



Influence of Dietary Physical Form on Mineral Status and Hematological Responses in Intensively Reared Goats

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ABSTRACT

The study was carried out during May–August, 2024 at the Goat Research Training Centre (GRTC), Department of Veterinary Physiology, College of Veterinary Science and Animal Husbandry, DUVASU, Mathura, India, to evaluate the influence of dietary physical form on hematological parameters, plasma mineral profile, and health status of intensively reared Barbari goat kids. Twenty-four male Barbari kids (3–4 months of age; 7.2 ± 0.8 kg body weight) were randomly allotted to four dietary treatments in a completely randomized design: separate feeding, complete feed mash, complete feed pellet, and complete feed block. All diets were iso-caloric and iso-nitrogenous, differed only in physical form. Blood samples were collected at monthly intervals for hematological evaluation, while plasma macro- (Ca, P, Mg) and trace minerals (Cu, Fe, Zn) were determined using ICP-OES. Dietary physical form had no significant ($p > 0.05$) effect on erythrocytic indices. Likewise, plasma concentrations of calcium, phosphorus, magnesium, copper, iron, and zinc did not differ among treatments and remained within normal physiological ranges. No incidences of mortality, morbidity, diarrhoea, bloat, or other digestive disorders were observed during the experimental period. The findings indicated that processing complete diets into mash, pellet, or block form did not adversely affect hematological profile, mineral homeostasis, or health of growing Barbari kids. Thus, complete feeds in processed forms could be safely utilized under intensive goat production systems without compromising physiological well-being.

KEYWORDS: Complete feed, physical form, pelleted feed, feed block

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1. INTRODUCTION

India is experiencing a rapid increase in the demand for animal-derived food products driven by population growth, urbanization, and rising incomes. Meeting this growing demand requires substantial improvements in the efficiency and productivity of livestock production systems (Anonymous, 2018; Anonymous, 2022). Achieving higher productivity, however, depends on maintaining animal health and nutritional status. Feed processing is increasingly employed in intensive goat production systems to improve feed utilization, animal performance, and production efficiency (Ostergaard et al., 2000; Anonymous, 2007). Among various feeding strategies, complete diet system stands out as a particularly effective approach. Complete diet refers to a nutritionally balanced and homogeneously mixed formulation of roughage and concentrates designed to fulfil the entire dietary requirements of an animal in every mouthful ensuring balanced nutrient intake, preventing selective feeding, and promoting synchronized nutrient availability in the rumen (Lailer et al., 2005; Beigh et al., 2017). It fundamentally contrasts with conventional feeding approaches where forages and concentrates are offered separately. With this traditional system of feeding, animals exhibit selective feeding behaviour, preferentially consuming concentrates while rejecting fibrous components. Such selective intake results in inconsistent nutrient consumption, reduced physically effective fibre intake, altered rumen fermentation, and impaired nutrient utilization, ultimately compromising animal performance (Miller-Cushon and DeVries, 2017; Humer et al., 2018; Kroger et al., 2019). Depending on the processing method, complete diets can be offered in different physical forms such as mash, pellets, and blocks, encompassing feed processing operations like grinding, mixing, pelleting, densification which significantly modify the particle size, physical structure of the diet and surface area available for microbial colonization, thereby influencing ruminal degradation kinetics and nutrient utilization. Appropriate processing can enhance feed efficiency by increasing nutrient availability, whereas excessive processing may impair rumen function through inadequate physically effective fibre and reduced chewing activity. Furthermore, structural modification of complete diets through processing significantly affects feed efficiency, animal performance and economic returns. These alterations can influence palatability, chewing activity, feed intake, saliva secretion, rumen fermentation, digesta passage rate, nutrient availability and feeding behaviour, thereby affecting nutrient metabolism and physiological responses of animals (Moeini et al., 2017). Although numerous studies have reported the effects of dietary physical form on feed intake, nutrient digestibility, and growth performance (Samanta et al., 2003; Blanco et al., 2014;

Karimizadeh et al., 2017; Quigley et al., 2018; Bilal et al., 2025), information regarding its influence on hematological parameters and mineral status in goats remains limited, particularly under tropical intensive production systems. Hematological parameters are widely used as indicators of physiological adaptation, nutritional adequacy, and health status (Radostits, 2008; Kaneko, 2008), while serum mineral concentrations provide valuable information regarding mineral metabolism and bioavailability. Macro minerals such as calcium, phosphorus, and magnesium play essential roles in skeletal development, enzyme function, and metabolic regulation, whereas trace minerals including zinc, copper, iron, and manganese are involved in immunity, antioxidant defense, oxygen transport, and numerous enzymatic processes (Suttle, 2010). In addition to blood parameters, field health indicators such as diarrhea incidence and mortality provide practical measures of animal well-being and adaptation to dietary interventions under commercial production conditions (Constable et al., 2017; Wong et al., 2021). Alterations in dietary physical form modify rumen fermentation characteristics, ruminal pH, digesta passage rate, and microbial activity (Vidya et al., 2024; Pressman et al., 2024), which may consequently influence mineral bioavailability (Suttle, 2010). Therefore, the present study was undertaken to evaluate the influence of dietary physical form on hematological responses, mineral status, and selected health indicators in intensively reared Barbari goat kids.

2. MATERIALS AND METHODS

2.1. Study sites

The study was carried out during May–August, 2024 at the Goat Research Training Centre (GRTC), Department of Veterinary Physiology, College of Veterinary Science and Animal Husbandry, DUVASU, Mathura, India (27.497° N, 77.673° E). The experimental protocol was approved by the Institutional Animal Ethics Committee (IAEC), DUVASU, Mathura, India (Approval No. IAEC/24/1/40), and all animal handling procedures were performed in accordance with the approved guidelines.

2.2. Animals, diets, and experimental design

Twenty-four male Barbari kids (3–4 months of age; average body weight 7.2±0.8 kg) were randomly allocated to four dietary treatments in a completely randomized design (n=6 per treatment) ensuring similar mean initial body weights among groups. The treatments consisted of separate feeding (SF), complete feed mash (CFM), complete feed pellet (CFP), and complete feed block (CFB). All diets contained 50% concentrate mixture and 50% gram straw on a dry matter basis and were formulated according to Anonymous (2013) nutrient requirements for growing goats. Diets were

identical in ingredient composition and nutrient content and differed only in physical form. The chemical composition (% DM basis) of the experimental diet was analyzed according to (Anonymous, 2005; Van Soest et al., 1991) and was presented in Table 1. In the SF group, concentrate and roughage were offered separately, whereas in the CFM, CFP, and CFB groups the diets were processed and offered as mash, pellets (6 mm diameter and 10–12 mm length), and blocks (12×12 cm²), respectively. Animals were housed individually in well-ventilated pens and fed twice daily at 0600 and 1800 h with ad libitum access to clean drinking water. The experiment consisted of a 15-day adaptation period followed by a 90-day feeding trial. All animals were dewormed before commencement of the experiment.

2.3. Blood collection and hematological analysis

Blood samples were collected from all animals at monthly intervals during the experimental period (day 0, 30, 60, and 90) by jugular venipuncture before morning feeding. Approximately 5 ml of blood was collected into EDTA-containing vacutainer tubes for hematological analysis. The hematological parameters evaluated included hemoglobin concentration (Hb), total erythrocyte count (TEC), packed cell volume (PCV), total leukocyte count (TLC), and differential leukocyte count including neutrophils, lymphocytes, monocytes, eosinophils, and basophils. Erythrocytic indices, namely mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC), were analyzed using automatic hematology analyzer (MS4s Auto Hematology Analyzer by Nexus medical solution, Malaysia)

2.4. Plasma mineral analysis

Additional blood samples were collected in anticoagulant-containing vacutainer tubes and centrifuged at 3000 rpm for 15 min to separate plasma. The plasma samples were carefully harvested, transferred into sterile microcentrifuge tubes, and stored at -20°C until further analysis. Plasma concentrations of macro minerals including calcium (Ca), phosphorus (P), and magnesium (Mg), and trace minerals including zinc (Zn), copper (Cu), iron (Fe), and manganese (Mn) were determined using an Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES; Agilent 5800 ICP-OES, Agilent Technologies, USA) following appropriate sample preparation and calibration procedures.

2.5. Health observations

Animals were monitored daily throughout the experimental period for general health status and the occurrence of clinical abnormalities. Particular attention was given to the incidence of diarrhea, digestive disturbances, morbidity, and mortality. Any health-related events were recorded and expressed as incidence per treatment group.

2.6. Statistical analysis

Data were analyzed using one-way analysis (Anonymous, 1994) under a completely randomized design using appropriate statistical software. Treatment means were compared using Duncan's multiple range test (Duncan, 1955) and differences were considered significant at $p < 0.05$.

3. RESULTS AND DISCUSSION

The chemical composition of the experimental diet was presented in Table 1. The diets contained 12.72% crude protein and 2100 kcal ME kg DM⁻¹, which met the nutrient requirements of growing Barbari kids as recommended by Anonymous (2013). The complete diets were characterized by moderate fibre concentrations (47.79% NDF and 27.98% ADF), ensuring adequate physically effective fibre for normal rumen function. Since the ingredient and nutrient compositions were identical across treatments and differed only in physical form; therefore, any observed variations in physiological responses could be attributed primarily to differences in dietary processing and presentation rather than nutrient supply.

Table 1: Chemical composition of the experimental diet offered to Barbari kids (% DM basis)

Parameter (% DM basis)	Experimental diet
Dry matter (DM, %)	91.34
Organic matter (OM, %)	82.43
Crude protein (CP, %)	12.72
Ether extract (EE, %)	2.90
Total ash (%)	8.92
Crude fibre (CF, %)	23.64
Nitrogen free extract (NFE, %)	51.81
Neutral detergent fibre (NDF, %)	47.79
Acid detergent fibre (ADF, %)	27.98
Metabolizable energy (kcal kg DM ⁻¹)	2100

Ingredient composition and nutrient composition of diets were identical across treatments and differed only in physical form, namely separate feeding (SF), complete feed mash (CFM), complete feed pellet (CFP), and complete feed block (CFB)

3.1. Hematological parameters

The effects of dietary physical form on hematological parameters of intensively reared Barbari kids were presented in Table 2. Dietary treatments had no significant effect ($p > 0.05$) on red blood cell count (RBC), white blood cell count (WBC), hemoglobin concentration (Hb), packed cell volume (PCV), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular

Table 2: Hematological profile of Barbari kids fed diets differing in physical form

Parameter	SF	CFM	CFP	CFB	SEM	<i>p</i> -value
RBC ($\times 10^6 \mu\text{l}^{-1}$)	12.07	12.02	12.96	12.42	0.40	0.32
WBC ($\times 10^3 \mu\text{l}^{-1}$)	11.65	11.78	12.36	11.40	0.24	0.06
Hb (g dl^{-1})	9.10	9.25	9.70	9.27	0.17	0.08
PCV (%)	29.76	29.90	29.61	29.59	0.79	0.99
MCV (fl)	24.86	16.13	16.09	16.03	0.23	0.65
MCH (pg)	7.67	7.76	7.77	7.73	0.12	0.94
MCHC (g dl^{-1})	30.58	34.89	35.49	35.08	0.64	0.92
MPV (fl)	3.60	3.69	3.76	3.84	0.15	0.71

SF: Separate feeding; CFM: Complete feed mash; CFP: Complete feed pellet; CFB: Complete feed block

hemoglobin concentration (MCHC), and mean platelet volume (MPV).

The RBC count ranged from 12.02 to $12.96 \times 10^6 \mu\text{l}^{-1}$, with numerically higher values observed in kids fed the complete feed pellet (CFP) diet. Similarly, hemoglobin concentration varied from 9.10 to 9.70 g dl^{-1} , whereas PCV values ranged from 29.59 to 29.90 %, with no significant differences among treatments. The maintenance of erythrocytic indices within normal physiological limits suggested that dietary processing and densification did not adversely affect erythropoiesis, oxygen carrying capacity, or overall physiological status of the animals. These findings indicated that all dietary forms adequately met the nutritional requirements necessary for normal red blood cell synthesis and function. The present findings were in agreement with reports of Karimizadeh et al. (2017), who observed no significant changes in hematological parameters in small ruminants fed complete diets differing in physical form. Similarly, Patil et al. (2024) reported that feeding gram straw-based complete feed pellets did not affect hematological and biochemical indices in goats, indicating that processed complete diets were physiologically safe and nutritionally adequate. Kumar et al. (2015) also reported comparable hematological responses in Barbari goats fed complete pellet diets containing unconventional feed resources.

Total leukocyte count varied from 11.40 to $12.36 \times 10^3 \mu\text{l}^{-1}$ and remained unaffected by dietary treatment ($p=0.06$), although numerically higher values were observed in the CFP group. Leukocyte counts were widely regarded as indicators of immune competence and physiological stress. The absence of treatment effects suggested that

none of the dietary forms elicited inflammatory responses or compromised immune status in the animals. Similar observations were reported by Singh et al. (2015), who found no adverse effects of densified feed resources on hematological and immune parameters in goats. Likewise, Ceriac et al. (2017) emphasized that maintenance of normal hematological indices reflected adequate nutritional and health status in goats.

The erythrocytic indices MCV, MCH and MCHC did not differ among treatments and remained within the normal physiological range reported for growing goats. These indices provided information on erythrocyte size and hemoglobin content and were commonly used to assess nutritional adequacy and anemia status. Their stability across treatments indicated that dietary physical form did not interfere with nutrient metabolism associated with erythrocyte production and maturation. Similar findings were reported in studies evaluating complete feed systems and processed diets in small ruminants (Dhuria et al., 2011; Malik et al., 2020).

Mean platelet volume also remained unaffected by dietary treatment, suggesting that platelet production and turnover were not influenced by feed processing technologies. Collectively, the absence of significant differences in hematological variables indicated good physiological adaptability of Barbari kids to diets differing in physical form under intensive production systems.

3.2. Health observations

Health observations recorded throughout the 90-day experimental period revealed no incidences of mortality, morbidity, diarrhea, bloat, or other digestive disturbances in any of the treatment groups. Furthermore, none of the animals required veterinary intervention during the course of the study. The absence of clinical abnormalities and digestive disorders indicated good palatability, acceptability, and physiological adaptation of goats to all dietary physical forms. These findings further supported the hematological results and suggested that processing complete diets into mash, pellet, or block form did not adversely affect animal health or welfare under intensive production systems.

3.3. Plasma mineral profile

The effect of dietary physical form on plasma mineral concentrations of Barbari kids was presented in Table 3. Dietary treatments did not significantly influence ($p>0.05$) plasma concentrations of calcium, phosphorus, magnesium, copper, iron, and zinc. Plasma calcium concentrations ranged from 10.24 to 11.12 mg dl^{-1} , phosphorus from 4.72 to 5.02 mg dl^{-1} , and magnesium from 2.79 to 3.11 mg dl^{-1} across the experimental groups. Similarly, plasma concentrations of copper, iron, and zinc varied from 1.43 to 1.59 mg l^{-1} , 1.87 to 2.21 mg l^{-1} , and 1.63 to 1.77 mg l^{-1} , respectively. The

Table 3: Plasma mineral concentrations of Barbari kids fed diets differing in physical form

Parameter	SF	CFM	CFP	CFB	SEM	<i>p</i> -value
Calcium (mg dl ⁻¹)	10.74	10.68	10.24	11.12	0.46	0.61
Phosphorus (mg dl ⁻¹)	4.73	4.90	5.02	4.72	0.12	0.31
Magnesium (mg dl ⁻¹)	2.79	3.11	2.87	3.06	0.18	0.88
Copper (mg l ⁻¹)	1.43	1.51	1.59	1.54	0.08	0.76
Iron (mg l ⁻¹)	2.11	1.87	1.95	2.21	0.16	0.99
Zinc (mg l ⁻¹)	1.77	1.63	1.68	1.71	0.18	0.65

SF; Separate feeding; CFM; Complete feed mash; CFP: Complete feed pellet; CFB: Complete feed block

concentrations of both macro- and trace minerals remained within the normal physiological ranges reported for healthy growing goats, indicating adequate mineral supply and maintenance of mineral homeostasis irrespective of dietary physical form. Calcium and phosphorus were essential for skeletal growth and metabolic functions, while magnesium was involved in enzyme activation and neuromuscular activity. Similarly, copper, iron, and zinc played important roles in erythropoiesis, immune competence, antioxidant defence mechanisms, and numerous enzymatic reactions. The maintenance of these mineral concentrations across treatments suggested that processing complete diets into mash, pellet, or block form did not adversely affect mineral absorption, metabolism, or utilization in the animals.

The absence of significant differences among treatments might be attributed to the identical ingredient composition and nutrient density of the diets, which differed only in physical form. Although feed processing could influence chewing activity, rumination behaviour, rumen fermentation, and nutrient digestibility, these effects were insufficient to alter systemic mineral status under the present experimental conditions. Similar findings were reported by Kumar et al. (2015) in Barbari goats fed complete pellet diets and by Patil et al. (2024) in goats fed gram straw-based complete feed pellets, where blood mineral and hematobiochemical profiles remained unaffected despite improvements in nutrient utilization and rumen fermentation characteristics. Likewise, Singh et al. (2015) reported that feeding densified complete feeds and multi-nutrient blocks maintained normal mineral and health status in goats. Comparable observations were also made by Karimizadeh et al. (2017), who reported minimal influence of dietary physical form on physiological and metabolic indicators in small ruminants.

4. CONCLUSION

Dietary physical form had no significant effect on the hematological profile, plasma mineral status, or health of intensively reared Barbari kids. Hematological and mineral parameters remained within normal physiological

ranges, indicating adequate nutrient supply and maintenance of mineral homeostasis. No incidences of mortality, morbidity, diarrhea, bloat, or other health disorders were observed. Complete diets offered as mash, pellet, or block were physiologically safe and supported good health and adaptability in intensively reared goats under tropical conditions.

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