *et al.* (2008) and Shelke *et al.* (2012) investigations. Ruminants' efficient glucose metabolism regulating mechanisms may maintain glucose homeostasis, resulting in stable blood glucose levels despite dietary variations.

Bucks fed high-NDF diets supplemented with bypass fat showed a significant improvement in DM, CP, NDF, and ADF digestibility. These findings are consistent with Hadad and Younis (2004), who also reported increased DM digestibility when bypass fat was included in the diet. The improved DM digestibility may be attributed to the higher TDN content in the supplemented groups, which enhanced nutrient utilization and energy absorption. Some studies, in contrast, reported that the DM, CP, NDF, and ADF digestibility were not influenced by NDF level or bypass fat supplementation, these findings align with previous reported studies of Tyagi *et al.* (2009) and Ngidi *et al.* (1990).

Conclusions and Recommendations

Overall bypass fat supplementation with high NDF levels resulted in an improved growth performance, feed efficiency, blood metabolites and nutrients digestibility in Beetal goat bucks and improve economics. Bypass fat is energy dense nutrient that can help to meet energy requirement of Beetal goats. It is recommended that bypass fat supplementation (40gm) with a high NDF (40%) diet, can be added in Beetal goat diet that will positively influence growth performance, nutrient digestibility and economic efficiency.

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Novelty Statement

This study presents novel data on how different levels of neutral detergent fiber (NDF) and dietary bypass fat supplementation influence Beetal goat bucks' growth performance, feed efficiency, blood metabolites, and nutrient digestibility. This study provides an in-depth awareness regarding how bypass fat and NDF can optimize growth metrics, improve feed conversion, and influence metabolic and digestibility profiles in Beetal goat bucks.

Author Contribution

Ahmed Abdullahi Salad, Saeed Ahmed and Ehsan Ullah Khan: The writers listed in this manuscript added to the study commencement and plan. Data collection, preparation of material and data analysis was completed.

Muhammad Shahbaz Zafar¹, Imran Mohsin², Mubarak Ahmad², Zakariye Abdifatah Ahmed³ and Muhammad Uzair: The draft of the research paper was written.

All authors have read and finalized the research paper.

Conflict of interest

The authors have declared no conflict of interest.

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