

Research Article



Impact of Housing Systems on Milk Yield, Composition, Behavior, and Welfare in Lactating Pateri Goats

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Abstract | An experimental study was carried out to evaluate the effects of two different housing systems on milk yield, composition, welfare, behavior and hematological profile in lactating Pateri goats. Fourteen goats were selected and randomly divided into two groups of seven (n=7 per group). Group A was kept in cages while Group B was kept under an open housing system. Both groups were provided with feed and fresh drinking water ad libitum for a 90-day experimental trial. Milk yield and composition, including ash, fat, lactose, protein, total solids, pH, and specific gravity, were significantly ($p<0.05$) higher in Group B compared to Group A. Conversely, the moisture content was significantly ($p<0.05$) higher in the milk of Group A goats. Behavioral observations indicated that eating, ruminating, and sleeping time were significantly ($p<0.05$) higher in Group B, whereas lying, standing, drinking, and licking times were significantly ($p<0.05$) higher in Group A. WBC and blood glucose levels of Pateri goats were significantly ($p<0.05$) higher in Group B as compared to Group A. The study concludes that the open housing system improves milk composition in Pateri goats compared to the cage housing system.

Keywords | Pateri goat, Housing system, Growth, Cage system, Blood profile, Goat milk

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INTRODUCTION

Both small-scale livestock keepers and traditional pastoralists rely heavily on income from goats, which are primarily kept for their milk and meat, with secondary uses including skins and hairs (Kioumaris et al., 2011). Goats provide a long-term economic stream, with fair market prices helping to alleviate poverty in rural communities associated with agriculture (Mahmuod, 2010). They are crucial to the livelihoods of low and medium input farmers and livestock-keeping households (Dossa et al., 2008). Ap-

proximately 90% of goats worldwide are found in developing nations, with Asia leading the way, producing 57% of global goat milk. Major producers include India, China, Pakistan, Bangladesh, Indonesia, Iran, and Türkiye (FAO, 2024). The agriculture of Pakistan primarily involves 87 million goats raised mainly by landless and poor people, significantly contributing to the national economy by producing 1,074 thousand tons of milk, 594 thousand tons of meat, 32.7 thousand tons of fur, and 33.53 million skins, and accounting for 1.5 percent of total national milk production (GoP, 2024).

Due to the country's topography and lack of natural pastures, free grazing is the primary approach used by small-scale farming in Pakistan. Feeding goats is often restricted by the use of concentrates, which increases output costs. Despite global challenges, numerous groups promote goat farming to address rural poverty (Solangi, 2017). Goats, among the earliest domesticated small ruminants, have been reared for milk and meat since at least 2500 B.C in the Middle East (Dubeuf and Boyazoglu, 2009; Salah, 2005). While more prevalent in hot, arid regions of developing nations, goats are adaptable to various habitats. Approximately 1.145 billion goats are reported worldwide, with 50.74% in Asia, 44.19% in Africa, 3.39% in Americas, 1.3% in Europe, and 0.39% in Oceania. Notably, 47.7% of these goats are found in the 25 least developed countries (FAO, 2024).

The Pateri goat breed, native to Sindh province in Pakistan, is reared for both milk and meat. These medium to large goats have a light brown to red head, foreleg, and collar coloration with a white body (Ghansham, 1999). Poor farmers particularly raise it for meat and milk. Rural people raise them for meat and milk, with male Pateri kids often fattened for Eid-ul-Azha sales (Pirzado et al., 2016). Milking goats are kept in various systems, including intensive and extensive, by different types of farmers, including pastoralists and smallholders. These goats are sometimes the only source of protein and sustenance for impoverished people in rural areas (Devendra, 2007).

Different housing systems have varying effects on growth, body conformation, and reproductive performance in dairy goats (Kor & Ertugrul 2011). In open or loose housing, goats can move freely, while in cage system they remain restricted to one cage. Some studies suggest that open housing can negatively affect milk production (Fernández et al., 2007), feeding (Aschwanden et al., 2009; Jørgensen et al., 2007) and lying behavior (Aschwanden et al., 2009) due to frequent conflicts among goats. Housing systems significantly impact dairy goat welfare (Stachowicz et al., 2018). There are welfare issues such as lameness and wall horn overgrowth when goats are kept confined indoors (Sailer et al., 2021). Similarly, greater welfare issues are reported in open housing dairy goat farms compared to confined ones (Salas et al., 2021). Intensifying farming methods can adversely affect milk microbiological quality and lead to issues like caprine arthritis encephalitis virus (CAEV) and other viral or metabolic disorders (Pirisi et al., 2007), as well as poor behavior and animal health (Caroprese et al., 2015).

Keeping in view the inconsistencies in the available literature and in order to optimize housing systems for Pateri goats the present study was conducted to evaluate the ef-

fects of two different housing systems (cage system and open housing system) on milk production, milk composition, welfare, behavior and hematological profile in lactating Pateri Goats.

MATERIALS AND METHODS

EXPERIMENTAL ANIMALS AND MANAGEMENT

The experiment was conducted at the Livestock Experiment Station, Department of Livestock Management, Sindh Agriculture University Tandojam, following the ethical guidelines of the Faculty of Animal Husbandry and Veterinary Sciences, Sindh Agriculture University Tandojam. The experimental station had a hot and arid climate, with average temperatures ranging from 30-39°C and humidity levels from 30-45% during the experiment. Fourteen lactating Pateri goats were selected and randomly divided into two groups, each consisting of seven goats (n=7). Group A was housed in cages (2m x 1.5m individual pens per goat, with slatted floors made with metal angular bars to facilitate ventilation), while Group B was kept under open housing system (20m x 15m paddock with natural soil and partial shading, allowing goats ample space for movement and social interaction). Commercial feed (16-18% crude protein and 65-70% total digestible nutrients) and fresh drinking water were provided *ad libitum* during the 90-day experimental trial. The feed was offered twice a day at approximately 0800 hours and 1600 hours. Milk was collected by the hand milking method, and samples were sent for laboratory analysis.

PHYSICAL AND CHEMICAL COMPOSITION OF MILK

The pH was evaluated by the method described by Ockerman (1985). Specific gravity, protein, ash, fat, lactose, total solids, and moisture content were determined according to the method described by the Association of Official Analytical Chemists (AOAC, 2005).

WELFARE AND BEHAVIOR OBSERVATION

Welfare and behavioral parameters were observed randomly throughout the day by visual inspection. Laying, movement, standing, running, drinking, eating, ruminating, browsing, sleeping, aggressiveness, licking, abscess, injury, lameness, body scoring, swelling joints, and parasite presence were assessed through visual and physical examination (Muri et al., 2013).

BLOOD HEMATOLOGY

Using a sterile 5 mL syringe, blood samples were aseptically drawn from the female goats' jugular veins. The samples were then placed into 1.5 mL tubes containing ethylene diamine tetraacetic acid (EDTA) anticoagulant. The samples were quickly sent to the Animal Medical Center (AMC) to determine the total blood count using an automated he-

matology analyzer (Wondfo, USA). The blood profile included the counting of red blood cells (RBC), white blood cells (WBC), hemoglobin (HB), and platelets. The standard values of blood components were found using the hematology analyzer. The glucose oxidase method was used to determine the blood glucose levels using a glucometer specifically calibrated for veterinary use (Abdel-Raheem and Hassan, 2021).

STATISTICAL ANALYSIS

Analysis of Variance (ANOVA) was used to statistically examine the collected data in a completely randomized design (Steel et al., 1960). The significance of mean differences was evaluated using Duncan's multiple range test (Duncan, 1955) using JMP software.

RESULTS

PHYSICAL AND CHEMICAL PROPERTIES OF MILK OF PATERI GOATS UNDER DIFFERENT HOUSING SYSTEMS

The pH, specific gravity, ash, fat, lactose, protein and total solids content were significantly ($p < 0.05$) higher in the milk of Pateri goats in the open housing group as compared to the cage system (Group B) on days 45 and 90, respectively (Table 1). A highly significant difference was observed among the groups (A and B). Conversely, moisture content was significantly ($p < 0.05$) higher in the milk of goats reared in the cage system compared to open housing system which was significantly different (Table 2). Moreover, the milk yield was recorded significantly higher in Pateri goats of Group B (open housing) compared to the milk yield of Pateri goats of Group A (cage system) on days 45 and 90, respectively.

BEHAVIOR PARAMETERS OF PATERI GOATS UNDER CAGE AND OPEN HOUSING SYSTEMS

The lying time and drinking time were higher in Group A (open housing) as compared to Group B (cage system), and the difference between the groups (A and B) was significant ($p < 0.05$). While there was no significant difference observed in standing time between the groups (A and B). The results for eating, rumination, browsing, and sleeping time show that, compared to Group A, a higher time was noted in Group B, indicating a substantial difference between the two groups. Aggressiveness time was noted in Group A, while it was absent in Group B. The licking time was higher in Group A compared to Group B. Statistically, the groups (A and B) differed from one another significantly (Table-4).

WELFARE PARAMETERS OF PATERI GOATS UNDER CAGE AND OPEN HOUSING SYSTEMS

According to results mentioned in Table-5, the abscess,

lameness and swelling joints were absent in both groups (A and B). However, injury was present in 3 and 2 goats in Group A and Group B, respectively. The body score of Pateri goats reared under Group A and Group B was noted to be good. Moreover, parasites were found in 4 and 2 goats in Group A and Group B, respectively.

HEMATOLOGICAL PARAMETERS OF PATERI GOATS

There was no significant difference noted in hemoglobin, RBC, and platelets in blood of Pateri goats between Group A (cage system) and Group B (open housing) on day 45 and day 90. However, the values were within the normal range for the goats. WBC and glucose levels of Pateri goats were significantly ($p < 0.05$) higher in the blood of Pateri goats of Group B (open housing system) compared to blood of Pateri goats of Group A (cage housing system). However, the values were within the normal range for the goats.

DISCUSSIONS

In our study, a significant effect of housing systems was found on the milk composition of Pateri goats. Greater values of protein, ash, lactose, fat, total solids, pH, specific gravity, and milk yield were observed under the open housing system compared to the cage housing system. These findings agree significantly with O'Callaghan et al. (2016), they recorded significantly higher values of milk yield, milk solids, protein, fat and lactose in cows housed outdoors as compared to cows housed indoors. Similarly, according to Zhu et al. (2020), the group of cows housed indoor showed significantly higher total solids content, which contributed to greater protein and fat content as well; indeed, among the components of milk composition, the two most susceptible to feeding system changes are fat and protein. The present study contradicts the findings of Casamassima et al. (2001), they concluded that milk yield and composition were not affected by the housing systems. However, they found significantly higher protein, fat and lactose concentrations during the middle of the trial in the group kept outdoors. According to the findings of Min et al. (2005), temperature and environmental conditions were linked to differences in milk production and composition. The higher the peak yield and total milk output, the longer it takes to reach peak yield. Animals in cages seemed to be more nutritionally restricted, resulting in earlier and lower peak output since their body reserves were depleted sooner (NRC, 2001; Bargo et al., 2003).

Regarding rumination, there was no discernible difference between the two groups. These results are consistent with those of Bhakat and Nagpaul (2005). The average rumination time was higher in goats under the loose housing system. Rumination is an important physiological behavior

Table 1: Physical parameters of milk of Pateri goat under different housing systems

Duration	Parameter	Group A	Group B	SEM	P-value
45 days	pH	6.58 ^b	6.78 ^a	0.9973	0.0254
	Specific gravity	1.0321 ^b	1.0343 ^a	0.9494	0.0024
90 days	pH	6.51 ^b	6.68 ^a	0.0300	0.0264
	Specific gravity	1.0271 ^b	1.0293 ^a	0.9494	0.0036

Different alphabets among the mean indicates significant difference at $P < 0.05$

Group A = Individual housing cage system, Group B=Open housing system

Table 2: Chemical parameters of milk of Pateri goat under different housing systems

Duration	Parameter (%)	Group A	Group B	SEM	P-value
45 days	Ash	0.67 ^b	0.84 ^a	0.0365	0.0264
	Fat	3.94 ^b	4.21 ^a	0.0500	0.0481
	Lactose	3.82 ^b	4.21 ^a	0.0328	0.0328
	Protein	3.75 ^b	3.94 ^a	0.0202	0.0164
	Total solids	12.20 ^b	13.23 ^a	0.0645	0.0193
90 days	Moisture	87.79 ^a	86.76 ^b	0.0645	0.0193
	Ash	0.64 ^b	0.80 ^a	0.0361	0.0077
	Fat	3.75 ^b	4.01 ^a	0.0483	0.0132
	Lactose	3.64 ^b	4.00 ^a	0.0316	0.0297
	Protein	3.57 ^b	3.75 ^a	0.0202	0.0142
	Total solids	11.62 ^b	12.60 ^a	0.0614	0.0250
	Moisture	88.37 ^a	87.39 ^b	0.0614	0.0250

Different alphabets among the mean indicates significant difference at $P < 0.05$

Group A = Individual housing cage system, Group B=Open housing system

Table 3: Milk yield (Kg) of Pateri goat under different housing systems

Duration	Group A	Group B	SEM	P-value
45 days	1.18 ^b	1.46 ^a	0.1076	0.0231
90 days	1.24 ^b	1.53 ^a	0.1127	0.0228

Different alphabets among the mean indicates significant difference at $P < 0.05$

Group A = Individual housing cage system, Group B=Open housing system

Table 4: Behaviour parameters of Pateri goat reared under open and cage housing system

Parameter	Unit	Group A	Group B	SE±	LSD (0.05)	P-value
Lying	min/day	175.14 ^a	168.86 ^b	3.4355	7.4853	0.0022
Standing	min/day	211.86 ^a	206.43 ^a	6.2232	13.559	0.4002
Drinking	min/day	71.56 ^a	45.71 ^b	4.0093	8.7356	0.0321
Eating	min/day	151.43 ^b	205.71 ^a	9.3823	20.442	0.0011
Rumination	min/day	341.57 ^b	397.29 ^a	13.606	29.645	0.0015
Browsing	min/day	0.00 ^b	140.00 ^a	5.1037	11.120	0.0014
Sleeping	min/day	240.29 ^b	260.29 ^a	9.7087	21.153	1.0020
Aggressiveness	min/day	50.33 ^a	0.00 ^b	2.3120	3.513	0.0001
Licking	min/day	61.59 ^a	20.44 ^b	7.2153	12.254	0.0011

Alphabets^(a,b) among the mean values indicates significant ($p < 0.05$) difference from each other.

Group A = Individual housing cage system, Group B=Open housing system

Table 5: Welfare parameters of Pateri goat reared under open and cage housing system

Parameter	Group A	Group B
Abscess	Absent in all	Absent in all
Injury	Present in 3 goats	Present in 2 goats
Lameness	Absent in all	Absent in all
Body score	Good	Good
Swelling joints	Absent in all	Absent in all
Parasites	Present in 4 goats	Present in 2 goats

Group A = Individual housing cage system, Group B=Open housing system

Table 6: Hematological parameters of Pateri goat under different housing systems

Duration	Parameter	Group A	Group B	SEM	P-value
45 days	Haemoglobin (g/dl)	6.28	6.31	0.2295	0.1362
	RBC (x10 ³ /μl)	1.06	1.05	0.0245	0.7752
	WBC (x10 ³ /μl)	13.15 ^b	14.50 ^a	0.3804	0.0041
	Platelets (x10 ⁶ /μl)	3.54	3.59	0.0416	0.2169
	Glucose (g/dl)	43.85 ^b	44.76 ^a	0.3237	0.0158
90 days	Haemoglobin (g/dl)	6.32	6.33	0.2312	0.4132
	RBC (x10 ³ /μl)	1.09	1.07	0.0222	0.3536
	WBC (x10 ³ /μl)	14.11 ^b	15.41 ^a	0.5936	0.0490
	Platelets (x10 ⁶ /μl)	3.70	3.71	0.0602	0.8708
	Glucose (g/dl)	45.77 ^b	46.65 ^a	0.3998	0.0465

Different alphabets within the row among the mean indicates significant difference at P<0.05

Group A = Individual housing cage system, Group B=Open housing system

ior that indicates the sound health, perfect digestion, and comfort of an animal. Goats in Group B eat more dry matter DM to meet their increased nutrition needs, which lengthens their periods of ruminating. In both groups, ruminating behavior was more prevalent at night than during the day under the different housing system. The rumination time was significantly higher when lying down than when standing. Radostits et al. (2007) discovered that kids typically begin to ruminate 30 to 90 minutes after eating. The type of diet and the roughness of the ruminal content dictated the amount of time spent ruminating. The amount of feed that is available but hasn't been consumed or the animal's response when fed can be used to gauge how hungry the animal is. Finding out how much feed the animals consume overall each day was crucial.

Regarding the feeding habit of the goats, there was no significant difference (P>0.05) across the housing systems. These results concur with those of Bhakat and Nagpaul (2005). The most fodder was consumed between 10 AM and 1 PM, following which it gradually decreased until 2 PM. From 2 PM to 5 PM, fodder intake increased once more. This pattern is due to the fodder being supplied twice a day, between 9 AM and 10 AM, and between 2 PM and 4 PM. Intake was high just after the fodder was offered, and even though there was a constant supply of

fodder, the intake decreased over time for both housing systems. These findings agree with Jørgensen et al. (2007). Additionally, it was discovered that goats routinely, but briefly, consume feed.

There were no significant differences in the goats' sitting or resting times between the two housing types. In both housing systems, the animals spent a considerable amount of time relaxing or sitting. Because they were completely confined in the cage housing system, the animals in the loose housing group spent less time reclining or resting. Most of the time between 2 and 3 AM and 6 and 9 PM, the animals stood still. These results are consistent with those reported by Bhakat and Nagpaul (2011). The maximum resting duration was maintained throughout the entire experiment. This is due to the exceptionally hot summer, when the temperature dropped, and the goats' rest and idle time decreased. The goats in loose housing stood, walked, and moved for 828.64 minutes out of a total of 1440 minutes during the day. The rest of the time was spent sleeping. The amount of time spent standing under the traditional system was 812.69 minutes, a considerably shorter amount of time than under the loose housing method. Because the animals in the traditional system were kept inside for the entire day, the idle period was much longer.

In our study, there was a significant effect of housing system on hemoglobin, WBC and glucose levels in Pateri goats reared under open housing and cage housing systems. However, non-significant differences were observed in RBC and platelet counts between the two housing systems. According to [Bansode et al. \(2019\)](#), there was no significant variation in haemoglobin content for Osmanabadi kids living in different housing systems. These results align with those of [Singh et al. \(2008\)](#) in Marwari and Patanwadi sheep, where higher values were reported, although the observed values in our study were lower. According to [Bansode et al. \(2019\)](#), blood glucose levels for Osmanabadi kids did not vary substantially across treatment groups. However, animals exposed to light during the summer season had increased blood glucose levels compared to those housed in the shade. These findings are consistent with those of [Singh et al. \(2008\)](#) in Marwari and Patanwadi ewes, who also reported that blood glucose levels rose when animals were exposed to light during the summer, compared to when they were kept in the shade. This research supports our study, which found that blood glucose levels in goats under the open housing system were higher than those in the cage housing system. Notably, the blood glucose levels observed in our study were somewhat higher than those reported by [Singh et al. \(2008\)](#). According to [Garkal et al. \(2016\)](#), the mean hemoglobin value in Group B was not significantly lower than that in Group A. The low hemoglobin levels observed in both groups may be attributed to hemodilution and reduced nutritional intake resulting from decreased food consumption as ambient temperature rise ([Abdelatif et al., 2009](#)), who also suggested that thyroid secretion depression, which can lead to decreased erythropoiesis, might contribute to these low hemoglobin levels. When comparing Group A to Group B, the mean total erythrocyte count was higher ($P>0.05$) in Group A. This finding aligns with the conclusions of [Marai and Haegeb \(2010\)](#). The substantial decrease in red blood cell counts by 12 to 20% under stressful conditions can be attributed to erythrocyte breakdown and the hemodilution effect. The total leucocyte count in Group A was significantly higher, which supports the findings of [Jabbar et al. \(2012\)](#), who also noted considerable seasonal variations in leucocyte levels. Nonetheless, all blood profile values were within the normal range for goats, as reported by [Adeyemi et al. \(2016\)](#). Future research should explore the effects of varying light conditions, different feed formulations, and diverse housing designs on goat welfare and productivity to address existing gaps and refine recommendations for optimal housing practices.

CONCLUSION

It is concluded that, the milk composition of Pateri goats was found to be better under the open housing system

compared to the cage housing system. Furthermore, WBC, and glucose levels were significantly higher in the blood of goats in Group B (open housing system) than in Group A (cage housing system). Additionally, goats in the open housing system exhibited increased movement, eating, ruminating, and sleeping times. Notably, abscesses, lameness, and swelling of joints were absent in both housing systems. Based on these findings, the open housing system is recommended for rearing Pateri goats to enhance both their health status and production.

CONFLICT OF INTEREST

The authors pronounce that they have no conflict of interest.

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The manuscript has not been published or submitted to other journals previously.

NOVELTY STATEMENT

This study present novel insights into the impacts of housing systems (cage and open housing) on milk yield, composition, behavior, welfare, and hematological profiles in lactating Pateri goats. By comparing both systems over an extended period, it identifies optimal housing conditions that enhance milk production, improve animal welfare, and support better health outcomes, providing valuable guidance for smallholder farmers in developing regions.

AUTHORS CONTRIBUTION

All authors contributed equally and all authors are in agreement with the content of the manuscript.

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