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Nutrient Digestibility as a Predictor of Haematological and Immune Status in Lactating Sahiwal Cattle Fed Phytogetic Supplements

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Abstract

This study investigated the association between nutrient digestibility fractions and haematological and immune attributes in lactating Sahiwal cattle receiving phytogetic feed supplementation. Twenty-eight lactating Sahiwal cows were allocated to four dietary treatments comprising a control group and three phytogetic supplementation groups. A digestion trial was conducted at the end of a 120-day feeding experiment, and blood samples were collected for haematological evaluation. Pearson's correlation and regression analyses were performed to determine relationships between nutrient digestibility fractions and blood health indicators. Correlation analysis revealed significant positive associations of dry matter digestibility with packed cell volume ($r = 0.398$, $P = 0.036$) and total leukocyte count ($r = 0.389$, $P = 0.041$). Crude fibre digestibility was positively correlated with packed cell volume ($r = 0.384$, $P = 0.044$) and negatively correlated with lymphocyte percentage ($r = -0.391$, $P = 0.039$). Regression analysis demonstrated that organic matter digestibility significantly predicted neutrophil percentage ($R^2 = 0.286$, $\beta = -0.535$, $P = 0.003$), while ether extract digestibility significantly influenced total leukocyte count ($R^2 = 0.221$, $\beta = 0.470$, $P = 0.012$). Furthermore, multiple regression analysis revealed that dry matter, crude fibre and nitrogen-free extract digestibility collectively explained 32.1% of the variation in packed cell volume ($R^2 = 0.321$, $P = 0.024$). The findings demonstrate that nutrient digestibility fractions are closely associated with physiological and immune responses and may serve as useful biomarkers of blood health status in lactating Sahiwal cattle. Improved nutrient utilization was associated with favourable haematological characteristics and immune homeostasis, highlighting the potential of digestibility-based indices for evaluating the biological effectiveness of phytogetic nutritional interventions in dairy cattle.

Keywords: Nutrient digestibility, Haematology, Immune status, Sahiwal cattle, Phytogetic feed additives, Nutritional biomarkers, Regression analysis

Introduction

Haematological attributes are widely recognized as valuable indicators of the physiological, nutritional and immunological status of dairy animals. Blood parameters provide important information regarding oxygen transport capacity, metabolic adaptation, immune responsiveness and overall health condition of animals. Among these, haemoglobin concentration (Hb), packed cell volume (PCV), total erythrocyte count (TEC) and total leukocyte count (TLC) are commonly used to assess erythropoietic activity, circulatory efficiency and immune competence in cattle (Jain, 1993; Radostits *et al.*, 2007) [4, 13]. Because blood variables respond rapidly to changes in nutritional and physiological status, they have been extensively utilized as reliable biomarkers for evaluating the effects of dietary interventions in livestock production systems.

In addition to conventional haematological indices, differential leukocyte counts such as neutrophil, lymphocyte, monocyte, eosinophil and basophil percentages provide valuable insights into immune regulation and physiological stress responses. The neutrophil-to-lymphocyte (N: L) ratio has emerged as a useful indicator of stress and immune balance in both humans and animals (Gross and Siegel, 1983; Davis *et al.*, 2008) [2, 3]. Variations in leukocyte populations are often associated with alterations in nutritional status, disease resistance and inflammatory responses. Therefore, understanding the factors influencing

haematological and leukocytic profiles is essential for improving animal health and productivity.

Nutrition plays a pivotal role in maintaining normal haematological functions. Adequate supply of nutrients is required for erythropoiesis, leukopoiesis, haemoglobin synthesis and maintenance of immune cell populations. Deficiencies or imbalances in nutrient availability can adversely affect blood formation and immune competence, whereas improved nutrient supply may support optimal physiological functioning (Kaneko *et al.*, 2008) ^[6]. Consequently, the relationship between nutrient utilization and haematological responses has attracted increasing attention among animal nutritionists and physiologists.

The efficiency with which animals digest and utilize dietary nutrients is an important determinant of their productive and physiological performance. Nutrient digestibility influences the availability of energy, protein, minerals and other essential nutrients required for maintenance, production and metabolic activities. Enhanced digestibility facilitates greater nutrient absorption and utilization, thereby improving the efficiency of biological processes within the body (Van Soest, 1994; McDonald *et al.*, 2011) ^[6, 8, 15]. Conversely, poor digestibility may limit nutrient availability and compromise physiological functions, including blood cell production and immune regulation.

In ruminants, nutrient digestion is largely dependent on microbial fermentation occurring within the rumen ecosystem. The ruminal microbiota converts complex dietary components into volatile fatty acids, microbial protein and other metabolites that serve as major nutrient sources for the host animal (Russell and Rychlik, 2001; Jami and Mizrahi, 2012) ^[14, 5]. Improvements in digestibility therefore not only enhance nutrient availability but may also influence physiological homeostasis, immune competence and metabolic efficiency. As a result, nutrient digestibility has become an important indicator for evaluating the biological effectiveness of feeding strategies in dairy animals.

Among the various digestibility fractions, dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE), crude fibre (CF) and nitrogen-free extract (NFE) digestibility provide comprehensive information regarding the utilization of dietary nutrients. Enhanced protein digestibility may improve amino acid availability for haemoglobin synthesis and tissue metabolism, while improved energy utilization may support immune cell proliferation and physiological adaptation. Likewise, efficient fibre digestion may contribute to improved rumen health and metabolic stability, which can indirectly influence haematological and immune responses. Despite these plausible biological relationships, information regarding the direct association between nutrient digestibility fractions and haematological attributes in dairy cattle remains limited.

In recent years, phytogenic feed additives have gained considerable attention as natural alternatives to synthetic growth promoters. These plant-derived products contain a wide range of biologically active compounds such as flavonoids, alkaloids, tannins, saponins and phenolic substances capable of modulating ruminal fermentation, nutrient metabolism and immune responses (Patra and Saxena, 2009; Patra, 2010) ^[12, 11]. Several studies have demonstrated the beneficial effects of phytogenic supplements on nutrient digestibility, antioxidant status,

feed efficiency and productive performance in ruminants (Windisch *et al.*, 2008) ^[16].

Among phytogenic feed resources, *Moringa oleifera* is recognized for its high nutritional value and abundance of bioactive compounds. The plant is rich in crude protein, essential amino acids, vitamins, minerals and antioxidants, making it a promising feed supplement for livestock (Makkar and Becker, 1996; Moyo *et al.*, 2011) ^[7, 10]. Similarly, *Leptadenia reticulata* is an important medicinal plant known for its galactagogue, immunomodulatory and adaptogenic properties. The plant contains several bioactive constituents that may positively influence physiological functions and animal health (Mohanty *et al.*, 2017) ^[9]. Previous investigations have reported favourable effects of these phytogenic resources on nutrient utilization and physiological responses in dairy animals. Recent investigations conducted in lactating Sahiwal cattle have also demonstrated beneficial effects of *Leptadenia reticulata* and *Moringa oleifera* supplementation on nutrient digestibility, haematological characteristics and immune responses, indicating their potential role in improving physiological efficiency and animal health (Kumar *et al.*, 2025; Kumar *et al.*, 2026a; Kumar *et al.*, 2026b) ^[17, 18, 19].

Although numerous studies have evaluated digestibility responses and haematological responses independently, relatively little information is available regarding the biological association between nutrient digestibility fractions and blood health indicators. Most published reports have focused primarily on treatment-wise changes in digestibility coefficients or haematological parameters, while the extent to which nutrient utilization efficiency is associated with haematological and immune responses remains poorly understood. Identification of such relationships may provide a mechanistic explanation for the physiological benefits observed following dietary supplementation with phytogenic feed additives.

It was hypothesized that improved nutrient digestibility would enhance nutrient availability for erythropoiesis, leukocyte production and immune regulation, thereby contributing to favourable haematological responses. Furthermore, specific digestibility fractions may serve as predictors of blood health indicators and immune competence in dairy cattle. Therefore, the present study was undertaken to investigate the association between nutrient digestibility fractions and haematological attributes in lactating Sahiwal cattle receiving dietary supplementation of *Leptadenia reticulata* and *Moringa oleifera*. Particular emphasis was placed on identifying digestibility variables associated with haematological and immune responses through correlation and regression analyses.

2. Materials and Methods

2.1 Experimental Animals and Feeding Management

The present investigation was conducted at the Instructional Dairy Farm, Nagla, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India. Twenty-eight healthy lactating Sahiwal cows of comparable age, body weight and stage of lactation were selected for the study. The animals were randomly allocated into four treatment groups comprising seven animals each and maintained under uniform feeding and management conditions throughout the experimental period of 120 days. The treatment groups were designated as T0 (control; basal diet), T1 (basal diet supplemented with *Leptadenia*

reticulata root powder @ 90 g/animal/day), T2 (basal diet supplemented with *Moringa oleifera* leaf powder @ 150 g/animal/day) and T3 (basal diet supplemented with *Leptadenia reticulata* root powder @ 45 g + *Moringa oleifera* leaf powder @ 75 g/animal/day). Experimental animals were fed according to the feeding standards recommended for lactating cattle and had free access to clean drinking water throughout the study period.

2.2 Digestibility Trial

A digestion trial was conducted at the end of the 120-day feeding experiment to determine nutrient digestibility coefficients. Representative samples of feed offered, feed refused and faeces were collected during the digestion trial period. The samples were processed and analyzed for proximate constituents following standard analytical procedures described by AOAC (2005) ^[1].

Digestibility coefficients of dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE), crude fibre (CF) and nitrogen-free extract (NFE) were calculated using standard formulae and expressed as percentages.

2.3 Collection and Analysis of Blood Samples

Blood samples were collected aseptically from the jugular vein of each experimental animal on the 120th day of the feeding trial. Samples intended for haematological analysis were collected into EDTA-coated vacutainer tubes and transported immediately to the laboratory for analysis.

Haematological parameters including haemoglobin concentration (Hb), packed cell volume (PCV), total erythrocyte count (TEC) and total leukocyte count (TLC) were determined using standard laboratory procedures. Differential leukocyte counts comprising neutrophils, lymphocytes, monocytes, eosinophils and basophils were also recorded. The neutrophil-to-lymphocyte ratio (N:L ratio) was calculated as:

$N:L \text{ Ratio} = \text{Neutrophil (\%)} / \text{Lymphocyte (\%)}$

2.4 Dataset Preparation

For the present study, individual animal observations obtained from the digestibility trial and haematological evaluation were combined into a single dataset. Nutrient digestibility variables included DM, OM, CP, EE, CF and NFE digestibility coefficients, whereas haematological variables included Hb, PCV, TEC, TLC, neutrophil percentage, lymphocyte percentage, monocyte percentage, eosinophil percentage, basophil percentage and N:L ratio.

2.5 Statistical Analysis

Pearson's correlation analysis was performed to evaluate the association between nutrient digestibility fractions and haematological attributes of lactating Sahiwal cattle. Correlation coefficients (r) and corresponding probability values were calculated to identify significant relationships between digestibility and blood variables.

To further determine the predictive ability of nutrient digestibility fractions, linear regression analyses were performed using selected haematological variables as dependent variables and digestibility coefficients as independent variables. Simple linear regression models were fitted to evaluate the influence of individual digestibility fractions on haematological responses, whereas multiple linear regression analysis was employed to assess the combined contribution of digestibility fractions to variations in blood parameters.

All statistical analyses were performed using IBM SPSS Statistics software. Differences and associations were considered statistically significant at $P < 0.05$.

3. Results and Discussion

3.1 Association between nutrient digestibility fractions and haematological attributes

The relationship between nutrient digestibility fractions and haematological attributes of lactating Sahiwal cattle was evaluated using Pearson's correlation analysis (Table 1). The results revealed several significant associations between nutrient utilization efficiency and blood health indicators, suggesting that digestibility characteristics may influence physiological and immune responses in dairy cattle.

Table 1: Pearson correlation coefficients between nutrient digestibility fractions and haematological attributes in lactating Sahiwal cattle

Digestibility trait	Haematological attribute	r-value	P-value
Dry matter (DM)	Packed cell volume (PCV)	0.398	0.036*
Dry matter (DM)	Total leukocyte count (TLC)	0.389	0.041*
Crude fibre (CF)	Packed cell volume (PCV)	0.384	0.044*
Crude fibre (CF)	Lymphocyte percentage	-0.391	0.039*

Correlation is significant at $P < 0.05$ (Pearson's correlation coefficient).

The significant correlations identified between nutrient digestibility fractions and selected haematological attributes are graphically presented in Figures 1-4.

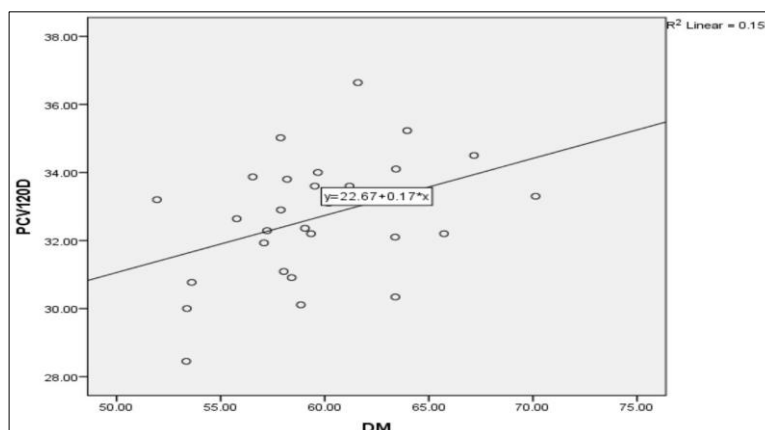


Fig 1: Relationship between dry matter digestibility (%) and packed cell volume (PCV) in lactating Sahiwal cattle.

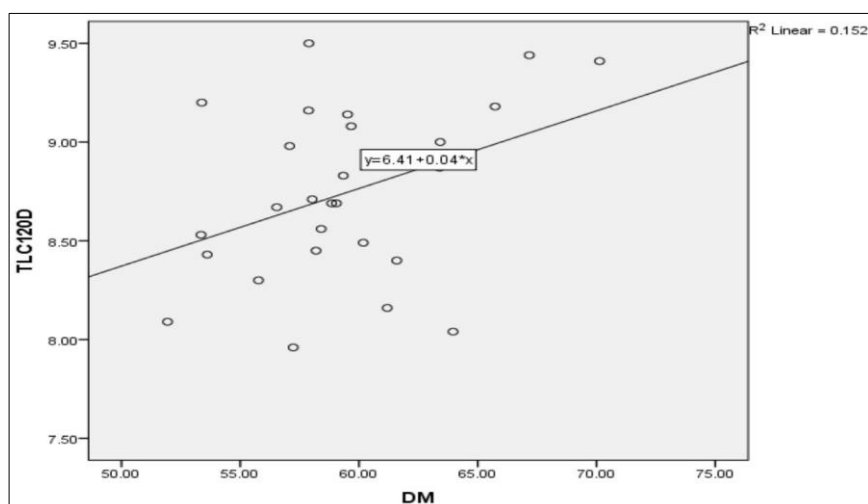


Fig 2: Relationship between dry matter digestibility (%) and total leukocyte count (TLC) in lactating Sahiwal cattle.

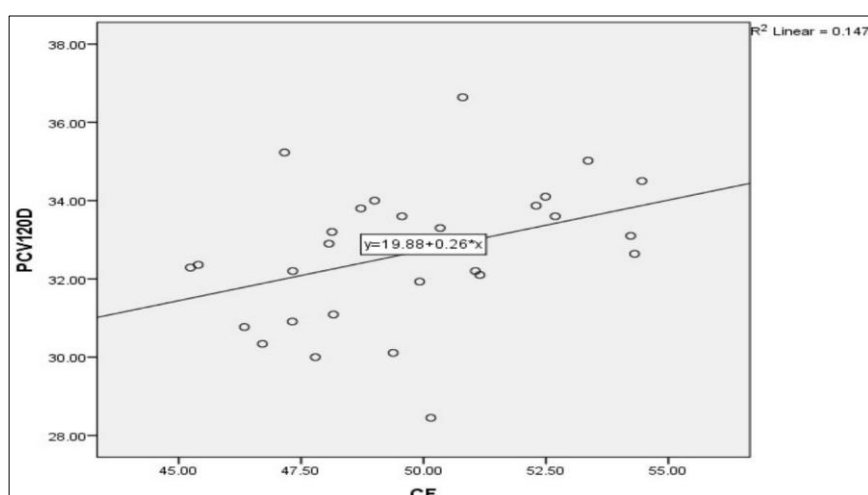


Fig 3: Relationship between crude fibre digestibility (%) and packed cell volume (PCV) in lactating Sahiwal cattle.

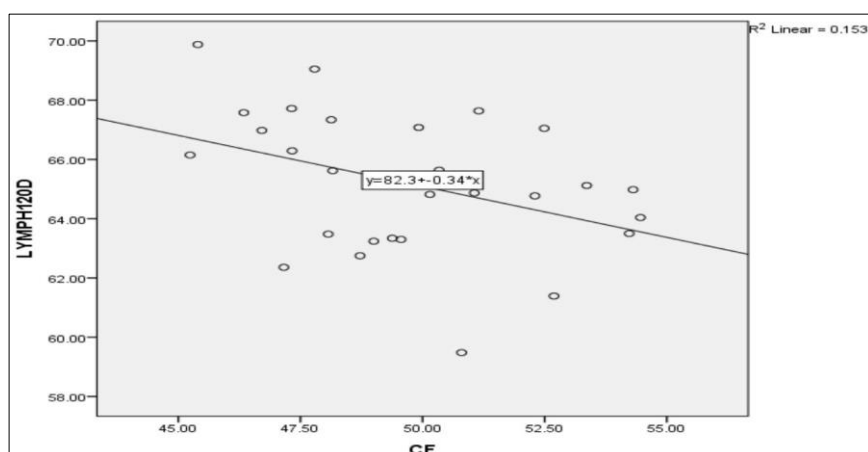


Fig 4: Relationship between crude fibre digestibility (%) and lymphocyte percentage in lactating Sahiwal cattle.

Dry matter (DM) digestibility exhibited a significant positive correlation with packed cell volume (PCV) ($r = 0.398$, $P = 0.036$). This finding indicates that animals with superior dry matter utilization tended to maintain higher PCV values. Packed cell volume is an important indicator of erythrocytic status and reflects the proportion of red blood cells present in circulation. Improved digestibility enhances nutrient availability, particularly energy, amino acids, vitamins and minerals required for erythropoiesis and

maintenance of blood cell populations. Therefore, animals capable of utilizing a greater proportion of dietary dry matter may experience improved physiological efficiency and enhanced oxygen-carrying capacity. Similar observations have been reported by Kaneko *et al.* (2008) [6], who suggested that improved nutritional status contributes to better haematological performance through enhanced nutrient availability for blood cell synthesis. Furthermore, McDonald *et al.* (2011) [6, 8] reported that efficient nutrient

utilization plays a critical role in supporting metabolic activities associated with blood formation and tissue maintenance. The present observations are consistent with earlier findings from the same experimental population, where phytogenic supplementation improved haematological attributes and physiological status of lactating Sahiwal cattle (Kumar *et al.*, 2025)^[17].

A significant positive association was also observed between DM digestibility and total leukocyte count (TLC) ($r = 0.389$, $P = 0.041$). Total leukocyte count is widely used as an indicator of immune competence and disease resistance. The positive relationship observed in the present study suggests that efficient nutrient utilization may contribute to improved immune function through enhanced availability of nutrients required for leukocyte production and maintenance. Adequate nutritional support is essential for proliferation, differentiation and functional activity of immune cells. Consequently, animals exhibiting superior dry matter digestibility may possess greater capacity to sustain normal leukocyte populations. Similar relationships between nutritional status and immune function have been documented in livestock, where improved nutrient availability was associated with enhanced immunological responsiveness and disease resistance (Jain, 1993; Radostits *et al.*, 2007)^[4].

Crude fibre (CF) digestibility demonstrated a significant positive correlation with packed cell volume ($r=0.384$, $P=0.044$). Fibre digestion in ruminants is largely dependent upon microbial fermentation within the rumen. Efficient fibre degradation promotes microbial growth and volatile fatty acid production, resulting in improved nutrient supply to the host animal. Enhanced ruminal fermentation may therefore contribute indirectly to erythropoietic activity and maintenance of normal haematological status. The positive association observed between CF digestibility and PCV suggests that animals exhibiting superior fibre utilization were able to maintain a more favourable erythrocytic profile. Previous studies have highlighted the importance of rumen efficiency in supporting nutrient metabolism and physiological adaptation in dairy cattle (Van Soest, 1994; Russell and Rychlik, 2001)^[14, 15]. Improved fibre utilization observed in phytogenically supplemented animals may partially explain the favourable haematological responses reported previously in the same feeding trial (Kumar *et al.*, 2025; Kumar *et al.*, 2026a)^[17, 18].

In contrast, crude fibre digestibility showed a significant negative correlation with lymphocyte percentage ($r=-0.391$, $P=0.039$). While the exact physiological mechanism underlying this inverse relationship warrants further investigation, it may reflect adaptive alterations in leukocyte distribution associated with improved nutrient utilization. Differential leukocyte counts are influenced by numerous physiological, nutritional and immunological factors. The observed inverse association may reflect adaptive changes in immune cell populations associated with improved rumen function and nutrient metabolism. Similar variations in

leukocyte profiles have been reported under differing nutritional and physiological conditions in cattle (Gross and Siegel, 1983; Davis *et al.*, 2008)^[2, 3].

No significant correlations were observed between crude protein digestibility and the evaluated haematological parameters ($P>0.05$). Likewise, monocyte, eosinophil and basophil percentages were not significantly associated with nutrient digestibility fractions. These findings suggest that not all digestibility components exert equal influence on blood variables and that specific nutrient fractions may be more closely linked with physiological and immune responses than others.

The significant associations observed in the present study collectively indicate that nutrient utilization efficiency is related to blood health indicators in lactating Sahiwal cattle. Improved digestibility may enhance nutrient availability for erythropoiesis, immune cell production and maintenance of physiological homeostasis. These observations support the hypothesis that digestibility characteristics can serve as useful indicators of haematological status and provide valuable insights into the biological responses of dairy cattle to nutritional interventions.

3.2 Regression analysis of nutrient digestibility fractions as predictors of haematological and immune responses

To further elucidate the relationship between nutrient utilization efficiency and blood health indicators, regression analyses were performed using selected haematological variables as dependent variables and nutrient digestibility fractions as predictor variables (Table 2). The results demonstrated that specific digestibility fractions significantly influenced haematological and immune parameters, indicating their potential utility as predictors of physiological status in lactating Sahiwal cattle.

Table 2: Regression models describing the influence of nutrient digestibility fractions on haematological and immune indicators in lactating Sahiwal cattle

Dependent variable	Predictor variable(s)	β coefficient	R ²	F-value	P-value
Neutrophil (%)	Organic matter (OM) digestibility	-0.535	0.286	10.418	0.003**
Dependent variable	Predictor variable(s)	β coefficient	R ²	F-value	P-value
Total leukocyte count (TLC)	Ether extract (EE) digestibility	0.470	0.221	7.366	0.012*
Packed cell volume (PCV)	DM + CF + NFE digestibility	—	0.321	3.779	0.024*

$P<0.05$; astat $P<0.01$.

β coefficient represents standardized regression coefficients. R² represents the proportion of variation explained by the regression model.

The relationship between organic matter digestibility and neutrophil percentage is illustrated in Figure 5.

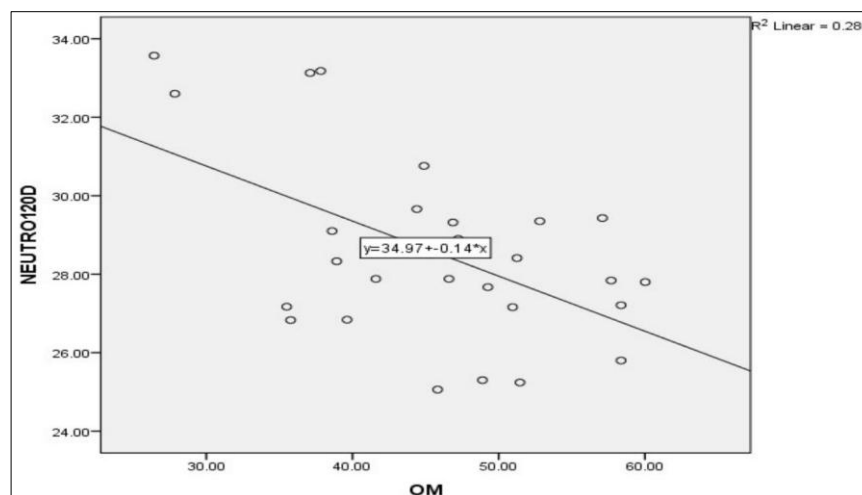


Fig 5: Relationship between organic matter digestibility (%) and neutrophil percentage in lactating Sahiwal cattle.

Organic matter (OM) digestibility emerged as a significant predictor of neutrophil percentage. The regression model explained 28.6% of the total variation in neutrophil counts ($R^2=0.286$; $P=0.003$), indicating a substantial contribution of organic matter utilization to immune cell dynamics. The negative standardized regression coefficient ($\beta = -0.535$) suggested that animals exhibiting higher organic matter digestibility tended to have lower neutrophil percentages. Neutrophils constitute an important component of innate immunity and often increase in response to physiological stress, inflammation and infection. Therefore, the observed reduction in neutrophil percentage with increasing organic matter digestibility may indicate improved physiological adaptation and reduced systemic stress.

The biological basis of this relationship may be attributed to enhanced nutrient availability resulting from improved digestion and fermentation of organic matter. Efficient utilization of organic matter promotes greater production of volatile fatty acids and microbial protein in the rumen, thereby improving the nutritional status of the host animal (Russell and Rychlik, 2001)^[14]. Improved nutritional status is frequently associated with reduced activation of stress-related immune pathways and maintenance of immune homeostasis. Similar observations have been reported in livestock studies where improved nutritional efficiency contributed to favourable immune responses and reduced indicators of physiological stress (Davis *et al.*, 2008; Radostits *et al.*, 2007)^[2, 4]. The present findings therefore suggest that organic matter digestibility may serve as an important indicator of immune regulation in dairy cattle. The observed relationship may represent one of the physiological mechanisms through which phytogenic feed additives exert immunomodulatory effects in lactating cattle, as reported in previous studies utilizing the same experimental animals (Kumar *et al.*, 2025; Kumar *et al.*, 2026b)^[17, 19].

Ether extract (EE) digestibility was identified as a significant predictor of total leukocyte count (TLC). The regression model accounted for 22.1% of the total variation in TLC ($R^2 = 0.221$; $P = 0.012$), while the positive regression coefficient ($\beta=0.470$) indicated that improved lipid digestibility was associated with increased leukocyte counts. Lipids perform several critical physiological functions, including maintenance of cellular membranes, synthesis of signalling molecules and regulation of immune responses. Efficient digestion and absorption of dietary

lipids may therefore enhance immune cell function and support leukocyte production.

The positive association observed between ether extract digestibility and TLC suggests that improved utilization of dietary fats may contribute to maintenance of normal immune cell populations. Furthermore, fat-soluble vitamins and essential fatty acids derived from dietary lipids play important roles in immune regulation and cellular integrity. Enhanced digestibility of lipid fractions may therefore improve immune competence and support the proliferation and activity of leukocytes. Previous studies have also emphasized the importance of dietary lipids in modulating immune responses and maintaining physiological resilience in livestock species (McDonald *et al.*, 2011; Kaneko *et al.*, 2008)^[6, 8].

Multiple linear regression analysis revealed that dry matter (DM), crude fibre (CF) and nitrogenfree extract (NFE) digestibility collectively exerted a significant influence on packed cell volume (PCV). The overall regression model explained 32.1% of the variation observed in PCV ($R^2 = 0.321$; $P=0.024$). Although individual predictors did not attain statistical significance within the model, their combined contribution was significant, indicating that erythrocytic status is influenced by multiple digestibility fractions acting simultaneously rather than by a single nutrient fraction alone.

Packed cell volume reflects the proportion of erythrocytes present in circulating blood and is widely used as an indicator of oxygen-carrying capacity and physiological well-being. The significant contribution of DM, CF and NFE digestibility to PCV variation suggests that efficient utilization of energy-yielding nutrients and fermentable carbohydrates may support erythropoiesis and maintenance of normal red blood cell populations. Enhanced digestibility improves nutrient absorption and metabolic efficiency, thereby providing substrates necessary for haemoglobin synthesis and erythrocyte production. Similar relationships between nutritional status and erythrocytic parameters have been reported in dairy cattle and other ruminants (Jain, 1993; Kaneko *et al.*, 2008)^[4, 6].

Collectively, the regression analyses indicate that nutrient digestibility fractions are not merely indicators of feed utilization efficiency but are also associated with important physiological and immunological responses. The ability of organic matter digestibility to predict neutrophil percentage, ether extract digestibility to predict total leukocyte count and the combined contribution of DM, CF and NFE

digestibility to packed cell volume highlights the close interaction between nutrition, metabolism and blood health in lactating Sahiwal cattle. These findings provide additional evidence that digestibility characteristics may serve as useful biological indicators for evaluating the effectiveness of phytogetic nutritional interventions and monitoring animal health status under field conditions.

3.3 Biological implications of nutrient digestibility-haematology relationships

The present findings collectively demonstrate that nutrient digestibility fractions are closely associated with haematological and immune indicators in lactating Sahiwal cattle. Although digestibility coefficients are traditionally used to evaluate feed utilization efficiency, the observed associations indicate that their biological significance extends beyond nutrient metabolism and may influence physiological and immunological responses.

Improved digestibility enhances the availability of nutrients required for maintenance, production and cellular functions. Efficient utilization of dry matter, organic matter and fibre fractions increases the supply of energy, amino acids, vitamins and minerals necessary for erythropoiesis and immune cell development. Consequently, animals exhibiting superior nutrient digestibility may maintain more favourable haematological profiles and improved physiological adaptation. The positive associations observed between digestibility traits and packed cell volume support this concept and suggest that enhanced nutrient utilization contributes to maintenance of erythrocytic status.

The significant negative relationship observed between organic matter digestibility and neutrophil percentage further indicates a potential interaction between nutrient utilization and immune regulation. Neutrophils are commonly elevated under conditions of physiological stress and inflammatory challenge. Therefore, reduced neutrophil percentages in animals exhibiting superior organic matter digestibility may reflect improved metabolic efficiency and reduced physiological stress. Similar observations have been reported in livestock studies where improved nutritional status was associated with favourable leukocyte profiles and enhanced immune homeostasis (Davis *et al.*, 2008; Radostits *et al.*, 2007) [2, 13].

Likewise, the positive influence of ether extract digestibility on total leukocyte count suggests that efficient lipid utilization may support immune cell maintenance and functionality. Dietary lipids contribute to membrane integrity, synthesis of signalling molecules and regulation of inflammatory responses. Enhanced digestibility of lipid fractions may therefore facilitate optimal immune responsiveness and contribute to maintenance of normal leukocyte populations.

Collectively, the present findings indicate that nutrient digestibility fractions may serve as useful physiological indicators of blood health and immune status in dairy cattle. The observed associations provide additional evidence that nutritional interventions capable of improving nutrient utilization may exert beneficial effects beyond productive performance and may contribute to improved physiological resilience and health status in lactating animals.

4. Conclusion

The present study demonstrated significant associations between nutrient digestibility fractions and haematological attributes in lactating Sahiwal cattle receiving phytogetic feed supplementation. Pearson correlation analysis revealed that dry matter digestibility was positively associated with

packed cell volume and total leukocyte count, while crude fibre digestibility exhibited a positive relationship with packed cell volume and a negative association with lymphocyte percentage.

Regression analysis further indicated that organic matter digestibility significantly predicted neutrophil percentage, explaining 28.6% of the observed variation, whereas ether extract digestibility significantly influenced total leukocyte count, accounting for 22.1% of the variation. Moreover, dry matter, crude fibre and nitrogen-free extract digestibility collectively explained 32.1% of the variation in packed cell volume, highlighting the combined contribution of nutrient utilization efficiency to erythrocytic status.

These findings demonstrate that nutrient digestibility fractions are not only indicators of feed utilization efficiency but also reflect important physiological and immunological responses in lactating Sahiwal cattle. Improved nutrient utilization was associated with favourable haematological characteristics and immune homeostasis, suggesting that digestibility-based indices may serve as useful biomarkers for evaluating the biological effectiveness of phytogetic nutritional interventions in dairy cattle.

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