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The feeding behavior of dairy cattle under tropical heat stress conditions at smallholder urban farming

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Abstract. *Despal, Faresty C, Zahera R, Toharmat R. 2022. Title The feeding behavior of dairy cattle under tropical heat stress conditions at smallholder urban farming. Biodiversitas 23: 3771-3777.* Dairy cattle (*Bos taurus*) feeding behavior influences feed intake and affect animal welfare and disease management. This study observed dairy cattle feeding behaviors under tropical smallholder urban farming environments. Thirty-six cattle at the Kebon Pedes area of Bogor City were observed during 12 h feeding (6 am-6 pm). These traits included eating, ruminating, resting duration, and frequencies, measured using a continuous method. Temperature, humidity, temperature-humidity index (THI), feed and nutrient intake, milk production, and components were measured. The results showed that the cattle were in mild to severe heat stress. The average cow daily eating, ruminating, and resting frequencies were 6.61, 7.61, and 22.33 times, while the average eating, ruminating, and resting durations per cow per 12 h were 129.64, 105.67, and 484.69 minutes, respectively. The dry matter intake was 11.17 kg with a roughage to concentrate ratio of 0.73:1. The protein, ash, ether extract, and crude fiber intake were 10.25, 6.62, 3.67, and 22.08% DM, respectively. The average milk productions and fat contents were 11.01 L/head/d and 5.44%. The results showed that eating and ruminating levels correlated positively with feed, and CF intakes while resting correlated negatively. It was concluded that the cattle were in heat-stressed (THI of >78) condition, reduced DM intake, and deficient in energy and CP, which led to lower milk production but higher milk components, specifically milk fat. It is recommended to improve forage quality that promotes eating and ruminating and reduces resting durations, improving milk production.

Keywords: Animal welfare, eating behavior, feed intake, milk production, ruminating

INTRODUCTION

This study explains the feeding behavior of dairy cattle (*Bos taurus*) and their actions toward procuring nutrients. Nutrient procurement is essential because the primary concern of dairy cattle producers is to promote dry matter intake (DMI) for the support of milk production (Lee et al. 2021), health, and productivity (DeVries 2019). Therefore, by understanding the feeding behavior of dairy cattle, farmers can detect early disease (von Keyserlingk and Weary 2010), improve forage management on pasture, improve animal comfort, arrange feeding and watering system location, optimize feed intake, and facilitate precision feeding technology (Halachmi et al. 2016). Any factors altering cattle feeding behavior and DMI will impact their performance, welfare, health, and farm profitability (Botheras 2019).

A high-producing Holstein can spend about 4.15 h/day eating, divided into nine meal frequencies/d (von Keyserlingk and Weary 2010). The proportion of meals eaten was shown to be higher in the morning than at night (Niu and Harvatine 2018). Furthermore, the feeding behavior of dairy cattle was also influenced by several factors, namely environment, management, health, and social interactions (Botheras 2019), also the availability of anti-nutrients, such as tannin (Dos Santos et al. 2021). Environmental factors were seen to affect voluntary feed intake and the utilization of dairy cattle's metabolizable energy (ME). The changes in feed intake have also been observed in the fluctuations of climatic conditions, such as temperature, relative humidity, and rate of air movement. The management of feeding influences behavior (Pollock et al. 2022), including grouping strategy, feeding system design and apparatus, composition and physical characteristics of the consumed feed, social hierarchy, and competition for food and water. The changes in feeding behavior could be used to identify animals at risk of certain diseases and metabolic disorders (Despal et al. 2017). In feeding, dairy cattle demonstrate social behavior, which is seen when feeding behavior in one individual encourages another to eat whether it is hungry or not. Conversely, it has been shown that cattle kept in groups consume more than those kept singly. It is essential to provide sufficient space and good bunk design to give the dairy cattle access for eating simultaneously, preventing competition, ensuring good feed access, and minimizing the risk of injury (DeVries 2019).

Many methods have been developed to measure the feeding behavior of dairy cattle using manual observation (Polsky and von Keyserlingk 2017; Ramón-moragues 2021) or automatic detectors (Porto 2015). Measurement has been conducted in heifers, early lactating cattle (Rumphorst et al. 2022), or transition cattle (Carvalho et al. 2012). The feeding behavior of dairy cattle has also been studied for those in pasture or stall (Porto 2015). However, most studies have been conducted in temperate regions (Hill and Wall 2014) or large dairy farms (Pollock et al. 2022). Limited information is available on the feeding behavior of urban tropical smallholder dairy farms.

Dairy cattle in temperate regions have different performance and requirements than in tropical areas due to different temperatures, humidity, feed types, and quality. On average, dairy cattle in the temperate area produced more milk than in the tropical area (Zahera et al. 2015; Hasanah et al. 2017; Riestanti et al. 2021). Therefore, the cattle require more nutrients and consume more feeds of better quality to replace the nutrients secreted via the milk. Forage in temperate areas has prime and first quality of relative forage value (RFV) compared to third and fourth RFV in tropical regions (Despal et al. 2021a, 2021b).

The large farm also has a different management system than smallholder dairy farmers. Free-stall and group feeding are mainly applied on large farms (Telezhenko et al. 2012), while individual stalls are more common for smallholders (Kathambi et al. 2019). Tropical Smallholder dairy farmers, especially those in urban areas, are challenged by the difficulties in providing fresh forage and depend more on roughage and concentrate. Some forage and roughage usually used in tropical areas were Napier grass, natural grass, corn leaves, corn husk, and rice straw (Despal et al. 2020). While the concentrated raw materials frequently used were copra meal, palm kernel meal, coffee husk, tofu waste, soy-sauce waste, brewer waste, and habbatussauda waste (Rosmalia et al. 2021). High lignocellulosic roughage such as rice straw and corn husk are frequently used to substitute fresh forage, especially during the dry season when the forages grow slower.

The different feeding management, feed type, and quality used can affect cattle feeding behavior. Therefore, this study aims to examine the feeding behavior of dairy cattle under smallholder urban farming in Bogor City, West Java Province, Indonesia, as the difference in climate, feed types, and management all play significant roles.

MATERIALS AND METHODS

Dairy cattle preparation

This study used 36 Friesian Holstein cattle with an average age of 5.21±2.00 years, 403.10±35.32 kg bodyweight, and 3.08±1.57 lactation period. The cattle were tied up in stalls at 12 different farms. The cattle were tethered at the neck to their stall individually, restricting movement and inhibiting their ability to socialize, graze, groom, and other natural behavior performances. Each stall was 1.3 m wide and 1.8 m in length, with an anti-slip rubber mat on the floor to aid the comfort and health of the cattle. The cattle belonged to 12 farmers in Kebon Pedes, Tanah Sareal District, Bogor City, West Java Province, Indonesia. Although the farming scale in Kebon Pedes was about 10 cattle per farm, only three selected cattle were observed from each farm. The selected cattle were placed close to each other to facilitate focal animal observation by one observer for each farm. The cattle were offered feeds twice daily at 6 am and 4 pm, consisting of forage and concentrate. Water was offered *ad libitum* using a water bowl. The cattle were milked manually twice daily.

Temperature (T) and relative humidity (Rh) were both measured to calculate the temperature-humidity index (THI) using the formula (Eq. 1). The stress level of the cattle was categorized according to Moran (2005).

$$THI = T-(0.55[(100-Rh)/100)](T-58))$$

Temperatures in the formula are expressed in degrees Fahrenheit, while relative humidity (Rh) is expressed in %. The temperature and Rh were measured using digital room temperature/relative humidity and recorded every hour manually. The animal houses were a semi-open barn with a full roof, a 1 m height of concrete wall on the four sides, and an open space for the entrance. The thermometer was hung on the barn pillar close to the observed cattle. Data of the morning, mid-day, and afternoon T and Rh were calculated as an average of T and RH at 6-10 am, 11 am-2 pm, and 3-6 pm observation, respectively.

Feeding behavior observation

The feeding behavior of dairy cattle was observed using a continuous method from 6 am to 6 pm, following the Martin and Bateson (1986) procedure. Due to the movement restriction of the cattle in tie-stall type, three focal cattle on each farm can be observed by one observer simultaneously. An ethogram to guide the observers was provided in Table 1.

A table containing 12 boxes representing 12 h observation was prepared to record the beginning and end of each behavior occurrence. Each hour, four possible occurrences of each behavior trait were prepared. The start and end of each occurrence were recorded in the table. The empty boxes represent non-occurrence feeding behavior. Feeding behavior observed included eating, ruminating, and resting. Each behavior's frequency and length were calculated by the observation's end. The pattern of feeding behavior was made by plotting the frequency and length of each behavior again observation time. The observation box of the feeding behavior is shown in Table 2.

Table 1. Ethogram category and description of dairy cattle feeding behavior observation in a tie-stall type (Zambelis et al. 2019)

Behavior item	Category	Description
Eating	Eating	The muzzle is located in or above the feed, with chewing or licking movements. It can be occure during lying or standing
Ruminating	Ruminating	Rhythmic side-to-side chewing of the cud in standing or lying position
Resting	Resting	Lying or standing idly with no behavioral modifier

Table 2. Observation box feeding behavior of each cattle

Behavior state	Eating		Ruminating		Resting	
	Start	End	Start	End	Start	End
Behavior occurrence time						
6 am						
1st	……..	……..	……..	……..	……..	……..
2nd	……..	……..	……..	……..	……..	……..
3rd	……..	……..	……..	……..	……..	……..
4th	……..	……..	……..	……..	……..	……..
…						
6 pm						
1st	……..	……..	……..	……..	……..	……..
2nd	……..	……..	……..	……..	……..	……..
3rd	……..	……..	……..	……..	……..	……..
4th	……..	……..	……..	……..	……..	……..

Feed and nutrient intake measurements

Forage and concentrate consumed by each cattle were measured daily. For seven days of observations, 2 kg of forage samples from each farm were taken daily, dried, and composed, then ground and analyzed in the laboratory for nutritional content. On the seventh day, 200 g of concentrate sample was taken and examined at the laboratory. The concentrated sample was taken only from 1 farm due to a similar supplier for all farms. Each cattle's seven-day feed refusal was collected daily, dried, and composted before being ground and analyzed in the laboratory. Dry matter (DM) was measured by drying the feed in an oven at 60˚C and then in an oven at 105˚C. Ash was measured by incineration in a muffle oven at a temperature of 600˚C for 4 hours. Crude protein (CP) was measured using the Kjeldahl method, while ether extract (EE) was measured by conducting extraction using the Soxhlet method. The crude fiber (CF) was analyzed after the feed was degraded in alkaline and base solution. The proximate component mentioned before (DM, ash, CP, EE, and CF) was analyzed according to AOAC (2005). The total digestible nutrient (TDN) was calculated using the equation according to Wardeh (1981).

Milk production and quality measurements

The amount of milk production was measured using a 1 L volumetric flask from morning and afternoon milking. 20 mL of the milk were sampled from each cow and analyzed using a Lactoscan SL-type to measure the milk fat, solid non-fat (SNF), protein, and lactose contents. Milk sample was taken directly from teets in the middle of manual milking or from the container after it had been well stirred.

Study design and data analysis

The observational method was used in this study. The data were analyzed using descriptive statistics. The pairwise Pearson correlations were made between feeding behavior with feed intake and milk production. The analysis was performed using the SPSS statistical software version 20.

RESULTS AND DISCUSSION

Temperature humidity index (THI) and heat stress level

THI of the study location and its impact on the stress level of the cattle are shown in Table 3. The table shows that the temperature in the location ranges from 80.06ºF in the morning to 85.7ºF at mid-day. In contrast, the humidity shows the lowest value at midday (69.7) and the highest in the morning (81.0). Calculating THI using formula 1 resulted in the THI value ranging from 78.0 in the morning to 81.0 from midday until afternoon. The temperature cooled down in the afternoon until morning, about 5.5˚F from 85.7 to 80.2˚F.

Based on Moran (2005), cattle stress levels were grouped into five categories according to the THI value. If THI < 72, cattle experience no stress. At 72 < THI < 78, cattle experiencing mild stress. At 78 < THI < 89, cattle were in severe stress. Very severe stress occurs if the THI increases up to 98. Suppose THI increases more than 98, and the cattle dead. Based on the calculated THI shown in Table 2, cattle observed in this research still experienced mild stress (closed to severe stress) in the morning but severe stress from mid-day until the afternoon. Heat stress affects the welfare, productivity (Davison 2020), and reproduction of the animals (Ramón-moragues 2021). During heat stress, the cattle's behavior was altered. Cattle showed a sign of exaggerated breathing motions and spent a long time feeding during these periods (Davison 2020). Conversely, increasing THI is detrimental to cattle welfare as it causes them to increase their general activity, change their feeding patterns, and decrease their rumination and resting behaviors (Ramón-moragues 2021).

The diurnal changes in temperature, humidity, and THI are shown in Figure 1. It is also shown that increasing temperature reduces humidity but still increases THI. THI < 72, the comfort threshold for dairy cattle (Pinto et al. 2020), was not found during 12 h observations. The THI < 78 (mild stress) was observed only up to 9 am. Afterward, the THI increases to a severe stress level. The highest THI in this study was 81, which occurred from 12 am-4 pm.

Table 3. THI and stress level of dairy cattle

Time	Temperature (ºF)	Relative humidity (%)	THI	Stress level
Morning (6-10 am)	80.2±1.5	81.0±3.8	78	Mild
Mid-day (11-2 pm)	85.7±1.2	69.7±5.3	81	Severe
Afternoon (3-6 pm)	84.9±1.3	71.0±5.7	81	Severe
Average	83.6±1.3	74.4±7.2	80	Severe

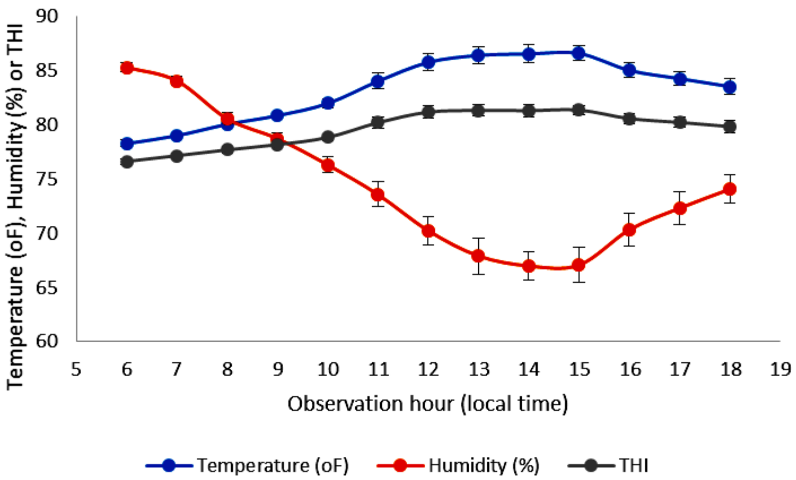

Figure 1. Diurnal changes in temperature, humidity and THI (Average and SEM)

This information enables the establishment of thresholds for heat stress conditions because temperature and humidity are essential in regulating animal latent heat exchange (Ramón-moragues 2021). If THI > 72, the animal uses the respiration mechanism more dominantly than convection and conduction (Despal et al. 2017). Additionally, cattle under increased heat stress seek to improve cooling by increasing standing time, decreasing lying time to 30%, and walking activity. It exposes more body surface area for heat abatement, sensible water loss, radiating surface area, and air movement (Polsky and von Keyserlingk 2017). A slight decrease in temperature (5.5ºF) in the evening had little effect on stress relief.

Feeding behavior

The feeding behavior of dairy cattle is shown in Table 4. It shows that the feeding behavior of cattle varies greatly. Cattle ate up to 8 times in 12 h, comparable to von Keyserlingk and Weary's (2010) report, and the eating duration found was less than 3 h, lower than that report. Although the observation duration in this study was only 12 h (6 am-6 pm), mainly cattle eating and ruminating behavior occurred during this period. Therefore, it represented dairy cattle's daily behavior. According to Beauchemin (2018), lactating dairy cattle spend about 4.5 h/d eating (range: 2.4-8.5 h/d). The shorter eating duration found in this study might be caused by the heat stress condition of the cattle (Ramón-moragues 2021). Furthermore, meals are a biologically relevant unit of short-term feeding behavior (Marchesini et al. 2011) that changes during the heat stress condition (Polsky and von Keyserlingk 2017).

It was also shown that cattle ruminated 5-9 times per 12 h with a total duration of 80-130 minutes. The rumination time of cattle found in this study was lower than von Keyserlingk and Weary's (2010) report (249 min) but in the range of Beauchemin's (2018) finding (average 7 h/d ruminating with a range: 2.5-10.5 h/d). He reported a maximum total chewing time of 16 h/d. The shorter ruminating duration found in this study might be caused by the cows in the tropical area primarily kept in a stall and fed a high proportion of concentrate (Lestari et al. 2015; Nugroho et al. 2015; Zahera et al. 2015; Hasanah et al. 2017; Riestanti et al. 2021). Longer chewing and rumination time in Beauchemin (2018) was due to higher neutral detergent fiber (NDF) from forages and large particle size of diet, such as those when cattle graze on pasture (Gregorini et al. 2013). Although high NDF content was also found in tropical fiber feed used in dairy cattle (Despal et al. 2020; Despal et al. 2021a), in urban dairy farming, such as in this study, its proportion in the ration was less due to its availability lacking.

Table 4. Feeding behavior of dairy cattle

Parameters	Frequency (cow/12 h)	Duration (minutes/cow/12 h)
Eating	6.6±1.2	129.6±33.2
Rumination	7.6±2.0	105.7±24.2
Resting	22.3±1.9	484.7±47.1

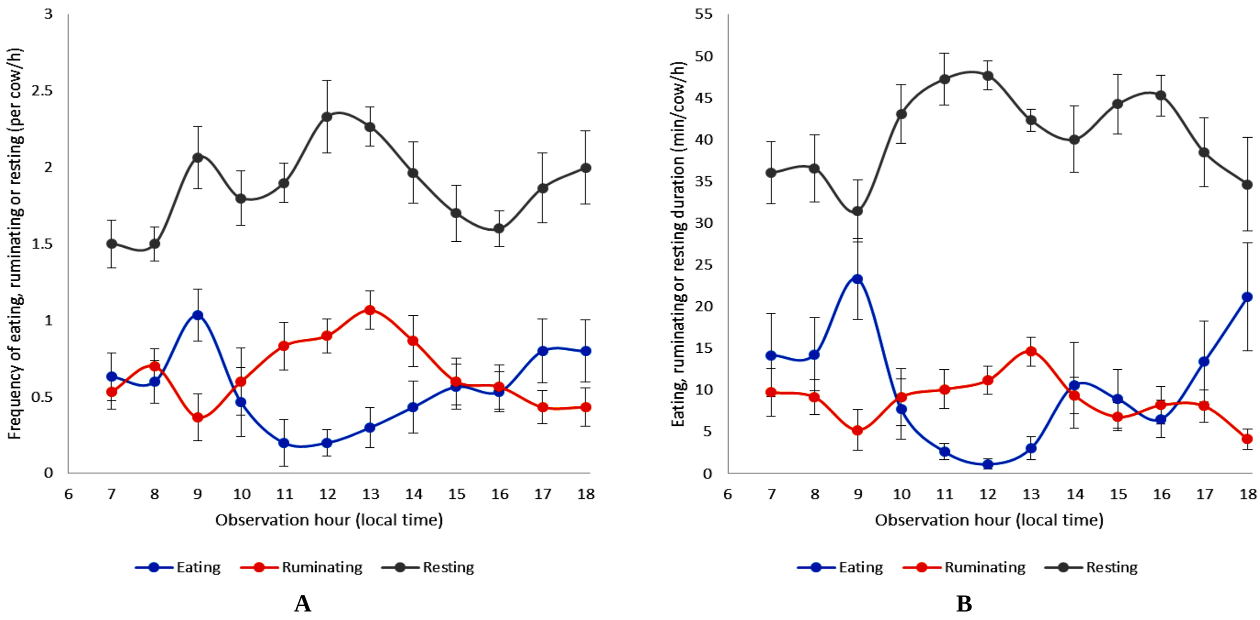

Figure 2. Average and SEM pattern of feeding behavior during 12 h observation (A: frequency/cattle/h; B: duration in min/cow/h)

The resting frequency of cattle observed was 20-24 times with a total duration of 440-530 minutes per 12 h. The cattle spent about 67% of their time resting. It was higher than that reported by Ramón-moragues (2021), where cattle spent more time ruminating. Figures 2A and 2B shows diurnal feeding behavioral changes. It shows that the eating frequency and duration were high at 8-10 am and 4-6 pm, while ruminating frequency and duration were higher from 11 am to 3 pm. This finding was similar to Pollock et al. (2022). The morning meal began at 6 am, followed by the afternoon meal at 4 pm. At 6-7 am, cattle began consuming concentrates, and due to its small particle size, it was consumed an hour before the forage was offered. While the cattle were consuming fodder, there was a considerable increase in eating activity between 8 and 10 am and 4 and 6 pm. Additionally, resting patterns were comparable to ruminating but opposed to eating.

Feed and nutrient intake

The feed and nutrient intake of cattle are shown in Table 5. It shows that, on average, cattle ate 11.17 kg DM with forage to concentrate ratio of 0.73:1. It means that they consumed more concentrates than forages. The average DMI as the percentage of cattle's body weight was 2.77%. Subsequently, with the average milk production of 11.01 kg, 2.77% DMI was shown to satisfy the requirements of cattle with 488 kg body weight (BW). Cattle in this study had a 403.10±35.32 kg BW, while with such a small BW, they should consume DM feed 3.11% of its BW (Despal et al. 2017) to fulfill their requirement. In other words, the average daily DM requirement used should be 12.53 kg. Only three out of the 36 cattle in this study fulfilled their DM requirements, while the rest were deficient. In this case, DM deficiency was due to cattle experiencing heat stress, reduced feed intake, and rumination time (Ramón-moragues 2021), resulting in lower nutrients available for milk synthesis (Despal et al. 2017).

Table 5. Daily feed and nutrient intake per cattle

Parameters	Average	Standard deviation
Feed Intake		
Forage		
Fresh forage (kg)	24.29	12.68
DM forage (kg)	5.05	2.70
DM forage (%BW)	1.25	0.64
Concentrate		
Fresh concentrate (kg)	29.15	5.04
DM concentrate (kg)	6.12	1.66
DM concentrate (%BW)	1.52	0.41
Total		
DM Feed intake (kg)	11.17	2.80
DM Feed Intake (% BW)	2.77	0.64
Forage/concentrate ratio	0.73:1	
Nutrient Intake (% DM)		
Ash	6.62	1.55
Crude Protein	10.25	1.54
Ether Extract	3.67	1.04
Crude Fibre	22.08	3.38
Ca	0.54	0.32
P	0.57	0.18
TDN	63.16	3.26

Note: FS: fresh substance; DM: dry matter; BW: body weight; Ca: calcium; P: phosphorus; TDN: total digestible nutrients

Table 6. Milk production and components

Parameters	Average	Standard deviation
Milk production (L)	11.01	4.06
Milk components		
Fat (%)	5.44	1.20
Solid non-fat (%)	7.84	0.44
Protein (%)	2.93	0.25
Lactose (%)	4.32	0.29

Table 7. Correlation coefficient ® between feeding behavior with feed intake and milk production

Parameters	Correlation						
	DM Intake	CF Intake	Milk production	Milk fat	Milk SNF	Milk protein	Milk lactose
Frequency							
Eating	0.037	0.190	-0.068	-0.123	-0.057	-0.107	0.024
Ruminating	0.159	0.236	-0.305	-0.006	0.127	0.124	0.190
Resting	-0.071	0.025	-0.084	0.085	0.206	0.130	0.206
Duration (minutes)							
Eating	0.365*	0.299	0.118	-0.220	-0.039	-0.136	0.119
Ruminating	0.336*	0.389*	-0.314	0.086	-0.051	0.101	-0.010
Resting	-0.437**	0.429**	0.119	0.086	0.056	0.024	-0.069

Note: *: significantly correlated (P < 0.05); **: very significantly correlated (P < 0.01); DM: dry matter; CF: crude fiber; SNF: solid non fat

Although TDN, CP, Ca, and P in the ration consumed were 63.16%, 10.25%, 0.54%, and 0.57%, respectively, they are equivalent to 7.05 kg TDN, 1.14 kg CP, 0.06 kg Ca, and 0.06 P. Meanwhile, the average daily nutrient requirement of the observed cattle was 7.24 kg TDN, 1.46 kg CP, 0.05 kg Ca and 0.36 kg P (NRC 2001). It can be seen that the cattle were deficient in DM, TDN, and CP while Ca and P were surplus. Although a high percentage of high energy concentrate was used in the ration (54.79%), it cannot compensate for the energy fulfillment due to deficit DM intake.

Milk production and quality

The average milk production of the component is shown in Table 6. The average milk produced was 11.01 L/head/d with 5.44% milk fat, 2.93% milk protein, and 4.32% milk lactose. The milk production was lower than the national average (13.5 L/head/d). Distinctively, it was lower than the average milk production in the tropical high land of Lembang (Lestari et al. 2015; Nugroho et al. 2015; Zahera et al. 2015; Hasanah et al. 2017), the suburban area of Bogor (Riestanti et al. 2021) or Pangalengan but higher than Sukaraja District of Sukabumi Regency (Despal et al. 2021a). However, the milk component, specifically milk fat, was higher.

Cattle in lowland tropical urban cities such as Bogor were seen to be experiencing heat stress and lacked the quality of feeds. With an average of 403 kg BW, 11.01 L daily milk production, 5.44% fat, and third period of lactation, cattle required at least 57.8% TDN, 11.68% CP, 0.46% Ca, and 0.30% (NRC 2001). Although the content of TDN, Ca, and P in the consumed ration was higher than the requirements, only the Ca and P requirements were satisfied. The TDN deficiency was caused by deficit DM intake. Meanwhile, CP deficiency was caused by deficit intake and lower CP content in the ration. Deficiencies of TDN and CP influenced the milk production and milk protein component. Therefore, it is essential to improve feed quality, primarily forage quality, by adding leafy proteins such as tropical legumes (Despal et al. 2020; Agustiyani et al. 2021). Increasing CP intake through forage quality is more suitable since the quantity of concentrate utilized in the typical ration was already high (Lestari et al. 2015). Supplementation of prill fat which contains high energy, was also shown to improve energy in ration and milk production in heat stress cattle (Riestanti et al. 2021).

The impact of feeding behavior on DMI and milk production are shown in Table 7. It shows that eating, ruminating, and resting frequencies did not significantly affect DMI, milk production, and components. However, the duration of eating, ruminating, and resting impacts DMI and crude fiber intake (CFI) but does not significantly affect milk production and its components.

The duration of eating and ruminating influenced DM and CF intake positively, while resting duration negatively correlated with both. The heat stress caused cattle to prolong the meal duration (Davison 2020) and reduce ruminating (Ramón-moragues 2021). Therefore, providing better feeding space and feed quality are essential to encourage cattle to eat more. It was concluded that the heat-stressed cattle (THI of > 78) reduced DM intake resulting in deficiencies of energy and CP, resulting in lower milk production but higher milk components, specifically milk fat. Therefore, it is suggested to increase feed quality, primarily forage quality, would promote eating and reduce resting durations, improving milk production. Supplementation of high energy prill fat is also suggested to increase energy in ration and alleviate metabolic heat production in heat-stressed cattle. All measures to prevent heat stress, such as designing a higher roof, better ventilation, providing fresh and clean drinking water ad libitum might also comfort the animal. Providing a sprinkler is not suggested since it might increase the humidity and THI. Excessive sprinklers might also wet the cow's udder, which might increase the risk of mastitis.

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