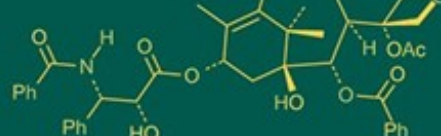


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Nutritional enhancement and milk quality dynamics in lactating Pantja goats supplemented with polyherbal additives (*Trigonella Foenum-Graecum*, *Moringa Oleifera* and *Tinospora Cordifolia*)

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ABSTRACT

The present study evaluated the effect of polyherbal dietary supplementation on the quality and composition of milk from Pantja goats. A total of 32 goats were included, comprising young animals (1-3 months; $n = 16$) and adults (12-18 months; $n = 16$). Within each age category, the animals were divided into four groups: control (T_0), *Moringa* + Fenugreek (T_1), *Moringa* + Giloy (T_2), and Giloy + Fenugreek (T_3). The experiment was carried out for 120 days following a one-week acclimatisation period, with the herbal supplements mixed with concentrate feed and provided daily. Milk samples were collected at 15-day intervals and analysed for physicochemical and mineral characteristics. Several milk-quality parameters showed greater changes during the later stages of supplementation. Milk protein increased over the experimental period and reached $4.28 \pm 0.07\%$ in T_1 at day 120. The highest milk fat content was recorded in T_3 ($5.48 \pm 0.16\%$), which also showed the highest SNF ($10.82 \pm 0.18\%$) and total solids ($15.15 \pm 0.14\%$) at day 120. Specific gravity was also highest in T_3 (1.036 ± 0.00). Among the minerals, calcium was highest in T_2 (898.36 ± 0.68 mg/L), iron in T_3 (0.74 ± 0.05 mg/L), and manganese in T_1 (117.21 ± 0.39 mg/L) at day 120, while zinc remained relatively stable throughout the study. Overall, the results suggest that polyherbal supplementation may have a positive effect on selected nutritional, physicochemical and mineral characteristics of Pantja goat milk, particularly during the later stages of supplementation.

Keywords: Polyherbal supplementation, Milk protein, Solids-not-fat (SNF), Phytogetic additives, Caprine dairy quality, Pantja goat

Introduction

Goat farming is an important component of India's agro-economy and provides livelihood to small and marginal farmers. Goats are called the "poor man's cow" since they require very little capital investment but provide good returns. Indigenous breeds include Pantja goat of Tarai region of Uttarakhand, which is an important dual-purpose (milk and meat) breed. However, small ruminant production is severely constrained by the high cost of feed and seasonal shortages of quality fodder. Feeding low quality crop residues during the dry period leads to nutritional deficiencies, low digestibility, impaired reproduction and low milk yield (Gebregiorgis *et al.*, 2011) [1].

India possesses 148.8 million goats according to the 20th Livestock Census (DAHD, 2019) [2] and needs approximately 358 million tons of dry fodder, 641 million tons of green fodder and 53 million tons of concentrates per annum for meeting their nutritional needs (Gorti *et al.*, 2012) [3]. Phytogetic herbs used as dietary supplements are a safe, available and cheap way to enhance animal productivity. Fenugreek (*Trigonella foenum-graecum*) is a natural galactagogue with GRAS status from US FDA (Wankhede *et al.*, 2016) [4] and has been proved as galactagogue (Yadav *et al.*, 2014) [5]. It is a rich source of protein (20-30%), essential fatty acids and bioactive compounds such as diosgenin, a phytoestrogen that stimulates mammary myoepithelial cells. Fenugreek increases the synthesis of milk but also has antioxidant and digestive benefits (Sahoo *et al.*, 2020) [6].

Moringa oleifera leaves are considered highly nutritious because they contain high levels of crude protein, essential minerals and vitamins, while having relatively low crude fibre and antinutrient contents (Dahot, 1998; Kasolo, 2010) [7, 8]. Supplementation with *Moringa* can help address protein deficiencies, support growth, and may also provide antiparasitic effects against internal parasites such as *Haemonchus contortus*. Similarly, Giloy (*Tinospora cordifolia*) contains more than 100 bioactive compounds (Krishna *et al.*, 2009; Prajwala *et al.*, 2019) [9] and is reported to have immunomodulatory, antioxidant and hepatoprotective prop

erties that may help improve the overall resilience of livestock. While these herbs have well-recognized nutritional and therapeutic properties individually, there is limited information on their combined use as phyto-genic dietary additives and their effects on milk quality and composition in Pantja goats. Therefore, the present study was undertaken to evaluate the effects of polyherbal supplementation with *Trigonella foenum-graecum*, *Moringa oleifera* and *Tinospora cordifolia* on the quality and compositional characteristics of milk from lactating Pantja goats.

Materials and Methods

Experimental animals and study design

A study was conducted on 32 Pantja goats to evaluate the effects of dietary polyherbal supplementation on milk quality and composition. The animals were divided into two age categories: young goats (1-3 months; $n = 16$) and adult goats (12-18 months; $n = 16$). The experimental period lasted 120 days, following a one-week acclimatization period. Within each age category, the goats were divided into four groups: a control group (T_0), a group receiving *Moringa* and Fenugreek (T_1), a group receiving *Moringa* and Giloy (T_2), and a group receiving Giloy and Fenugreek (T_3). The herbal supplements were mixed with concentrate feed and provided daily. All animals were given dry fodder, green fodder, and concentrate according to their body weight and standard feeding recommendations.

Preparation of herbal supplements and animal management

Fresh leaves of *Moringa oleifera* were collected from the University of Pantnagar premises. The leaves were cleaned by removing the stalks and stems, then sun-dried for 4 to 5 days before being ground into a powder. *Trigonella foenum-graecum* seed powder and *Tinospora cordifolia* stem powder were sourced from Radhe Herbals Trading Company in Bareilly. The animals were kept under semi-intensive conditions in individual enclosures, ensuring adequate ventilation, access to clean drinking water, and regular cleaning of the enclosures.

Milk sampling

Individual fresh milk samples were collected in the early morning at 15-day intervals during the 120-day experimental period. The samples were collected in sterile 100-mL bottles, transported to the laboratory under chilled conditions, and stored at approximately 5 °C until analysis.

Milk quality analysis

Milk samples were analysed for fat, protein, solids-not-fat (SNF), total solids (TS), ash, pH, specific gravity and titratable acidity using standard methods. Fat, protein, pH, specific gravity and titratable acidity were determined using the Gerber method (IS:1224 Part 1, 1977) [10], micro-Kjeldahl method (AOAC, 2005) [11], digital pH meter (IS:1479 Part 2, 1961) [12], lactometer (IS:1183, 1965) [13], and IS:1479 Part 1 (1968), respectively. Total solids and SNF were calculated using standard formulae based on corrected lactometer reading and fat content. Ash was determined by igniting 5 g of milk sample in a muffle furnace at 550 °C following AOAC (2005) [11].

Statistical analysis

The experimental data were analyzed using one-way analysis of variance (ANOVA). Significant differences among treatment means were separated using Duncan's post hoc test, with statistical significance considered at $P < 0.05$ (Snedecor *et al.*, 1994) [14].

Results and Discussion

Milk pH

The pH of Pantja goat milk varied slightly among the treatment groups during the 120-day experimental period. Most differences were non-significant ($P > 0.05$), except on day 45 ($P = 0.001$). On day 45, the highest pH was recorded in T_2 (6.95 ± 0.05), followed by T_3 (6.93 ± 0.05), T_1 (6.85 ± 0.05) and T_0 (6.60 ± 0.06). By day 120,

pH values were 6.96 ± 0.04 , 7.00 ± 0.00 , 7.00 ± 0.00 and 7.00 ± 0.00 in T_0 , T_1 , T_2 and T_3 , respectively. Overall, the largely non-significant variation suggests that polyherbal supplementation did not consistently affect milk pH. The observed changes may be related to differences in milk composition and physiological conditions during lactation. Similar trends in goat milk pH have been reported by Chakraborty (1979) [15], Haenlein (1980) [16], Patil (1982) [17], and Fandlalan and Davide (2001) [18].

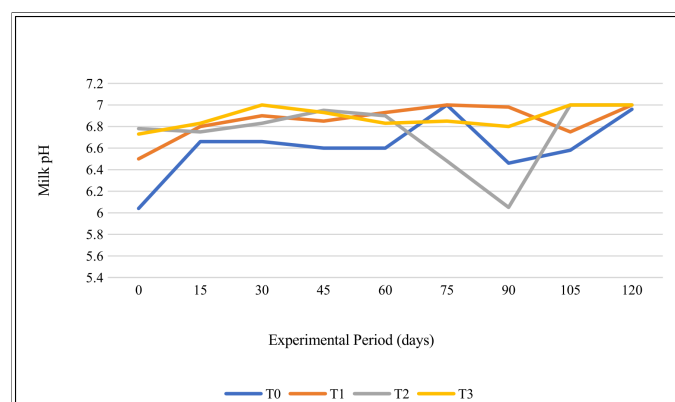


Figure 1. Changes in milk pH of Pantja goats during the 120-day experimental period

Water content

Water content of the milk remained relatively stable during the initial and middle stages of the experiment, but significant differences among treatments were observed on days 105 ($P < 0.001$) and 120 ($P = 0.01$). At day 120, water content was highest in T_0 ($86.45 \pm 0.07\%$) and lowest in T_2 ($84.65 \pm 0.37\%$), while T_1 and T_3 recorded $85.67 \pm 0.14\%$ and $84.79 \pm 0.30\%$, respectively. The lower water content in some supplemented groups toward the end of the trial may indicate an increase in the solids fraction of milk. These values were consistent with those reported by Devendra (1980) [19], Singh *et al.* (1992) [20], and Sanyal (1993) [21], whereas Prata *et al.* (1998) [22] reported comparatively higher water contents.

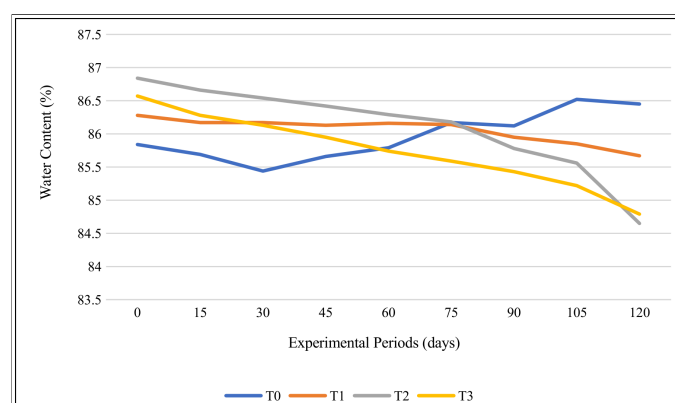


Figure 2. Changes in water content of Pantja goat milk during the 120-day experimental period

Milk protein

Milk protein content showed an increasing trend during the experimental period, particularly in the supplemented groups. Differences among treatments were non-significant up to day 75 ($P > 0.05$), but became significant on days 90 ($P = 0.001$), 105 ($P = 0.022$) and 120 ($P = 0.01$). At day 120, the highest protein content was recorded in T_1 ($4.28 \pm 0.07\%$), followed by T_3 ($4.11 \pm 0.04\%$), T_2 ($4.09 \pm 0.04\%$) and T_0 ($3.84 \pm 0.05\%$). The higher protein content in the supplemented groups during the later stages may be related to improved nutrient availability from the supplemented diet, suggesting a possible positive influence of polyherbal supplementation on the protein fraction of milk.

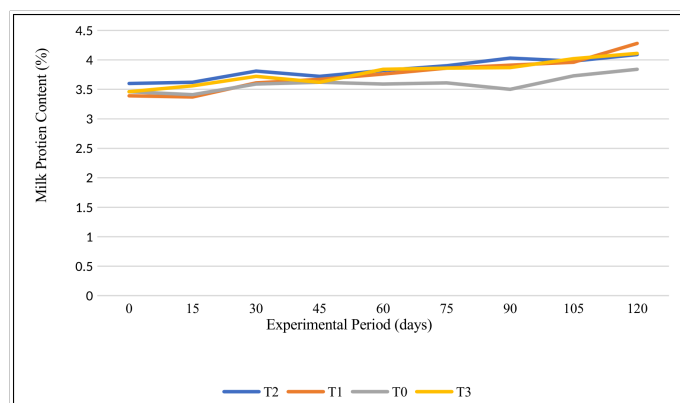


Figure 3. Changes in milk protein content of Pantja goats during the 120-day experimental period

Solids-not-fat (SNF)

The SNF content showed a gradual increase during the experimental period. Differences among treatment groups were non-significant during the early observations, while significant differences were observed from day 60 onward ($P < 0.05$). At day 120, SNF was highest in T_3 ($10.82 \pm 0.18\%$), followed by T_1 ($10.20 \pm 0.42\%$), T_2 ($10.12 \pm 0.43\%$) and T_0 ($8.97 \pm 0.21\%$). The higher SNF content in the supplemented groups, particularly during the later stages, indicates an increase in the non-fat solids fraction of milk. Similar observations were reported by Saini *et al.* (1991) [23], Sanyal (1993) [21], Gol *et al.* (1997) [24], and Antunacet *et al.* (2001) [25]. Miklic *et al.* (2000) [26] also reported variations in the SNF content of goat milk.

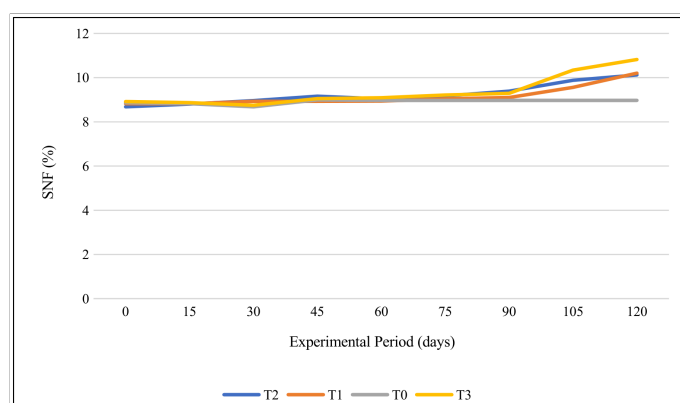


Figure 4. Changes in solids-not-fat (SNF) content of Pantja goat milk during the 120-day experimental period

Total solids (TS)

Total solids content showed a progressive increase during the experimental period. Differences among treatments were non-significant up to day 75, while significant differences were observed on days 90, 105 and 120 ($P = 0.001$). At day 120, TS content was highest in T_3 ($15.15 \pm 0.14\%$), followed by T_2 ($15.14 \pm 0.08\%$) and T_1 ($15.03 \pm 0.11\%$), whereas T_0 recorded $14.33 \pm 0.04\%$. The higher total solids content in the supplemented groups, particularly during the later stages, indicates an improvement in the solids fraction of milk. The present findings are comparable with those reported by Prakash and Jennes (1968) [27], Ali *et al.* (1991) [28], Chornobai *et al.* (1999) [29], Cortes *et al.* (1993) [30], Prasad *et al.* (1994) [31], Davide *et al.* (2001) [32], and Aganga *et al.* (2002) [33].

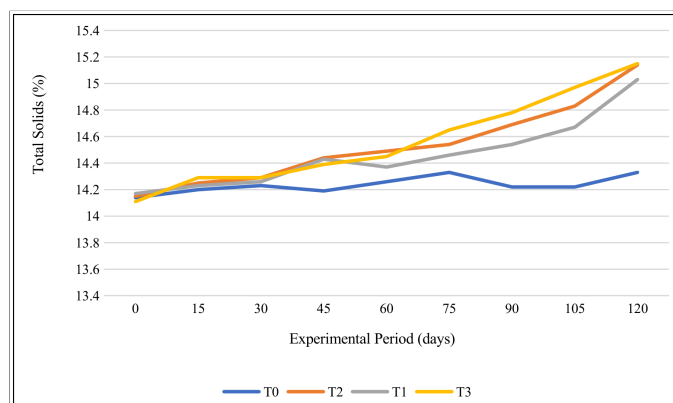


Figure 5. Changes in total solids content of Pantja goat milk during the 120-day experimental period

Specific gravity

Specific gravity of milk showed a gradual increase during the experimental period. Significant differences among treatments were observed on days 30 ($P = 0.01$), 105 ($P < 0.001$) and 120 ($P = 0.006$), while the remaining observations were non-significant. At day 120, the highest specific gravity was recorded in T_3 (1.036 ± 0.00), followed by T_2 (1.034 ± 0.00), T_1 (1.032 ± 0.00) and T_0 (1.024 ± 0.00). The higher specific gravity in the supplemented groups toward the end of the experiment may be related to the increased concentration of milk solids. The findings are comparable with those reported by Agrawal *et al.* (1961) [34], Leonhard (1963) [35], Chang *et al.* (1978) [36], and Chornobai *et al.* (1999) [29].

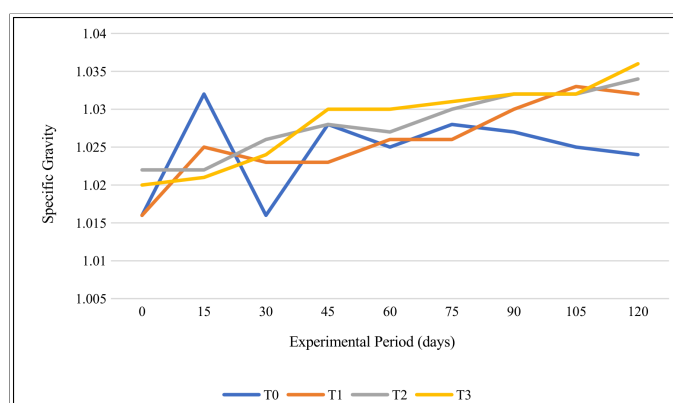


Figure 6. Changes in specific gravity of Pantja goat milk during the 120-day experimental period

Ash content

Milk ash content showed relatively small variations during the initial stages, followed by significant differences among treatments on days 90, 105 and 120 ($P < 0.05$). At day 120, the highest ash content was recorded in T_2 ($0.78 \pm 0.003\%$) and T_3 ($0.78 \pm 0.005\%$), followed by T_1 ($0.77 \pm 0.006\%$) and T_0 ($0.75 \pm 0.003\%$). The higher ash content in the supplemented groups during the later stages may indicate variation in the mineral fraction of milk associated with dietary supplementation. The findings are consistent with those reported by Devendra (1972) [37], Puri *et al.* (1963) [38], Agrawal and Bhattacharya (1978) [39], Boros *et al.* (1988) [40], Cortes *et al.* (1993) [30], Prata *et al.* (1998) [22], Haenlein (2002) [41], and Maree (2003) [42].

Titrateable acidity

Titrateable acidity remained relatively stable during the early stages of the experiment but increased in the supplemented groups during the later stages. Differences among treatments were non-significant up to day 75, while significant differences were observed on days 90, 105 and 120 ($P < 0.05$). At day 120, the highest acidity was recorded in T_3 (0.137 ± 0.00), followed by T_1 and T_2 (0.136 ± 0.00), whereas T_0

recorded the lowest value (0.126 ± 0.00). The higher titratable acidity in the supplemented groups during the later stages may be associated with changes in milk composition during lactation. Similar variations have been reported by Patel *et al.* (1964) [43], Boros *et al.* (1988) [40], Ali *et al.* (1991) [28], Chornobai *et al.* (1999) [29], and Fandalian *et al.* (2001) [18].

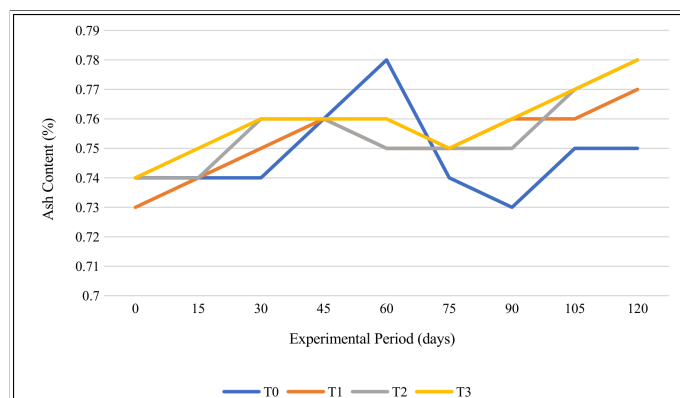


Figure 7. Changes in ash content of Pantja goat milk during the 120-day experimental period

Milk fat

Milk fat content showed an increasing trend during the 120-day experimental period, particularly in the supplemented groups. Differences among treatments were non-significant on days 0 and 30, while significant differences were observed on day 15 and from day 45 onward. At day 120, the highest fat content was recorded in T_3 ($5.48 \pm 0.16\%$), followed by T_2 ($5.25 \pm 0.18\%$), T_1 ($5.10 \pm 0.13\%$) and T_0 ($4.20 \pm 0.33\%$). The higher milk fat content in the supplemented groups, especially during the later stages, suggests a possible positive effect of polyherbal supplementation on milk fat composition. The findings are in agreement with Patel *et al.* (1964) [43], Prakash and Jennes (1968) [27], Mittal *et al.* (1971) [44], Chakraborty (1979) [15], Mittal (1984) [45], Ali *et al.* (1991) [28], Prasad *et al.* (1994) [31], Szymanowska *et al.* (1997) [46], Haenlein (2002) [41], and Kuchtik *et al.* (2003) [47].

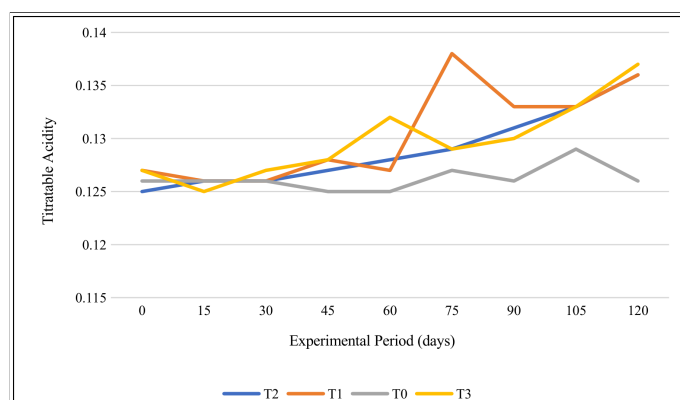


Figure 8. Changes in titratable acidity of Pantja goat milk during the 120-day experimental period

Calcium content

Milk calcium content showed an increasing trend in the supplemented groups during the later stages of the experiment. Significant differences were observed on days 45, 75, 90, 105 and 120, while the difference on day 60 was non-significant. At day 120, calcium content was highest in T_2 (898.36 ± 0.68 mg/L), followed by T_1 (897.78 ± 0.67 mg/L), T_3 (894.28 ± 2.01 mg/L) and T_0 (885.36 ± 1.42 mg/L) ($P < 0.001$). The higher calcium concentration in the supplemented

groups during the later stages suggests a possible improvement in the mineral composition of milk. The observed values are comparable with those reported by Underwood (1981) [48], Guler (2007) [49], Khan *et al.* (2006) [50].

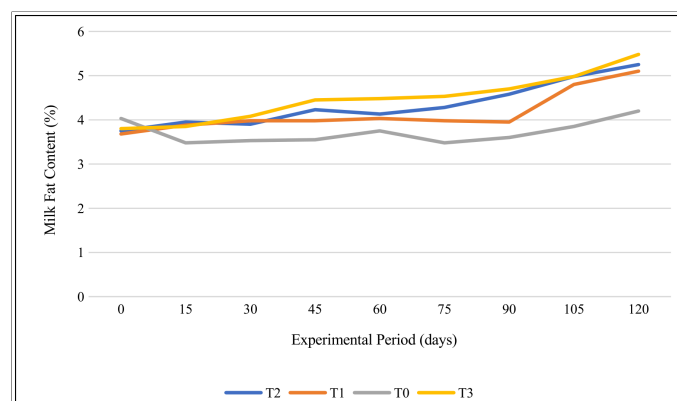


Figure 9. Changes in milk fat content of Pantja goats during the 120-day experimental period

Zinc content

Milk zinc content remained relatively stable throughout the experimental period, with no significant differences among treatment groups at any sampling interval ($P > 0.05$). At day 120, zinc content ranged from 2.35 ± 0.014 mg/L in T_0 to 2.37 ± 0.011 mg/L in T_2 , indicating little variation among the groups. The stable zinc concentration suggests that polyherbal supplementation did not significantly influence the zinc content of milk under the conditions of the present study. The observed values were comparable with those reported by Slacanac *et al.* (2011), while Underwood (1981) [48] and Mestawet *et al.* (2012) [51] reported higher zinc concentrations in goat milk.

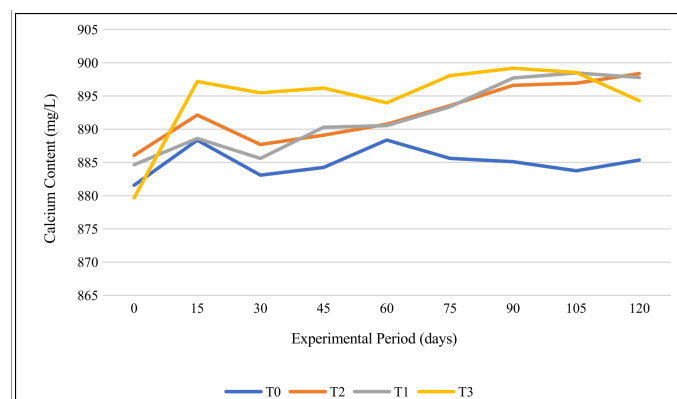


Figure 10. Changes in calcium content of Pantja goat milk during the 120-day experimental period

Iron content

Milk iron content generally increased during the experimental period, particularly in the supplemented groups. Differences among treatments were non-significant during the early observations, while significant differences were observed on days 60, 90, 105 and 120. At day 120, the highest iron content was recorded in T_3 (0.74 ± 0.05 mg/L), followed by T_2 (0.63 ± 0.05 mg/L), T_1 (0.58 ± 0.07 mg/L) and T_0 (0.46 ± 0.06 mg/L) ($P = 0.036$). The higher iron content in the supplemented groups during the later stages indicates a possible improvement in the mineral composition of milk. The observed values were comparable with those reported by Miles *et al.* (2001) [52], whereas Guler (2007) [49] reported a higher iron concentration in goat milk.

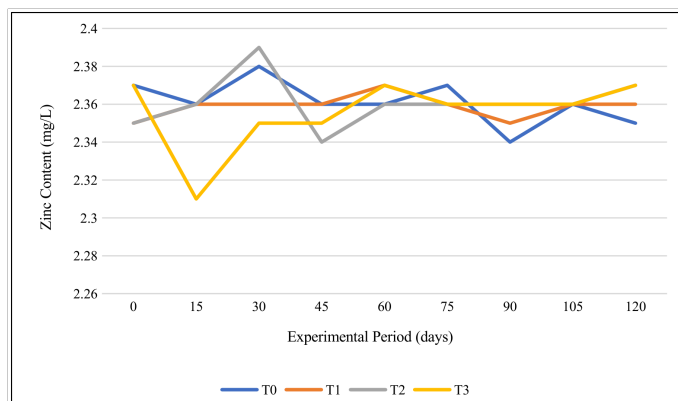


Figure 11. Changes in zinc content of Pantja goat milk during the 120-day experimental period

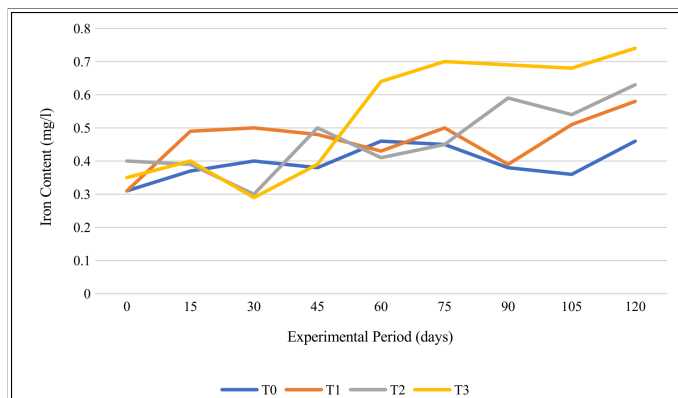


Figure 12. Changes in iron content of Pantja goat milk during the 120-day experimental period

Manganese content

Milk manganese content remained relatively stable during the initial and middle stages, with no significant differences among treatments up to day 90 ($P > 0.05$). Significant differences were observed on days 105 ($P = 0.010$) and 120 ($P = 0.019$). At day 120, manganese content was highest in T_1 (117.21 ± 0.39 mg/L), followed by T_3 (115.97 ± 0.04 mg/L), T_2 (115.43 ± 0.61 mg/L) and T_0 (115.28 ± 0.31 mg/L). The increase in manganese content during the later stages, particularly in T_1 , suggests a possible effect of polyherbal supplementation on the mineral composition of milk.

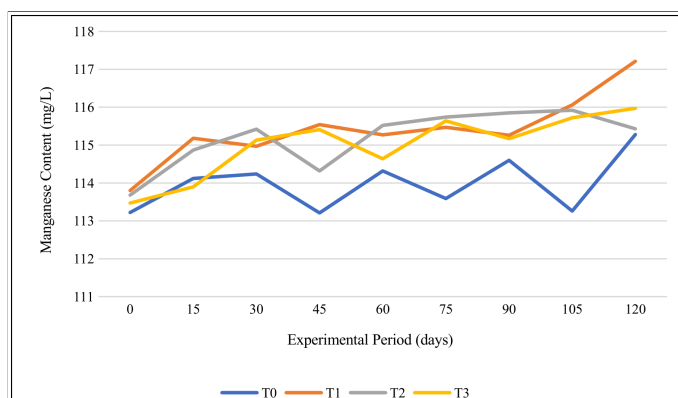


Figure 13. Changes in manganese content of Pantja goat milk during the 120-day experimental period

Conclusion

The present study demonstrated that dietary supplementation with polyherbal combinations of *Moringa oleifera*, *Trigonella foenum-graecum* and *Tinospora cordifolia* influenced several milk quality and compositional attributes of Pantja goats during the 120-day experi-

mental period. The supplemented groups generally showed higher protein, fat, SNF and total solids contents during the later stages compared with the control group. Improvements were also observed in selected mineral components, particularly calcium and iron, while zinc content remained relatively stable. Manganese showed significant differences during the later stages, particularly in the *Moringa* + Fenugreek group. Overall, the findings suggest that polyherbal supplementation may improve selected nutritional, physicochemical and mineral characteristics of Pantja goat milk.

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