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Effect of Shearing on Thermo-Physiological, Behavior, and Productivity Traits of Two Indonesian Local Sheep Breeds

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ABSTRACT

Thin-tailed sheep (TTS) and Fat-tailed sheep (FTS) are local Indonesian sheep breeds characterized by coarse wool. This study aimed to investigate the effects of wool shearing on the thermo-physiological, behavior, and productivity traits of these sheep. Sixteen selected rams were utilized in this study. Animals were assigned to a factorial completely randomized design and divided into two groups (TTS and FTS) and two treatments (sheared and unsheared). The study spanned three months under controlled conditions. Variables observed included environmental conditions, thermo-physiological parameters (respiratory rate/RR, pulse rate/PR, rectal temperature/RT, and heat stress index/HSI), sheep behavior (feeding duration, drinking frequency, rumination duration, urination frequency, defecation frequency, standing duration, and lying duration), and sheep productivity (feed intake, average daily gain/ADG, and feed conversion ratio/FCR). Data were analyzed using two-way ANOVA. Throughout the study, average temperature and humidity ranged from 25.13-30.48 °C and 64.50%-91.67%, respectively. Wool shearing significantly influenced (p<0.05) sheep's thermo-physiological, behavior, and productivity traits. These effects were consistent across sheep breeds, with no significant differences noted. Wool shearing significantly reduced (p<0.05) RR, PR, and RT, while the impact on average HSI was not significant. Additionally, sheared sheep exhibited increased (p<0.05) feeding, rumination, standing duration, and higher defecation frequency. Conversely, drinking frequency, urination frequency, and lying duration decreased in the sheared sheep group. Moreover, the sheared sheep demonstrated higher (p<0.05) feed intake and ADG, leading to a reduced (p<0.05) FCR compared to the unsheared group. In conclusion, shearing is a recommended practice for coarse wool-type sheep in tropical environments. This technique does not induce stress and enhances their thermo-physiological, behavior, and productivity traits.

Keywords: Indonesian sheep; sheep behavior; sheep performance; thermo-physiological traits; wool shaving

INTRODUCTION

Sheep are very popular in Indonesia as meat producers, and they are kept by many Indonesian farmers, especially smallholder farmers and those operating on a small scale. Sheep also play a significant role in various economic activities, poverty alleviation, household income, religious festivities, and cultural traditions (Ibrahim *et al.*, 2020). Livestock productivity can be measured by growth rate, influenced by environmental factors, genetics, and their interactions (Budisatria *et al.*, 2021). Environmental factors, including management, feed, temperature, and humidity, are crucial in sheep productivity. Despite having high production potential due to superior genetics, this potential cannot be fully expressed without proper environmental support (Irmawaty, 2018).

Most domestic sheep have wool to cover their bodies. Several studies have evaluated the significance of wool in relation to sheep's physiological conditions, behavior, and productivity (Leite *et al.*, 2020). There is a connection between behavioral, physiological, and biochemical indicators when evaluating animal adaptive capacity and welfare. Climatic conditions and shearing can impact sheep's thermoregulatory mechanisms and welfare (Casella *et al.*, 2016). Changes in heart rate or pulse rate (PR), respiration rate (RR), and rectal temperature (RT) are vital parameters that indicate physiological adaptation mechanisms in small ruminants (Berihulay *et al.*, 2019). The heat stress index (HSI) is frequently used as a marker of thermal well-being (Yakubu *et al.*, 2017).

Fleece enhances sheep's ability to adapt to harsh environmental conditions. It acts as a barrier to heat dissipation in sheep and can potentially cause heat stress (Taofik *et al.,* 2021; Seixas *et al.,* 2017; De *et al.,* 2017). While wool is a protective shield, it makes water evaporation and heat loss through sweating more challenging. Wool sheep naturally have lower thermoregulation, which is further intensified when they are sheared, reducing the insulating effect of wool. This decreased insulation, however, has features that also reduce heat loss through convection. Even with thinner wool, the fleece has stable air, minimizing heat loss (Wojtas *et al.,* 2014; Titto *et al.,* 2016).

Shearing is an alternative approach that can be implemented in sheep-rearing management. It can impact the productivity, quality, and quantity of wool fiber as well as the well-being of sheep (Gelaye *et al.,* 2021). Shearing provides a balance between production and heat dissipation because hair loss, acting as an insulator, facilitates heat dissipation from the body (Irmawaty, 2018). It enhances heat exchange between the sheep's body and the environment. Animal behavior and physiological status serve as early indicators of adaptation and response to environmental changes (Taofik *et al.,* 2021; Seixas *et al.,* 2017; De *et al.,* 2017). Animals exhibit different behaviors during heat stress, such as active rumination during the day and rest at night. They protect themselves from environmental extremes by dissipating body heat, taking advantage of hair absence on certain body parts, shedding hair, regulating feed intake, and managing water consumption (Berihulay *et al.,* 2019).

Apart from the mentioned benefits, shearing can also cause stress in sheep, resulting from thermal stress or the shearing method. Shearing induces physical and subsequent heat stress, leading to a temporary increase in rectal temperature, a phenomenon observed in various warm-blooded species. Shorn sheep experience a significant increase in respiratory rate after shearing, likely due to its close association with heat loss through evaporation (Casella *et al.,* 2016). A thick fleece layer provides an advantage to unshorn lambs, enabling them to tolerate hot and dry conditions with high solar radiation compared to short ones. Shearing, a common practice in managing wool sheep, enhances energy exchange between the animal and its surroundings, albeit at the cost of reduced thermal protection (McManus *et al.,* 2020).

Woolly sheep require shearing twice yearly, which has become a necessary treatment and processing step for wool (Scobie *et al.,* 2015). In Indonesia, farmers do not regularly shear the wool of their sheep because most of them keep local sheep that are not bred for wool production (Taofik *et al.,* 2021). Thin-tailed sheep (TTS) and Fat-tailed sheep (FTS) are primarily kept for meat production by farmers, and these sheep have coarse wool fibers (Ibrahim *et al.,* 2024). While there are numerous advantages to shearing wool-type sheep (Sighn *et al.,* 2018; Inan & Aygun, 2019), studies on meat-type sheep in tropical environments are limited or unclear. The increase in temperature and heat load can cause thermal stress effects on livestock production, impacting biological functions and behavior in livestock, such as reducing feed consumption. Due to the impact of wool on sheep and the environmental conditions, many studies have been conducted to investigate the effect of shearing on sheep (Al-Zabaie & Sultan, 2020; McManus *et al.,* 2020).

The advantages and disadvantages of shearing's impact on sheep are of particular concern for sheep breeders, especially in tropical environmental conditions. Studies on the impact of shearing in tropical environments are still limited and need to be conducted, particularly using local sheep commonly raised by breeders in Indonesia. These studies will help determine whether shearing sheep is necessary or not. Therefore, this study aims to assess the effect of shearing on the thermo-physiological, behavior, and productivity traits of Thin-tailed sheep (TTS) and Fat-tailed sheep (FTS) reared in tropical environmental conditions.

MATERIALS AND METHODS

Ethical Clearance

This study received approval from the Animal Care and Use Committee of the Faculty of Veterinary Medicine, Universitas Gadjah Mada, under ethical clearance number 0110/EC-FKH/Eks./2022.

Location and Animals

The research was conducted at the research farm of the Faculty of Animal Science, Universitas Gadjah Mada, Yogyakarta, Indonesia. The study took place over three months, from April to June, during the dry season, as classified by the Indonesian climate category, with monthly rainfall ranging from <5 mm/day (Indonesian Agency for Meteorological, Climatological and Geophysics, 2022). Sixteen rams with an initial average body weight of 42.70±6.74 kg, aged between 1 to 2 years, and covered with coarse wool, were used in this study. The animals were assigned to a factorial completely randomized design (2x2 factorial experiment) and divided into two breed groups (Thin-tailed sheep/TTS and Fat-tailed sheep/FTS) and two treatments (sheared and unsheared), with each factor consisting of four rams as replicates.

Animal Management and Data Collection

The sheared group of sheep was treated by shearing until the remaining hair measured about 0.5 cm in length, which was accomplished using a hair shaving machine (BaoRun™ S1). All sheep were housed in controlled conditions within individual stage pens measuring 2x1x1 m^3. They received feed in the morning (at 07:00) and in the afternoon (at 14:00). In the morning, they were provided with commercial concentrate feed, and in the afternoon, they were given fresh forage in the form of *Pennisetum purpureum* grass. The nutritional content of the commercial concentrate feed included dry matter (DM) at 88.68%, crude protein at 16.49%, crude fat at 27.05%, crude fiber at 15.21%, ash at 7.62%, and non-nitrogen-free extract at 53.76%. The nutritional content of *P. purpureum* included dry matter (DM) at 20.49%, crude protein at 11.23%, crude fat at 2.42%, crude fiber at 31.56%, ash at 12.76%, and non-nitrogen-free extract at 41.82%. Feeding was provided on a limited basis according to each animal's needs, calculated based on the dry matter (DM) feed/head/day requirement, set at 3% of the animal's body weight. Drinking water was provided ad libitum. Data collection encompassed environmental conditions (temperature and humidity), sheep hair length, sheep thermo-physiological status (respiratory rate/RR, pulse rate/PR, rectal temperature/RT, and heat stress index/HSI), sheep behavior (feeding duration, drinking frequency, rumination duration, urination frequency, defecation frequency, standing duration, and lying duration), and sheep productivity (feed intake, body weight, average daily gain/ADG, and feed conversion ratio/FCR).

Farm environmental conditions were assessed four times daily (every six hours from 6 a.m., GMT +7) over three months, specifically in the middle of each month. Farm environmental conditions were observed using a thermohydrometer (HTC-1™) with 0.1 °C temperature and 1% humidity accuracy. Hair length measurements were taken at the beginning of the treatment (0 days) and repeated monthly for three months. Hair length measurements were taken at the beginning of the treatment (0 days) and repeated monthly for three months. Hair length growth was measured monthly using a ruler (Joyko™ RL-ST30) from the base to the tip of the hair on the withers. This measurement was repeated three times and averaged. Physiological status data were collected every six hours (four times daily) with three repetitions starting at 6 a.m. (GMT +7). Thermo-physiological traits were sampled in the middle of each month for three months. Respiration frequency was measured by placing the back of the palm on the sheep's nose to feel exhalation. Pulse frequency was measured by pressing on the femoral artery until a pulse was felt. Both respiration and pulse frequencies were measured for one minute and repeated three times. Rectal temperature measurement was carried out by inserting a rectal thermometer (digital thermometer - Magic Star™) into the sheep's rectum approximately one-third of the way in until the alarm signal sounded. The relationship between RR and PR measurements, along with the average normal value, was used to calculate the heat stress index (HSI) based on the following formula: HSI = (RR/PR) × (NPR/NRR), where RR represents the measured respiratory rate, PR the measured pulse rate, NPR the normal pulse rate, and NRR the normal respiratory rate (Yakubu *et al.*, 2017).

The sheep behavior data were collected through behavioral observations conducted 3 times a day for 24 hours in the middle of each month (Nugroho *et al.*, 2015). A stopwatch (Joyko™ SW-500) was used in this study. Feeding duration represents the time (in minutes per day) sheep spend on feeding, observed by calculating the time taken to approach the feed, eat, and stop eating. Drinking frequency indicates the number of times the sheep engage in drinking activity per day, observed by counting their behaviors when approaching a drinking place and drinking until they stop. Rumination duration is the time (in minutes per day) sheep spend on rumination, observed by calculating how long they carry out rumination behavior until it finishes. Urination and defecation frequency (times per day) represent the number of times sheep urinate and defecate, respectively. Observations of urination and defecation frequency involved counting the instances of each behavior. Standing duration indicates the time (in minutes per day) sheep spend standing on the floor, including feeding, drinking, walking, and standing rumination. Lying duration represents the time (in minutes per day) sheep spend lying down, including rumination and sleeping (Nugroho *et al.*, 2015; Nejad & Sung, 2017; De *et al.*, 2017; Li *et al.*, 2018).

Feed consumption was measured monthly over three months in the middle of each month. Feed intake was calculated by subtracting the amount of feed refused from the amount given (Nugroho *et al.*, 2015). The sheep were weighed at the beginning of the study and then monthly for three months. Feed weighing was performed using a digital scale (CAMRY™) with a capacity of 10 kg and an accuracy of 1g, while sheep weighing was carried out using a hanging scale (CAMRY™) with a capacity of 100 kg and an accuracy of 500 g. The body weight data were used to calculate the average daily gain (ADG) by finding the difference between the final and initial weights and dividing it by the research duration (in days). The feed conversion ratio (FCR) was calculated by dividing the daily feed intake by ADG (Karthik *et al.*, 2021).

Data Analysis

Differences in hair length growth, thermo-physiological, behavior, and productivity traits between treatments and sheep breed groups were analyzed using two-way ANOVA. Initial hair length and initial body weight were used as covariates for analyzing hair length growth and sheep performance, respectively. Statistical analyses were conducted using SPSS version 25.0 software (IBM, USA).

RESULTS

Environmental Condition

Table 1 presents the temperature and humidity of the house pen environment. The temperature and humidity fluctuated from morning to night, with average temperatures at 6 a.m., 12 p.m., 6 p.m., and 12 a.m. measuring 25.18, 30.59, 28.11, and 26.21 °C, respectively. The corresponding average humidity levels were 92.33%, 64.22%, 76.11%, and 88.33% for the same time intervals.

Hair Length

Table 2 illustrates the sheep's hair lengths, and Figure 1 shows the average increase in hair length.

Table 1. Environmental condition in the housing treatment (mean ± SD)

Variables	Month	Time			
		6 a.m.	12 a.m.	6 p.m.	12 p.m.
Temperature (°C)	1st	24.80±0.62	30.47±0.59	28.07± 0.60	26.03±0.25
	2nd	25.37±1.18	30.40±0.36	28.50± 0.40	26.17±0.72
	3rd	25.37±1.36	30.90±1.97	27.77± 0.40	26.43±0.55
	Average	25.18±0.99	30.59±1.07	28.11± 0.52	26.21±0.50
Humidity (%)	1st	96.67±3.21	66.67±4.16	79.67±10.79	91.00±3.61
	2nd	88.67±1.53	62.00±7.55	69.67± 5.86	84.67±4.93
	3rd	91.67±3.51	64.00±9.64	79.00± 4.36	89.33±4.04
	Average	92.33±4.30	64.22±6.78	76.11± 8.12	88.33±4.64

Table 2. Hair length growth (cm/month) in sheep with shearing treatment and different breed (mean ± SD)

Month	Shearing treatments (T)		Breeds (B)		Significance		
	Sheared	Non-sheared	TTS	FTS	T	B	TxB
1st	2.30±0.78	1.75±1.07	2.24±1.00	1.81±0.91	NS	NS	NS
2nd	2.06±0.82	1.63±1.16	2.00±1.16	1.69±0.84	0.042	NS	NS
3rd	2.19±1.25	1.50±1.54	1.50±1.10	2.19±1.65	NS	NS	NS
Average	2.18±0.37	1.63±0.60	1.92±0.67	1.89±0.48	0.035	NS	NS

Note: NS= non-significant, TTS= Thin-tailed sheep, FTS= Fat-tailed sheep.

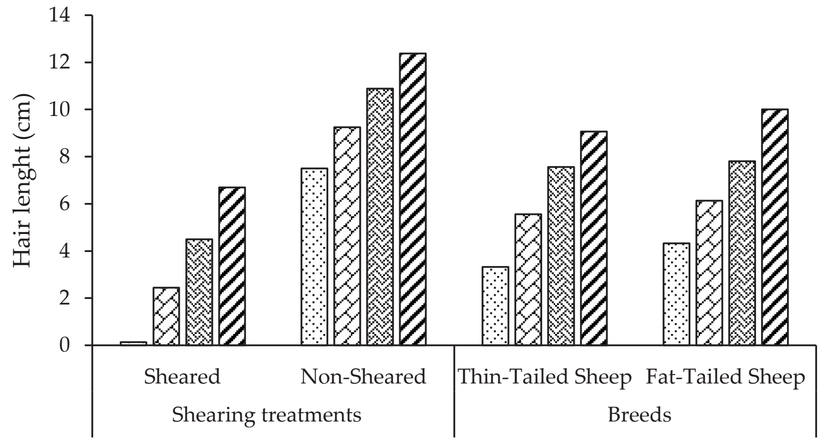

Figure 1. Hair length (cm) in sheep with shearing treatment and different breed.
Initial 1st month 2nd month 3rd month

Shearing significantly impacted hair length (p<0.05), while neither breed nor their interaction affected it. The length of sheep hair increased, regardless of shearing, with an average growth of 1.13-2.50 cm each month. Significant differences (p<0.05) in hair growth were observed in the second month (sheared: 2.06±0.82 cm vs. unsheared: 1.63±1.16 cm) and in the overall average hair length (sheared: 2.18±0.37 cm vs. unsheared: 1.63±0.60 cm). The breed and the treatment x breed interaction had no effect.

Thermo-Physiological Traits

Table 3 presents the thermo-physiological traits of sheep in the study. No interaction was observed between shearing and sheep breeds. Differences in sheep breeds did not significantly affect the physiological response, whereas shearing treatment led to significant differences (p<0.05), except for RT in the second month. On average, sheared sheep exhibited lower (p<0.05) respiratory rates (RR), pulse rates (PR), and rectal temperatures (RT) compared to unsheared sheep (38.48±0.57 vs. 41.49±0.78 breaths/minute, 68.65±0.93 vs. 38.73±0.28 beats/minute, and 38.46±0.08 vs. 38.73±0.28 °C, respectively). The shearing treatment did not significantly impact the average HSI values over the three months (sheared: 1.50±0.03 vs. unsheared: 1.49±0.03). Although significant differences were observed in the first and second months, the pattern was inconsistent.

Sheep Behavior

Table 4 illustrates the observed sheep behavior. Shearing significantly affected (p<0.05) the sheep's behavior, including feed intake duration, water intake frequency, rumination duration, urination frequency, defecation frequency, standing duration, and lying duration. Neither the breed nor the interaction between treatment

Table 3. Thermo-physiological traits in sheep with shearing treatment and different breed (mean ± SD)

Month	Shearing treatments (T)		Breeds (B)		Significance		
	Sheared	Non-shared	TTS	FTS	T	B	TxB
Respiratory rate (breath/minute)							
1st	36.04±0.59	38.61±1.02	36.96±1.40	37.70±1.70	<0.01	NS	NS
2nd	38.01±0.89	40.73±0.94	39.03±1.82	39.71±1.52	<0.01	NS	NS
3rd	41.40±1.31	35.12±0.88	43.29±2.22	43.22±2.34	<0.01	NS	NS
Average	38.48±0.57	41.49±0.78	39.76±1.67	40.21±1.79	<0.01	NS	NS
Pulse rate (times/minute)							
1st	64.48±0.88	66.53±0.73	65.29±1.36	66.72±1.32	<0.01	NS	NS
2nd	66.88±1.70	74.24±1.07	70.29±1.43	70.83±4.14	<0.01	NS	NS
3rd	74.60±0.63	83.51±2.15	79.01±5.18	79.10±4.86	<0.01	NS	NS
Average	68.65±0.93	74.76±0.89	71.53±3.47	71.88±3.30	<0.01	NS	NS
Rectal temperature (°C)							
1st	38.44±0.13	38.74±0.29	38.51±0.26	38.66±0.27	0.021	NS	NS
2nd	38.46±0.11	38.69±0.33	38.50±0.22	38.66±0.29	NS	NS	NS
3rd	38.49±0.16	38.75±0.24	38.60±0.23	38.65±0.25	0.025	NS	NS
Average	38.46±0.08	38.73±0.28	38.53±0.22	38.66±0.26	0.023	NS	NS
Heat Stress Index/HSI							
1st	1.49±0.03	1.55±0.03	1.51±0.03	1.53±0.05	<0.01	NS	NS
2nd	1.52±0.05	1.46±0.04	1.48±0.05	1.50±0.06	0.038	NS	NS
3rd	1.48±0.05	1.44±0.06	1.46±0.07	1.46±0.05	NS	NS	NS
Average	1.50±0.03	1.49±0.03	1.49±0.03	1.50±0.03	NS	NS	NS

Note: NS= non-significant, TTS= Thin-tailed sheep, FTS= Fat-tailed sheep.

x breed affected sheep behavior. Sheared sheep spent longer ($p<0.05$) on feeding (292.29±15.03 vs. 224.67±7.43 min/day), rumination (426.96±19.65 vs. 361.21±21.56 min/day), defecation (10.33±0.76 vs. 8.46±0.51 times/day), and standing (635.96±30.70 min/day) but shorter times ($p<0.05$) on drinking (8.25±0.68 vs. 10.04±1.04 times/day), urinating (10.58±0.72 vs. 12.25±0.79 times/day), and lying (804.04±31.76 vs. 873.63±41.17 min/day).

Sheep Productivity

Figure 2 presents the body weight (kg) of sheep in different treatments and breeds. The productivity data in Table 5 revealed significant differences ($p<0.05$) between sheared and unsheared sheep. Breed and the interaction between treatment and breed did not affect sheep productivity, except for FCR in the third month. Sheared sheep exhibited higher feed intake or dry matter intake (DMI), average daily gain (ADG), and a lower FCR compared to unsheared sheep. In this study, the average DMI, ADG, and FCR in sheared sheep were 946.67±19.8 g/day, 50.22±6.63 g/day, and 19.15±2.60 g/g, respectively, whereas for unsheared sheep, they were 892.55±54.99 g/day, 23.33±6.63 g/day, and 40.31±9.19 g/g, respectively.

DISCUSSION

The two primary environmental factors influencing livestock production are ambient temperature and humidity. The tropics are characterized by high levels of solar radiation and heat stress, which are the main factors limiting livestock development and production (Seixas *et al.*, 2017). The temperature and humidity of the house pen environment in this study fluctuated from morning to night, with an average temperature ranging from 25.18 °C to 30.59 °C and humidity between 64.22% and 92.33% (Table 1). Temperature and relative humidity significantly impact livestock comfort and are influenced by irradiation intensity. Livestock's ability to cope with heat stress depends on exposure to low temperatures at night, especially the duration and intensity of these lower temperatures. Lower nighttime temperatures can aid recovery from thermal stress experienced during the day (Seixas *et al.*, 2017). In Indonesia, ambient temperatures in the morning and evening are lower than during the day, whereas humidity is higher in the morning and evening than during the day. A previous study reported that Yogyakarta, Indonesia, has an average temperature of 27.28 °C and humidity of 82.17% (Atmoko *et al.*, 2020). The housing environment in this study falls within the range of thermal and humidity comfort zones. For sheep, the thermal comfort zone typically ranges from 15 **°C** to 30°C, and the humidity comfort zone ranges from 60% to 70% (Junior *et al.*, 2014; Nelvita *et al.*, 2018).

In this study, the breed difference did not significantly affect sheep hair length and hair length growth. Sheared sheep exhibited a higher ($p<0.05$) average hair length growth than non-shorn sheep (2.18±0.37 vs. 1.63±0.60 cm/month). In the 3rd month period in this study, unsheared Thin-tailed sheep (TTS) and Fat-tailed sheep (FTS) had hair lengths of 11.25 ± 3.77 cm and 13.50 ± 2.65 cm, respectively (Table 2). Hair length varies across different sheep breeds. For instance, Gubalafto sheep and Habru sheep in the 1 pair of permanent incisors (PPI) age group had average hair lengths of 9.78 ± 0.30 cm and 8.43 ± 0.35 cm, respectively

Table 4. Behavior traits in sheep with shearing treatment and different breed (mean ± SD)

Month	Shearing treatments (T)		Breeds (B)		Significance		
	Sheared	Non-sheared	TTS	FTS	T	B	TxB
Feeding duration (min/day)							
1st	253.25±14.09	224.92±16.67	240.58±22.68	237.58±19.39	<0.01	NS	NS
2nd	314.75±22.41	217.67±17.04	267.13±54.72	265.29±52.09	<0.01	NS	NS
3rd	308.71±27.14	231.50±15.46	266.87±50.90	273.33±38.38	<0.01	NS	NS
Average	292.29±15.03	224.67± 7.43	258.21±38.54	258.75±34.37	<0.01	NS	NS
Drinking frequency (time/day)							
1st	9.58±0.97	11.54±1.47	10.58±1.56	10.54±1.64	<0.01	NS	NS
2nd	8.29±1.07	9.67±2.58	8.92±1.69	9.04±2.42	0.021	NS	NS
3rd	6.88±0.90	8.88±0.95	7.79±1.14	7.96±1.57	<0.01	NS	NS
Average	8.25±0.68	10.04±1.04	9.08±1.14	9.21±1.38	<0.01	NS	NS
Rumination duration (min/day)							
1st	419.29±31.35	326.50±25.10	373.71±56.18	372.08±54.29	<0.01	NS	NS
2nd	424.46±35.82	386.96±36.99	401.79±41.80	409.62±40.07	<0.01	NS	NS
3rd	437.13±28.06	369.88±37.44	408.04±43.30	398.96±51.29	<0.01	NS	NS
Average	426.96±19.65	361.21±21.56	394.50±39.30	393.67±39.52	<0.01	NS	NS
Urination frequency (time/day)							
1st	8.67±1.24	9.96±1.33	9.29±1.27	9.33±1.61	<0.01	NS	NS
2nd	11.25±1.15	13.17±1.43	12.12±1.51	12.29±1.73	<0.01	NS	NS
3rd	11.67±1.52	13.54±1.18	12.42±1.38	12.79±1.89	<0.01	NS	NS
Average	10.58±0.72	12.25±0.79	11.33±1.05	11.50±1.22	<0.01	NS	NS
Defecation frequency (time/day)							
1st	11.96±1.37	9.17±0.82	10.71±1.94	10.42±1.67	<0.01	NS	NS
2nd	9.96±1.00	8.21±0.83	9.12±1.19	9.04±1.37	<0.01	NS	NS
3rd	9.25±1.03	7.83±0.76	8.50±1.06	8.58±1.25	<0.01	NS	NS
Average	10.33±0.76	8.46±0.51	9.42±1.14	9.38±1.17	<0.01	NS	NS
Standing duration (min/day)							
1st	627.92±46.79	481.62±55.91	551.75±62.98	557.79±111.79	<0.01	NS	NS
2nd	650.88±53.84	540.67±47.68	601.17±70.00	589.83± 80.84	<0.01	NS	NS
3rd	629.29±44.32	677.04±54.40	647.29±33.89	659.04± 69.95	<0.01	NS	NS
Average	635.96±30.70	566.50±36.45	600.33±37.56	602.13± 58.10	<0.01	NS	NS
Lying duration (min/day)							
1st	812.08±54.51	958.42±60.06	888.25±72.34	882.25±111.80	<0.01	NS	NS
2nd	789.13±65.71	899.62±68.79	838.58±89.70	850.17± 85.46	<0.01	NS	NS
3rd	810.71±48.65	762.96±61.77	792.71±49.06	780.96± 69.95	<0.01	NS	NS
Average	804.04±31.76	873.63±41.17	839.83±35.90	837.83± 62.76	<0.01	NS	NS

Note: NS= non-significant, TTS= Thin-tailed sheep, FTS= Fat-tailed sheep.

(Mohammed *et al*., 2015). Romney and Wiltshire sheep exhibit hair lengths ranging from 16.14-17.88 cm and 10.10-12.90 cm, respectively (Scobie *et al*., 2015). Chinese Merino sheep display a hair length of 9.23-12.29 cm, a fiber mean diameter of 19.60-19.83 µm, and a greasy fleece weight of 2.96-3.74 kg (Li *et al*., 2017). In our study, sheep hair length growth ranged from 1.63-2.18 cm/month or the equivalent of 0.54-0.73 mm/day. In purebred Lincoln ewes, hair can grow 4.5-5.5 mm in 7 days, equivalent to 0.64-0.79 mm/day (Scobie *et al*., 2015). Hair growth is influenced by genetics, growth period, hormones, livestock age, sex, feed quality, and applied management practices (Mohammed *et al*., 2015; Scobie *et al*., 2015; Li *et al*., 2017). The timing and frequency of shearing can impact wool quality and quantity. More frequent shearing, done more than once a year, can, in some cases, increase annual wool production and enhance fleece quality (Gelaye *et al*., 2021).

The assessment of characteristics related to the adaptive capacity of animals should consider physiological parameters such as rectal temperature (RT), respiratory rate (RR), heart rate or pulse rate (PR), and the heat stress index (HSI) (Seixas *et al*., 2017; Yakubu *et al*., 2017; Leite *et al*., 2020). This study revealed no interaction between shearing and the breed of sheep (Table 3). This aligns with the findings of Purnamasari *et al.* (2020), who reported that differences in sheep breeds do not affect physiological responses, specifically RR, PR, and RT, in Javanese Thin-Tailed sheep and Garut sheep. Similar results were observed in hair sheep (Santa Ines and F1 Dorper x Santa Ines) in tropical and coastal environments (Junior *et al*., 2014). However, in contrast to the research conducted by Seixas *et al.* (2017) on Santa Ines and Morada Nova sheep in Brazil, they found that breed differences influence RR, PR, and RT.

In this study, the shearing treatment influenced the respiratory rate (RR) and pulse rate (PR). Sheared

Table 5. Productivity aspects in sheep with shearing treatment and different breed (mean ± SD)

Month	Shearing treatments (T)		Breeds (B)		Significance		
	Sheared	Non-sheared	TTS	FTS	T	B	TxB
Feed intake (DM g/day)							
1st	946.40±37.11	871.47±78.13	912.42±102.48	905.44±12.69	0.027	NS	NS
2nd	984.19±27.89	921.26±75.50	962.89± 83.32	942.55±39.51	NS	NS	NS
3rd	909.41±12.70	884.93±22.78	895.86± 27.39	898.48±16.38	0.031	NS	NS
Average	946.67±19.81	892.55±54.99	923.72± 68.64	915.50±18.43	0.02	NS	NS
Average daily gain (g/day)							
1st	56.25±14.50	20.42±11.47	41.67±23.16	34.00±21.57	<0.01	NS	NS
2nd	60.42±12.14	32.50±10.80	49.17±19.98	43.75±17.13	<0.01	NS	NS
3rd	35.00± 7.97	17.08± 6.77	28.75±11.26	23.33±12.22	<0.01	NS	NS
Average	50.22± 6.63	23.33± 6.63	26.67± 7.91	20.00± 3.27	<0.01	NS	NS
Feed conversion ratio (g/g)							
1st	18.18±4.83	56.20±35.33	28.11±13.78	46.26±41.47	<0.01	NS	NS
2nd	16.94±3.82	30.68± 8.42	23.50±11.28	24.13± 8.11	<0.01	NS	NS
3rd	27.20±6.20	58.90±21.74	35.38±13.12	50.71±27.91	<0.01	NS	0.03
Average	19.15±2.60	40.31± 9.19	26.47± 9.86	32.99±15.02	<0.01	NS	NS

Note: NS= non-significant, TTS= Thin-tailed sheep, FTS= Fat-tailed sheep.

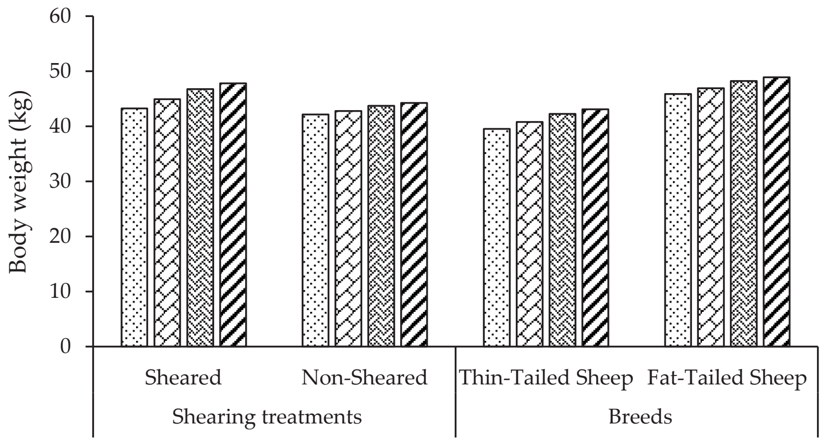

Figure 2. Body weight (kg) in sheep with shearing treatment and different breed

Initial 1st month 2nd month 3rd month

sheep exhibited lower RR and PR compared to their non-sheared counterparts (p<0.01). Additionally, sheared sheep had a lower rectal temperature (RT) than unsheared sheep (p<0.05), except in the 2nd month. These findings are consistent with previous research indicating that shearing in fattening lambs decreases RR and RT (Moslemipur & Golzar-Adabi, 2017). Shearing is a common practice in sheep farming and can aid in thermogenesis induction (Taofik *et al.*, 2021). The respiratory rate of livestock serves as the primary thermoregulation mechanism to maintain their body temperature (Seixas *et al.*, 2017). RR indicates heat load and stress in livestock, with an average RR of 25-30 breaths per minute in sheep (Taofik *et al.*, 2021). The classification of heat stress includes the following categories: no stress (up to forty breaths/min), low stress (40-60 breaths/min), moderate stress (61-80 breaths/min), high stress (81-120 breaths/min), very high stress (121-193 breaths/min), and severe heat stress (more than 192 breaths/minute) (Wojtas *et al.*, 2014; McManus *et al.*, 2016). In this study, sheared sheep were classified as unstressed (38.48 breaths/min), while non-sheared sheep were classified as experiencing low stress (41.49 breaths/min). In a similar study on Santa Ines and Morada Nova sheep in Brazil, the average RR in the morning and evening was 25.0 breaths/min and 44.0 breaths/min, respectively (Seixas *et al.*, 2017).

Reference values for sheep in tropical conditions indicate a rectal temperature (RT) ranging from 38.3 °C-39.9 °C and a pulse rate (PR) between 70-90 beats/min (Seixas *et al.*, 2017). In this study, both sheared and unshorn sheep exhibited RT within the reference range. The PR in sheared sheep was below the reference values, whereas non-sheared sheep exhibited PR within the reference range. According to Seixas *et al*. (2017), RT in sheep can increase above average when the ambient temperature reaches 32 °C. However, in this study, despite being conducted at temperatures above this threshold (above 38 °C), the RT in both sheep breeds remained within the reference range.

The heat stress index (HSI) is a crucial indicator frequently employed to assess thermal comfort. The adverse impacts of heat stress on animal performance primarily stem from two sources: the physiological adjustments animals make to regulate their body temperature and the negative consequences of their inability to manage body temperature effectively. Therefore, selection for regulation of thermal indices during heat stress could increase thermotolerance (Yakubu *et al.,* 2017). This study considered the standard respiratory rate (RR) and pulse rate (PR) in sheep, which are typically 30 breaths per minute (Taofik *et al.,* 2021) and 80 beats per minute (Seixas *et al.,* 2017), respectively. The findings unveiled that the HSI in this investigation exhibited sensitivity to shearing treatments during the initial and second months, while it remained unaffected during the third month and overall. The HSI values observed in this study ranged from 1.44 to 1.55. Notably, the HSI values recorded for the TTS and FTS breeds in this study were lower compared to male (HSI = 1.60) and female (HSI = 1.63) West African Draft sheep (Fadare *et al.,* 2012). Furthermore, these values were lower than those found in female Red Sokoto goats (HSI = 1.93) but higher than those in female Sahel goats (HSI = 1.34) (Yakubu *et al.,* 2017).

This study was conducted over three months, from April to June, during the early dry season based on the Indonesian climate category (Indonesian Agency for Meteorological, Climatological and Geophysics, 2022). The environmental conditions during this period showed an average temperature ranging from 25.37 °C to 30.59 °C and humidity between 64.22% and 92.33% (Table 1). The average Heat Stress Index (HSI) values (ranging from 1.49 to 1.50) in this study were lower than those reported by Fadare *et al.* (2012) in a study conducted on West African Dwarf sheep in the hot humid tropics of Abeokuta, Nigeria (HSI was 1.64 in the late dry season and 1.59 in the early rainy season). It was noted that the HSI value obtained for the late dry season was higher than that for the early rainy season. The lower rectal temperature (RT), respiratory rate (RR), pulse rate (PR), and heat stress index (HSI) observed during the wet season could be attributed to the cooler ambient temperatures and improved nutritional conditions resulting from the availability of pasture. The animals experienced stress due to the hot climatic conditions. The higher RT observed in the late dry season could be attributed to the elevated ambient temperature and relative humidity during this period, exceeding the animals' comfort zone and causing an imbalance in heat energy production and dissipation (Fadare *et al.,* 2012).

Within this study, thermo-physiological traits consistently remained within the normal range, indicating the effective adaptation of both sheared and unsheared TTS and FTS breeds to their environment. It's worth noting that livestock adapted to hot climates often exhibit morphological and physiological traits that facilitate heat dissipation (Seixas *et al.,* 2017). The findings from this study demonstrate that shearing sheep in tropical environmental conditions does not adversely impact their thermo-physiological conditions, regardless of whether they are TTS or FTS. Shearing does not induce stress in the sheep; on the contrary, it enhances their comfort by improving factors like RR, PR, and RT. These results align with a statement that shearing can alleviate heat stress in sheep. This positive effect is due to the increased heat dissipation through conduction, convection, and radiation, as well as the more effective utilization of evaporative heat loss in these sheep (McManus *et al.,* 2020).

Table 4 indicates that shearing treatment affected the sheep's behavior. This aligns with the findings of Hefnawy *et al.* (2018), who observed that shearing of sheep leads to longer periods of standing idle and grooming. Ungerfeld *et al*. (2018) also reported that shearing affects sheep behavior, resulting in increased time spent standing and grazing and decreased time allocated to resting, reflecting an enhanced feed consumption. Moreover, Ungerfeld & Freitas-de-Melto (2019) stated that after shearing, sheep experience an increased need to regulate their body temperature, prompting them to spend more time on their feet, engaging in heightened muscular activity. This heightened activity results in greater energy demand and triggers the release of thyroid hormones, potentially accounting for the weight loss observed in these sheep. Consequently, recently sheared animals tend to extend their grazing time and consume more feed.

Behavior is an early indicator of livestock welfare, reflecting individual environmental adaptation. Changes in the activity patterns of farm animals are frequently utilized as indicators to evaluate livestock welfare (De *et al.,* 2017). Shearing is necessary to enhance the physical welfare of livestock since domesticated sheep do not naturally shed their hair. Immediate benefits of shearing include increased comfort, particularly in hot weather, and the correction of wool blindness in closed-faced breeds. The decreased frequency of standing in sheared sheep can be linked to increased feeding behavior. This heightened feeding frequency results from the increased heat production needed to maintain body temperature after shearing, reducing heat stress. The decrease in drinking behavior may be attributed to the reduced heat stress resulting from shearing the sheep's hair and the limited heat loss occurring through cutaneous evaporation (Ungerfeld & Freitas-de-Melo, 2019; Ungerfeld *et al.,* 2018; De *et al.,* 2019).

In this study, the shearing treatment affected feed intake, average daily gain (ADG), and feed conversion ratio (FCR) (Table 5). Moslemipur & Golzar-Adabi (2017) reported different results, stating that shearing did not affect feed intake and weight gain but improved the FCR. In our study, sheared sheep exhibited higher feed intake (dry matter intake/DMI), ADG, and a lower FCR compared to non-sheared sheep, with values of 946.67±19.8 vs. 892.55±54.99 g/day, 50.22±6.63 vs. 23.33±6.63 g/day, and 19.15±2.60 vs. 40.31±9.19 g/g, respectively. The average feed intake, ADG, and FCR in this study were lower than those observed in Najdi sheep under fattening maintenance (DMI= 1.10 kg/day, ADG= 175 g/day, and FCR= 5.9) (Obeidat & Obeidat, 2022) and Fat-Tailed rams under day feeding conditions (DMI= 1.078 kg/day, ADG= 66 g/day) (Aprilliza *et al.,*

2014) but better than those in Arsi-Bale sheep fed with ad libitum grass hay (DMI= 606 g/day, ADG= 1.10 g/day, FCR= 21.6) (Adugna *et al.,* 2023). Previous research indicated that shearing significantly affects sheep production (Irmawaty, 2018). Shearing proves beneficial in sheep farming systems, especially for pre-lambing ewes. This practice leads to lambs having higher birth weights, ewes producing more milk, and consequently, enhanced growth in their lambs, compared to lambs born to non-sheared ewes. Consequently, the overall survival rate of lambs until weaning is higher in ewes subjected to pre-lambing shearing (Ungerfeld & Freitas-de-Melo, 2019; Nieto *et al.,* 2020).

An increase in the frequency of feeding behavior (Table 4) results in higher feed consumption in sheared sheep, leading to greater average daily gain (ADG) (Table 5). Sheared sheep are more efficient in dissipating body heat through convection and conduction, requiring less energy to maintain their basic physiological functions. In contrast, non-sheared sheep face challenges in dissipating body heat, often struggling to maintain their homeothermic state. Consequently, these sheep utilize a smaller portion of the consumed energy for growth and instead allocate it towards essential life processes and heat dissipation (Irmawaty, 2018).

Shearing, the process of removing fleece from sheep, facilitates heat dissipation, leading to changes in body heat content and consequently affecting body temperature. This shift in heat production can be seen as an adaptive response, demonstrating the sheep's ability to adapt to its environment. However, the advantages of shearing in promoting thermoregulation largely depend on environmental conditions, considering the insulating properties of the fleece. Conversely, shearing can induce stress in sheep due to thermal stress or the shearing process itself (Casella *et al.,* 2016). A thick fleece layer provides an advantage to unshorn lambs, enabling them to tolerate hot and dry conditions with high solar radiation compared to their shorn counterparts. Shearing, a common practice in managing wool sheep, enhances energy exchange between the animal and its surroundings, albeit at the expense of reduced thermal protection (McManus *et al.,* 2020).

The findings of this study demonstrate that shearing local sheep (TTS and FTS) in tropical environmental conditions does not induce stress and, in fact, tends to enhance the comfort and productivity of the sheep. It has been proven that sheared sheep exhibit better thermo-physiological conditions, behavior, and productivity compared to their unshorn counterparts. Therefore, it can be concluded that shearing management for coarse wool-type sheep in tropical environmental conditions is recommended as it ensures sheep welfare while aligning with efforts to enhance sheep productivity. Further research is essential to assess the effects of shearing in tropical environments across various breeds, ages, agroecological zones, and sheep-rearing management practices, employing more advanced and comprehensive study methods.

CONCLUSION

The research findings indicate that shearing local sheep in tropical environmental conditions does not induce stress but instead tends to enhance their comfort and productivity. Therefore, it can be concluded that shearing management for coarse wool-type sheep in tropical environments can still ensure the welfare of the sheep while aligning with efforts to increase their productivity.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial, personal, or other relationships with other people or organization related to the material discussed in the manuscript.

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