Supplementation of Aloe Vera Extract in Lactating Goats Diet: Effects on Rumen Fermentation Efficiency, Nutrient Utilization, Lactation Performance and Antioxidant Status

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Abstract

The present work was conducted to investigate the effects of supplementing *aloe vera* extract on rumen fermentation efficiency, nutrient utilization, lactation performance and antioxidant status of goats. Twenty-four crossbreed lactating goats (Alpine × Beetal) were divided into three experimental groups (AV0, AV2 and AV4). AV0 had no supplementation, group AV2 and AV4 received ready to feed aqueous extract of *aloe vera* at 20 and 40 g/kg dry matter intake, respectively, along with basal diet and experiment lasted for 100 days. Average DMI did not vary ($P > 0.05$) among treatment groups; however, the cumulative metabolic bodyweight of AV4 was significantly lower ($P < 0.05$) than the AV0 and AV2 groups (AV0 = AV2 > AV4). Intake and digestibility of DM, OM, CP, NDF, ADF, and EE was unaffected ($P > 0.05$) by *aloe vera* supplementation. The milk production, yield of milk fat, protein, lactose and solids not fat (SNF) of goats in the AV4 group was significantly higher ($P < 0.05$) than other groups (AV4 > AV2 = AV0). The activity of superoxide dismutase and catalase and levels of plasma ferric reducing total antioxidant power were high ($P < 0.01$) in the *aloe vera* supplemented group (AV4 = AV2 > AV0). There was no significant difference ($P = 0.979$) in the pH, acetic acid ($P = 0.449$), butyric acid ($P = 0.864$) concentration of the rumen liquor among the treatment groups. The propionic acid concentration was similar between AV2 and AV4 and significantly higher ($P = 0.024$) than the AV0 group (AV4 = AV2 > AV0). Moreover, C2:C3 values were significantly lower ($P = 0.037$) in the AV4 group compared to the Control (AV0). Thus, *aloe vera* supplementation enhanced milk yield, propionic acid production, and antioxidant status without affecting nutrient utilization; however, results were better in the AV4 group. The inclusion of a*loe vera* at 40 g/kg of DMI would improve the rumen fermentation efficiency, lactation performance and overall health status of the dairy goats.

Introduction

The instigation of the one-health notion has gained paramount importance for food safety, food security, and sustainable food production systems (Garcia et al., 2020). One health is a multidisciplinary holistic approach, where the health of humans, animals, and the environment are inextricably linked (Lainé and Morand, 2020). Globally, sustainable food production systems are required to ensure the complexity and scale of food safety and security to feed a growing population (King et al., 2017). Animals reared for food production undergo tremendous stress due to the cascade of events occurring around the parturition and lactation period; consequently, compromising their immunity and further exposure to diseases (Colitti et al., 2019). Application of conventional antimicrobials agents to combat infections and upsurge production has been standard practice in farm animals rearing (Singh et al., 2021a; Mann et al., 2021). However, growing concerns about in-feed antibiotic usage due to their devastating effects caused by the emergence of multidrug-resistant pathogens have led to antibiotics ban by the European Union and other countries (Singh et al., 2021b; Benchaar, 2021). A paradigm shift has driven animal nutritionists to look for safe and natural feed additives to conventional antimicrobials for sustainable animal production with one health concept in consideration (Huang et al., 2018). Several newer emerging feed additives, which can be used as an alternative to antibiotics, have been suggested within the livestock industry. One such

category gaining interest is natural phytogenic feed additive (PFA) (Banakar et al., 2019), which leaves no residue in the animal products (Zhou et al., 2020), or its presence in minor quantity increases its nutraceutical value (Santos et al., 2017) and further strengthening animal antioxidant status making resilient to stress (Suman et al., 2015).

Plant-derived products or the plant secondary metabolites (PSMs) viz essential oils, saponins, condensed tannins, flavonoids, and phenolic compounds, forms the major constituents of PFAs (Frutos et al., 2020). Cumulative research findings indicate that PSMs at appropriate levels modulate protozoal populations, increases bacterial and fungal abundance. This results in higher propionate production, increases microbial yield, reduces methanogenesis and enhances productive performance in ruminants (Banakar et al., 2019). As revealed in scientific literature, this shift in the fermentation pattern is primarily ascribed to the antimicrobial and antioxidant properties of PFAs that boost animal health which in turn enhance production performance (Huang et al., 2018).

Aloe vera (AV) is one such source of PSMs that comprises the potential properties of PFAs. *Aloe barbadensis* Mill is the scientific name of AV commonly found in India, which belongs to the Aloeaceae family (Sánchez-Machado et al., 2017). *Aloe vera* is used in ethnoveterinary medicine and has a positive impact on animal health and welfare. Around 75 bioactive compounds are identified in *aloe vera* extract. Anthraquinones, polyphenols, and polysaccharides are among the major constituents, whereas vitamins (α-tocopherol, β-carotene, and folic acid) and minerals constitute the minor components (Kumar et al., 2019). Various *in vitro* studies report antioxidant, anti-inflammatory, and antimicrobial properties of AV (Lucini et al., 2015), indicating the potential of AV to modulate the animals' rumen fermentation and health status. Besides, *in vivo* studies of AV supplementation carried out in monogastric animals (poultry and swine) revealed its nutrigenomic effect on animal products and animal welfare (Darabighane et al., 2011; Ghasemi-Sadabadi et al., 2020). However, there are no *in vivo* studies in ruminants reporting its interaction with the animals' rumen fermentation and it is a source of interest. The present work was designed to investigate the effects of supplementing *aloe vera* extract on rumen fermentation efficiency, nutrient utilization, lactation performance and antioxidant status of goats.

Materials And Methods

Lactating goats and experimental diets

Twenty-four crossbreed lactating goats (Alpine × Beetal) were selected after ten days of parturition, i.e., early to mid-lactation period, from the Livestock Research Center, NDRI, Karnal. Based on the average body weight (37.28±1.69 kg) and the milk yield (1776.21±93.21 g/day), animals were randomly assigned into three groups of 8 animals each. Goats were fed with a basal diet containing berseem and concentrate mixture (60:40) to fulfill the animals' nutrient requirement (ICAR, 2013). The ingredients' composition and chemical composition of the diets are presented in Tables 1 and 2, respectively. Goats were housed in well-ventilated pens with individual animal feeding arrangements and had 24 hr free access to water. After an adaptation period of 10 days, the animals were switched over to their respective

experimental diets for 90 days. Group I (AV0) had no supplementation, animals in Group II (AV2) and Group III (AV4) received ready to feed aqueous extract of *aloe vera* (procured from Herbal consultant®, India) at 20 and 40 g/kg dry matter intake, respectively (2% and 4% of DMI), along with basal diet.

Data recording

The experimental animals' daily dry matter intake (DMI) was recorded by assessing the dry matter of diet offered and residue left. Also, the lactating goats' daily milk yield and fortnightly body weight were measured using an automated electronic weighing scale. Metabolic body weight was calculated using the formula, $BW^{\wedge 0.75}$.

Sample collection

Feed samples were collected daily to ascertain the DMI of individual lactating goats after assessing the dry matter of feed offered and residue left. Milking of individual animals was carried out twice daily, i.e., at 5:30 AM and 3:00 PM. The sampling ($1/100^{th}$ of milk yield) was done at every fortnight interval from each milking and analyzed immediately for composition. Blood was collected from the jugular vein in a sterile vacutainer containing acid citrate dextrose as an anticoagulant on the 0, 30, 60, and 90^{th} day of the experiment. At the end of the investigation, 200 mL of rumen liquor was collected using a rumen liquor collection pump to estimate the pH and individual volatile fatty acids (IVFA). A digestion trial of a 7-d collection period was conducted to evaluate the apparent nutrients' digestibility. Total feces from individual animals were collected in plastic containers and mixed thoroughly to obtain a composite sample. Part ($1/1000^{th}$) of the total collected feces was acidified with H_2SO_4 for nitrogen estimation.

Sample processing and analysis

Proximate analysis and apparent nutrient digestibility

Representative feces and feed (offered and residue) samples were oven-dried at 60°C for 48 h, ground, and passed through 1 mm sieve and stored in a ziplock plastic bag till analysis. Dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE), neutral detergent fibre (NDF) and acid detergent fibre (ADF) were estimated as per the standard procedures of the Association of Official Analytical Chemists (AOAC, 2010). Apparent digestibility was calculated using the formula (Singh et al., 2021a):

Apparent digestability (%) = Nutrient intake - Nutrient output/Nutrient intake x 100

Milk components

Milk composition was determined using a pre-calibrated automatic milk analyzer (Lactostar, FUNKE GERBER, Berlin) to calculate the yield of milk fat, protein, lactose and solids not fat (SNF)

Animals' antioxidant status

Collected blood samples were immediately transferred to a laboratory with a cold chain maintained at 4°C and centrifuged at 3000 rpm for 10 mins to separate plasma from packed erythrocytes. The erythrocyte antioxidant enzyme activity and ferric reducing total antioxidant power (FRAP) were estimated using RBC hemolysate (prepared from the packed erythrocytes) and plasma, respectively. Antioxidant enzyme activity such as catalase (Aebi, 1984), SOD (Madesh and Balasubramanian, 1998), and GPx (Paglia and Valentine, 1967) were determined spectrophotometrically (Specord 200, Germany) within two days after collection and processing of blood. FRAP assay was performed as described by Prakova et al. (2010).

Rumen liquor pH

Immediately after collecting rumen liquor, it was strained through double layered muslin cloth to measure pH using an electronic pH meter (pH Spear, EC- PHWPSEN04; Eutech instruments, Malaysia), calibrated against standard buffer solutions.

Individual volatile fatty acid estimation

For estimating IVFA, strained rumen liquor samples were preserved by adding 0.2 ml of 25 % metaphosphoric acid per ml of rumen liquor (RL). Then samples were centrifuged (5000 rpm for 20 min) after 2 h of the stand at 4 °C and the supernatant was used for estimation of IVFAs. The aliquot (3 µl) was injected using 10 µl Hamilton syringe (Hamilton, Nevada, USA) into Gas chromatograph (GC, Nucon 5700, Nucon Engineers, New Delhi) equipped with a flame ionization detector and stainless steel column packed with Chromosorb –101 mesh 80–100 as described by Miri et al. (2015). For fractionation of IVFA, analytical conditions were as follows: Injection port temperature, 250ºC; column temperature, 190ºC and detector temperature, 260ºC. The flow rate of nitrogen (carrier gas) was maintained at 40 ml/min, hydrogen at 30ml/min and air, 300 ml/min. Based on the retention time and their concentration (mM), different IVFA's of each sample were identified and calculated by comparing the retention time as well as the peak area of standards after deducting the corresponding blank values.

Statistical analysis

Data collected were analyzed using General Linear Model (GLM) by the Analysis of Variance (ANOVA) method of the Statistical Package for the Social Sciences (SPSS, v21.0; Chicago, IL, USA). The following statistical model was used:

$$Y_{ijk} = \mu + D_i + P_j + (D \times P)_{ij} + e_{ijk}$$

where, Y_{ijk} = dependent variable

µ = overall mean

D_i = effect of i_{th} dietary treatment

P_j = effect of j_{th} period

$(D \times P)_{ij}$ = interaction effect of i_{th} dietary treatment with j_{th} period

e_{ijk} = casual effect of each observation.

One-way ANOVA was performed for nutrient intake, apparent digestibility of nutrients and rumen liquor parameters. DMI, bodyweight changes, production performance parameters, antioxidant enzyme activity and FRAP values were analyzed using Two-way ANOVA. Duncan's multiple range test was used for the pair-wise comparison of means. GraphPad Prism 8.1 (San Diego, CA, USA) was used to develop figures. The effects were considered significant at $P < 0.05$ (*) and high statistical significance at $P < 0.001$ (**), whereas non-significance at $P > 0.05$.

Results

Dry matter intake and metabolic body weight changes

The fortnightly DMI and metabolic body weight changes of goats are depicted in Figure 1. Periodic changes in the DMI varied significantly (P < 0.001) in all the treatment groups. There was a remarkable decrease ($P < 0.05$) in the DMI of the AV4 group in the first fortnight in comparison to Control (AV0) and AV2 groups. However, this decrease in DMI got nullified in the subsequent weeks. As a sequela of the changes in DMI, metabolic body weight changes displayed significant treatment ($P = 0.002$) and periodic changes (P = 0.026) in different groups. Goats in the AV4 group exhibited decreased (P < 0.05) metabolic body weight than AV2 and AV0 group in the first fortnight; however, the values remained similar in the subsequent fortnights. Nevertheless, average DMI did not vary (P > 0.05) among treatment groups (Table 3); on the contrary, the cumulative metabolic bodyweight (Table 3) of AV4 was significantly lower (P < 0.05) than the AV0 and AV2 groups (AV0 = AV2 > AV4).

Nutrient intake and their apparent digestibility

Nutrient intake and the apparent digestibility of dietary treatment groups are presented in the Table 3. Dry matter intake (kg/100kg BW) was similar ($P > 0.05$) among treatment groups during the digestion trial; however, values were numerically higher in AV2 and AV4 than in the AV0 group. Intake of OM, CP, NDF, ADF, and EE was unaffected ($P > 0.05$) by *aloe vera* supplementation. Likewise, we did not observe the influence ($P > 0.05$) of treatment diets on the apparent digestibility (%) of DM, OM, CP, NDF, ADF, and EE among different groups.

Milk yield and milk components

The average milk and milk components yield are given in Table 4. Treatment ($P = 0.001$) and periodic changes ($P < 0.001$) were observed in milk yield (Figure 2) among treatment groups. There was an increase in milk yield of AV2 and AV4 groups over Control (AV0) since the third fortnight of *aloe vera* supplementation. During the experimentation period, the milk yield of AV4 was the highest, followed by

AV2 and AV0 (AV4 > AV2 ≥ AV0). Cumulatively, over the whole experimental period, the milk yield of goats in the AV4 group was statistically higher ($P < 0.05$) than AV2 and AV0 group (AV4 > AV2 = AV0). Similarly, the yield of milk fat, protein, lactose and solids not fat (SNF) was significantly higher ($P < 0.05$) in the AV4 group compared to AV2 and AV0 group.

Antioxidant status

The periodic changes and the cumulative values of erythrocyte antioxidant enzyme activities are shown in Figure 3 and Table 5. There was a significant increase ($P < 0.001$) in erythrocyte SOD and catalase enzyme activity in AV2 and AV4 groups over AV0 since the first month of *aloe vera* supplementation and followed the trend of AV4 > AV2 ≥ AV0 throughout the experiment. Moreover, significant ($P < 0.001$) periodic variations were observed in SOD, catalase activity, and FRAP values in all the treatment groups. Furthermore, over the whole experimental period, the activity of SOD and catalase was higher ($P < 0.01$) in the 2 and 4% *aloe vera* supplemented group than in the Control (AV4 = AV2 > AV0). Nevertheless, we could not comprehend any perceivable difference ($P > 0.05$) in the activity of GPx among the treatment groups. *Aloe vera* supplementation had a significant influence ($P < 0.001$) on the total antioxidant activity expressed in FRAP terms, which followed the same trend as SOD and catalase. Overall, cumulative values of FRAP were significantly higher ($P < 0.001$) in AV2 and AV4 than in the control group.

The individual volatile fatty acid and pH of rumen liquor

Data on IVFA (mmol/L) and pH of the rumen liquor are presented in Table 6. There was no significant difference ($P = 0.979$) in the pH of the rumen liquor among the treatment groups. Among the IVFA, acetic acid (C2) tended to decrease with the graded level of *aloe vera* supplementation (AV2 and AV4) but it was statistically non-significant ($P = 0.449$). Similarly butyric acid (C4) concentration did not vary ($P = 0.864$) among different groups. The propionic acid concentration was similar between AV2 and AV4 and significantly higher ($P = 0.024$) than AV0 group (AV4 = AV2 > AV0). Also, C2:C3 values were significantly lower ($P = 0.037$) in AV4 group compared to control (AV0).

Discussion

Palatability of feed is directly correlated with voluntary feed intake (VFI) of animals. Levels of tannins or polyphenols influence the palatability of feed and, in turn, its VFI (Frutos et al., 2004; Patra and Saxena, 2011). DMI of 4% *aloe vera* supplemented group decreased in the first fortnight, though subsequent fortnights did not show a significant difference in the DMI. Present findings may be due to the short-term influence of the astringency effect (Landau et al., 2000) of *aloe vera* polyphenols or tannins during the adaptation period. Similar to DMI, fortnightly metabolic bodyweight changes followed the same trend. Since the nutrient intake during the first fortnight did not satisfy the animal's requirement (maintenance and lactation), a decrease in the bodyweight was observed. However, there was a steady intake of DM in the subsequent fortnight, resulting in increased body weight as the lactation progressed. It is well noted that with a low to moderate level of tannins in the diet, VFI remains unchanged. However, when tannins rich diet is introduced to the animals, it may take some time for them to adjust to the new diet (Frutos et

al., 2020). Nonetheless, goats have the capacity to degrade tannins (Correddu et al., 2020) and ability to make it less astringent by secreting tannin binding proline-rich proteins in the saliva (Frutos et al., 2004). Our findings are in line with Buccioni et al. (2015b), (2017), Rana et al. (2012), Suman et al. (2015), and Toral et al. (2011), who found no significant difference in the total dry matter intake with tannins or polyphenols levels varying between 1 g to 40 g/kg diet.

In the current research work, DM, OM, CP, EE, NDF and ADF intake and digestibility remained unchanged ($P > 0.05$). Our results agree with Holtshausen et al. (2009), who observed no significant difference in DM, CP, NDF and ADF's apparent digestibility on supplementing *Yucca schidigera* and *Quillaja saponaria* at 10 g/kg of DM. Similarly, Rana et al. (2012) reported no change in the CP, NDF and ADF digestibility when tannin-rich *Terminalia chebula* was included in the diets (0.59 and 1.79% of DM) of kids. Nevertheless, Hristov et al. (2013) found that DMI reduced in lactating Holstein Friesian cows with the inclusion of oregano at different levels (0, 250, 500, 750 g/day) in the diet; however, digestibility of nutrients was unaffected.

Aloe vera has bioactive compounds such as flavonoids and polyphenols that exhibit potent antioxidant, anti-inflammatory, and antimicrobial activity. These bioactive compounds can quench free radicals and activate antioxidant enzymes like catalase, SOD, and GPx to prevent oxidative stress (Danish et al., 2020; Kumar et al., 2019; Maan et al., 2018; Sánchez-Machado et al., 2017). Nonetheless, activation of the antioxidant system by bioactive compounds is more pronounced during stressful conditions (Rubió et al., 2013). Lactating animals undergo a state of oxidative stress, i.e., the disparity between animals' antioxidant status and oxidants, especially after calving, early and mid-lactation stages (Berchieri-Ronchi et al., 2011; Sharma et al., 2011). Stress mainly prevails because of the metabolic and physiological changes occurring after kidding and during lactation.

Consequently, to counteract oxidative stress, there will be changes in the antioxidant enzyme activity, which is evident in the current study. Significantly higher values of antioxidant enzyme activity in *aloe vera* supplemented groups point to its potential for easing oxidative stress (Huang et al., 2018) during the lactation period. Ferric reducing total antioxidant power (FRAP) is another parameter that provides essential information on the animal's antioxidant status, explaining the imbalance between pro-oxidants and antioxidants (Ghiselli et al., 2000). *Aloe vera* supplemented groups displayed higher FRAP values than Control which further strengthens the fact that *aloe vera* has a beneficial role in combating oxidative stress.

Current findings are in line with Zhong et al. (2012), who observed an increase in the total antioxidant capacity and SOD activities in plasma of lambs fed with *Astragalus membranaceus* root and Astragalus polysaccharide. Similarly, *Fructus Ligustri Lucidi's* inclusion in the sheep diet improved the animal's antioxidant status by enhancing SOD and glutathione reductase (Qiao et al., 2012). Suman et al. (2015) reported an increase in the erythrocyte SOD and catalase activity and increased plasma FRAP value when fed with a tanniniferous *Terminalia chebula* plant extract-based diet in goats.

Production performance (reproduction and milk production) of the dairy animals depends on the overall well-being (Gross and Bruckmaier, 2019). During the lactation period, external or abiotic (environmental) and internal or biotic (metabolic) stressors may have adverse effects on animal health (Colitti et al., 2019). Under such conditions, the animal homeorhetic system may repartition nutrients towards maintenance, resulting in a transient decrease in milk production. (Bradford et al., 2015; Bruckmaier and Gross, 2017). However, the animal can recover if the stressors are lessened for overall well-being and when an animal gets the required nutrients (Sordillo and Aitken, 2009) for metabolic adaptation resulting in sustained milk production. The better antioxidant status of the lactating goats in the *aloe vera* supplemented group contributes to the animal's welfare; it might have resulted in a high overall milk yield compared to the non-supplemented group (Maheswari et al., 2021). As reported by Liu et al. (2013), condensed tannins (10 g /kg of DM) in the diet of transition dairy cows alleviate oxidative stress and increase the antioxidant status by inhibiting lipid peroxidation and enhancing the antioxidant enzyme activity.

Furthermore, the increase in propionic acid production in the present study might have improved milk production in the 4% *aloe vera* supplemented group. In the current investigation, a decreasing trend in acetic acid concentration and C2:C3 might have increased glucose production and improved fermentation efficiency and is reflected in milk production. As a consequence of the increased milk production, the milk fat, protein, lactose, and SNF yield were high in the 4% *aloe vera* supplemented group. Our findings are consistent with Buccioni et al., 2015b, who observed an increase in the average milk yield with tannins (80 g/kg DM) in the dairy ewes' diet. Similar results are reported by Tekippe et al. (2011) (oregano leaf), Heidarian Miri et al. (2013) (Cumin extract, 2.53% DMI) and Zhou et al. (2020) (*Piper sarmentosum* extract, 1,200 mg/kg DM) with the plant extracts in the diet of dairy animals. However, at the same time, no effects on milk yield have been reported on inclusion of tannins or polyphenols, or herbal mixture in the diet of dairy animals (Moate et al., 2014; Jain et al., 2013, and Hristov et al., 2013; Buccioni et al., 2015a).

Overall, researchers contrasting findings could be due to 1) variations in the sources of PSMs; 2) the composition of polyphenols or bioactive compounds in the diet; 3) animal species. Nevertheless, low to moderate levels of tannins or polyphenols in the diet of dairy animals did not affect the animals' overall performance.

Conclusions

Dietary inclusion of *aloe vera* extract did not affect the overall dry matter intake, nutrients intake and apparent digestibility. However, milk yield increased in the 4% aloe vera supplemented group by improving the overall health status of the animals, which is evident in the increased antioxidant status of the animal. Increased propionic acid production and decreased C2:C3 in supplemented groups indicate the beneficial effect on rumen fermentation efficiency. Based on these results, we surmise that dietary supplementation of *aloe vera* at 40 g/kg of DMI would improve the overall health status, rumen fermentation efficiency and lactation performance of the dairy goats.

Declarations

Author contribution

BPS, SK, AKT: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Project administration, Validation, Writing – original draft, review & editing.. **VVV and SD:** Laboratory work, Formal analysis, Software, Visualization, Graph development, Writing - review & editing.

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Declarations

Ethical considerations

The present study of 100 days duration, including ten days adaptation period, was carried out as per the guidelines laid down by Institutional Animal Ethics Committee (Reg No. 1705/GO/ac/13/CPCSEA, Dt. 3/7/2013), ICAR-National Dairy Research Institute, Karnal, India (IAEC. No. 116/16, Dt. 3/12/2016).

Conflict of interest

The authors declare no competing interests.

Data availability statement

The authors affirm that the data supporting the current study's conclusions are found in the manuscript (and/or supplementary materials).

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Tables

Table 1 Ingredients composition of the diet (on DM basis)

Ingredients (parts)	AV0	AV2	AV4
Concentrate mixture: 40			
Maize	33	33	33
Groundnut cake	18	18	18
Mustard oil cake	10	10	10
Cottonseed cake (decorticated)	5	5	5
Bajra	20	20	20
Wheat Bran	6	6	6
De-oiled rice bran	5	5	5
Mineral Mixture	2	2	2
Common salt	1	1	1
Green fodder (Berseem): 60			
Extract Supplement			
Aloe vera plant extract (%)	0	2	4

Table 2 Chemical composition of diets (% DM basis)

Nutrients	Berseem	Concentrate
Dry matter (DM)	16.18±0.37	89.95±0.39
Organic matter (OM)	90.87±0.2	92.63±0.52
Crude protein (CP)	16.71±0.17	17.62±0.36
Ether extract (EE)	2.45±0.04	3.67±0.04
Neutral detergent fibre (NDF)	53.305±0.5	30.72±0.4
Acid detergent fibre (ADF)	30.52±0.34	14.05±0.14
Crude fibre (CF)	25.96±0.23	7.54±0.23
Total ash (TA)	9.045±0.12	7.37±0.52

Table 3 Nutrient utilization in goats with supplementation of *aloe vera* extract[¥]

Attributes	AV0	AV2	AV4	SEM	Significance
Nutrient intake (g/d)					
DM (kg/100kg BW)	3.69	3.80	3.76	0.034	0.270
DM (g/kg W^0.75)	92.16	93.92	93.02	0.847	0.467
OM	1334.90	1322.20	1312.60	18.23	0.670
CP	274.83	274.5	275.95	2.153	0.816
NDF	668.96	676.16	679.99	6.934	0.580
ADF	305.43	311.9	312.56	6.057	0.684
EE	41.83	41.55	42.02	0.255	0.515
Apparent digestibility of nutrients (%)					
DM	65.84	66.11	67.22	0.373	0.170
OM	67.14	67.80	68.86	0.338	0.246
CP	68.83	68.74	69.25	0.459	0.704
NDF	57.05	57.88	58.19	0.390	0.293
ADF	37.63	38.87	38.45	0.342	0.184
EE	75.91	75.73	76.37	0.331	0.503

[¥] AV0 = 0% *Aloe vera* extract; AV2 = 2% *Aloe vera* extract; AV4 = 4% *Aloe vera* extract. SEM= standard error of means.

Table 4 Average production performance parameters of goats with supplementation of *aloe vera* extract[¥]

Attributes	AV0	AV2	AV4	SEM	Significance		
					D	P	T*P
Dry matter intake (kg/100 kg BW)	3.97	3.94	3.96	0.018	0.779	<0.001	0.037
Metabolic Bodyweight, BW^0.75 (Kg)	15.29^{a}	15.25^{a}	14.61^{b}	0.179	0.002	0.026	0.998
Milk yield (g/d)	1566.78^{b}	1582.96^{b}	1670.09^{a}	11.82	0.001	<0.001	0.051
Milk fat (g/d)	59.95^{b}	60.13^{b}	63.86^{a}	0.012	<0.001	<0.001	<0.001
Milk protein (g/d)	57.72^{b}	58.55^{b}	61.63^{a}	0.018	<0.001	<0.001	0.033
Milk lactose (g/d)	78.74^{b}	79.97^{b}	83.95^{a}	0.019	<0.001	<0.001	0.047
Milk solid not fat (g/d)	123.26^{b}	125.20^{b}	131.41^{a}	0.069	<0.001	<0.001	0.050

¥ AV0 = 0% *Aloe vera* extract; AV2 = 2% *Aloe vera* extract; AV4 = 4% *Aloe vera* extract. SEM= standard error of means. Means with different superscripts in a row differ significantly (P<0.05). D: Diet effect; P: Period effect.

Table 5 Erythrocyte antioxidant enzyme activity and plasma FRAP level of lactating goats in different treatment diets¥.

Attribute	AV0	AV2	AV4	SEM	Significance		
					D	P	T*P
SOD (U/mg Hb)	99.91^{b}	105.72^{a}	112.14^{a}	0.760	<0.001	<0.001	0.004
Catalase (µmoles of H2O2 consumed/min/g Hb)	51.22^{b}	56.13^{a}	56.98^{a}	0.828	<0.001	<0.001	0.002
GPx (µmol of NADPH oxidised/g Hb/min)	15.41	15.84	15.26	0.271	0.709	0.534	0.997
FRAP [mmol/L (mM) Fe 2+]	266.15^{b}	284.3^{a}	286.62^{a}	4.305	<0.001	<0.001	<0.001

¥ AV0 = 0% *Aloe vera* extract; AV2 = 2% *Aloe vera* extract; AV4 = 4% *Aloe vera* extract. SOD: Superoxide Dismutase; GPx: Glutathione Peroxidase; and FRAP: Ferric Reducing total Antioxidant Power. SEM= standard error of means. Means with different superscripts in a row differ significantly (P<0.05). D: Diet effect; P: Period effect.

Table 6 Individual volatile fatty acid content in rumen liquor and pH of rumen of goats supplemented with *aloe vera* extract¥

VFA (mmol/L)	AV0	AV2	AV4	SEM	Significance
pH	6.7025	6.6875	6.775	0.034	0.979
Acetic acid (C2)	129.67	129.08	127.13	0.811	0.449
Propionic acid (C3)	38.25^{b}	41.67^{a}	43.03^{a}	0.808	0.024
Butyric acid (C4)	1.59	1.63	1.57	0.030	0.864
C2:C3	3.38^{a}	3.12^{ab}	2.96^{b}	0.073	0.037

¥ AV0 = 0% *Aloe vera* extract; AV2 = 2% *Aloe vera* extract; AV4 = 4% *Aloe vera* extract. SEM= standard error of means. Means with different superscripts in a row differ significantly (P<0.05).

Figures

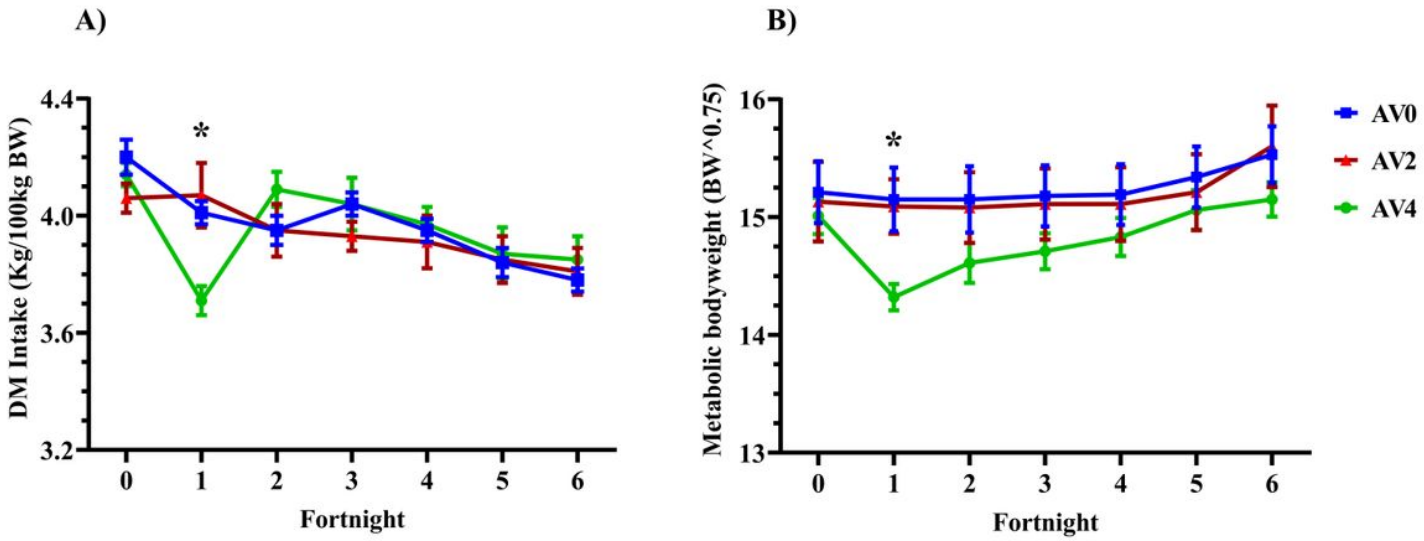

Figure 1

Periodic changes in the dry matter intake and metabolic bodyweight changes of lactating goats in different treatment diets. AV0 = 0% Aloe vera extract; AV2 = 2% Aloe vera extract; AV4 = 4% Aloe vera extract. Values are expressed as mean ± SEM.

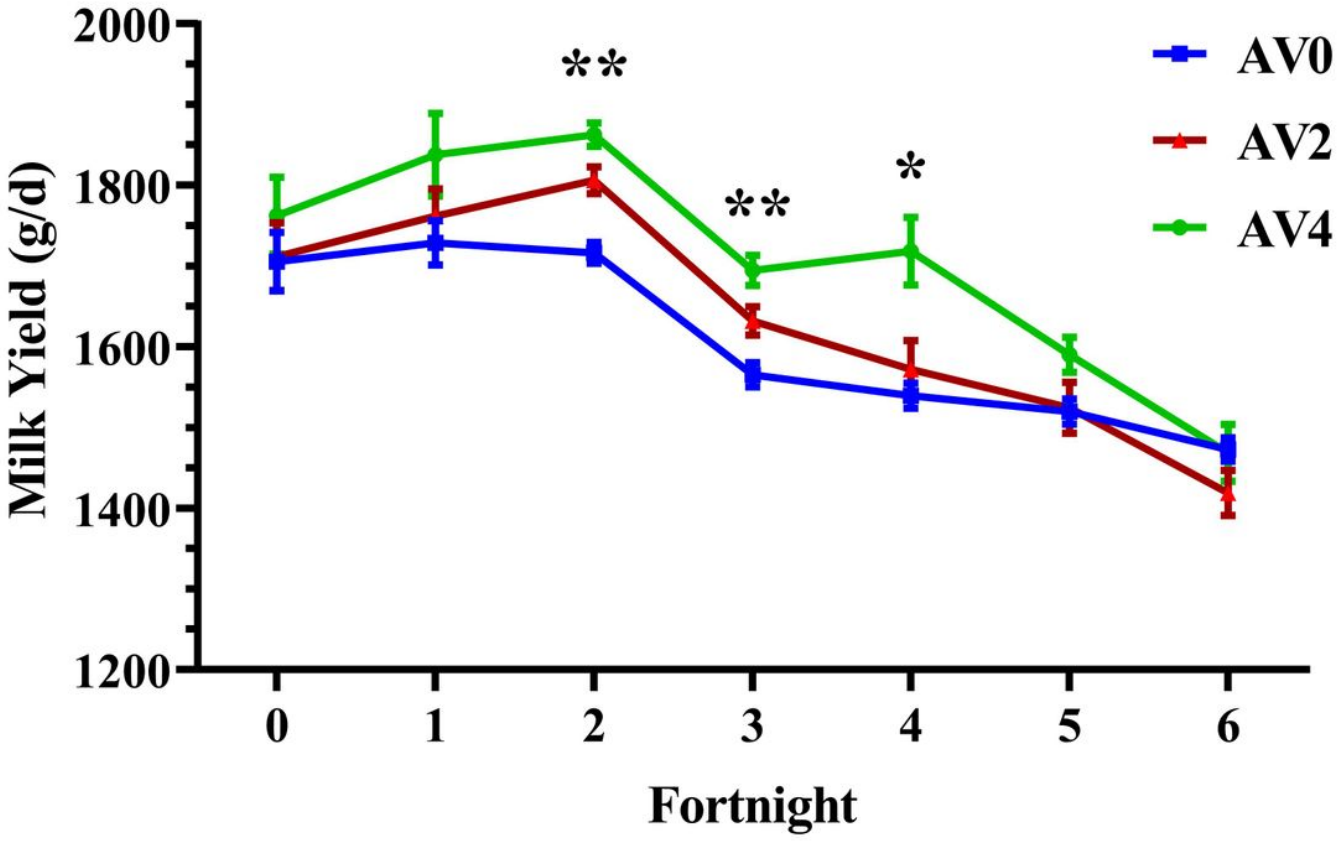

Figure 2

Periodic changes in the milk yield of lactating goats in different treatment diets. AV0 = 0% Aloe vera extract; AV2 = 2% Aloe vera extract; AV4 = 4% Aloe vera extract. Values are expressed as mean ± SEM.

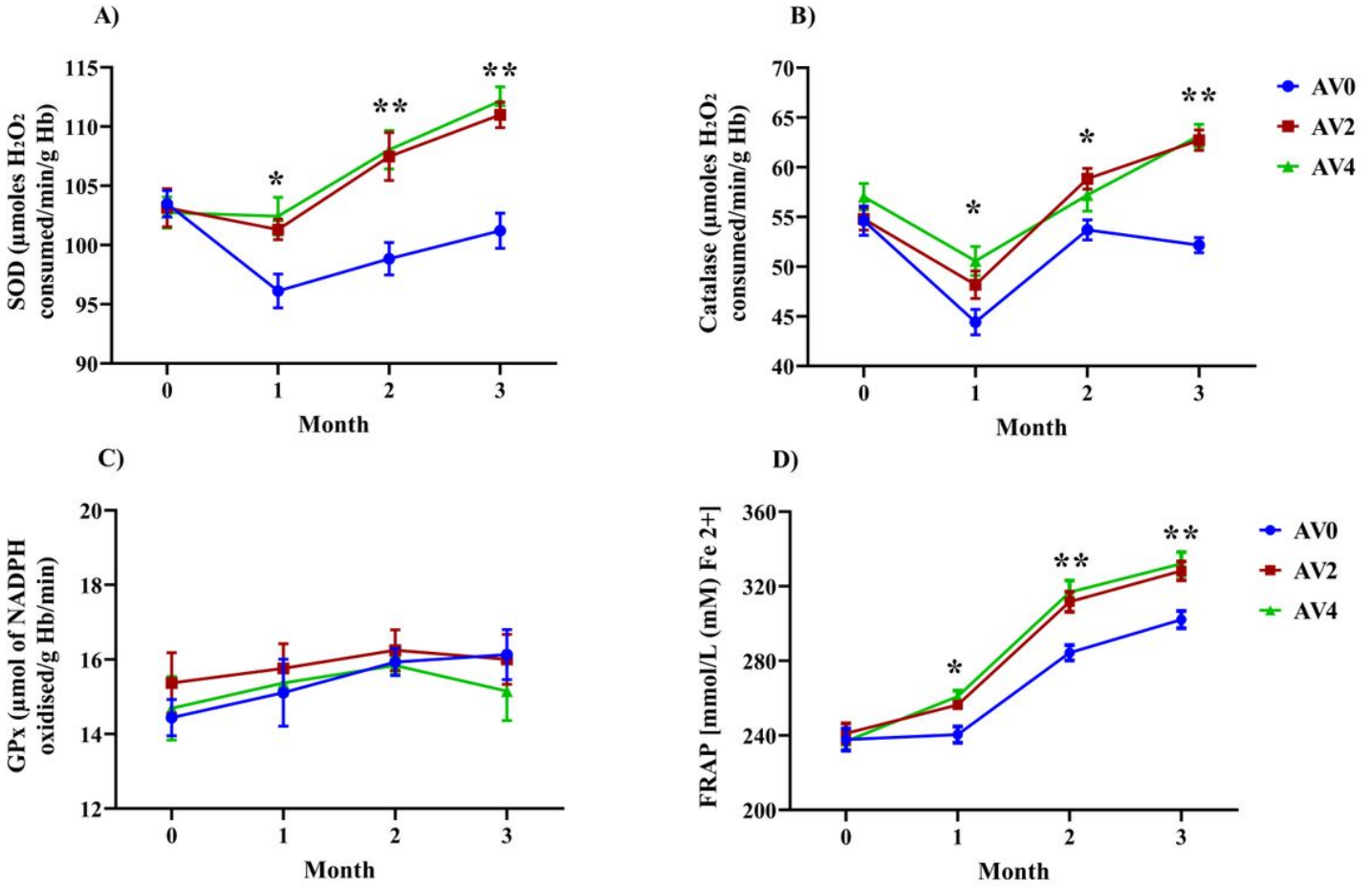

Figure 3

Periodic changes in the erythrocyte antioxidant enzyme activity A) SOD: Superoxide Dismutase, B) Catalase, C) GPx: Glutathione Peroxidase and D) Plasma FRAP (Ferric Reducing total Antioxidant Power) level of lactating goats in different treatment diets. AV0 = 0% Aloe vera extract; AV2 = 2% Aloe vera extract; AV4 = 4% Aloe vera extract. Values are expressed as mean ± SEM.