



Performance, Physiological Status, and Heat Tolerance of Holstein Friesian Dairy Cows at Different Lactation Phases

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Abstract | The lactation period in Holstein Friesian dairy cows has a significant impact on their production performance. Therefore, it is important to observe and determine the dairy cows' physiological status, performance, and heat tolerance at different lactation phases. This study utilized a completely randomized design with three experimental and five replicates, involving 15 Holstein Friesian Dairy Cows. The cows were divided into three experimental based on their lactation phase i.e., early lactation (1–3 months) post-partum; middle lactation (4–6 months) post-partum; and late lactation phase (7–10 months), respectively. The study revealed that the lactation phase had a significant effect on the body condition score ($P=0.04$) and respiratory frequency ($P=0.02$). However, it had no significant effect ($P>0.05$) on either dry matter intake of forage, concentrate, total consumption, milk yield, feed conversion efficiency, heart rate, body temperature, heat tolerance coefficient, or Benezra coefficients. In early lactation, dairy cows are susceptible to negative energy balance, which can reduce performance and affect physiological values. Proper feed intake can help address the negative energy balance (NEB), many cows get NEB during this phase. Performance and physiological values at different phases vary, requiring adjustments to nutritional intake based on the lactation phase.

Keywords | Heat tolerance, Heat stress, Holstein Friesian dairy cows, Lactation phase, Performance, Physiology

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INTRODUCTION

The performance and physiological well-being of Holstein Friesian dairy cows can be affected by various internal and external factors. Internal factors affecting the performance and physiology scores of dairy cows include breed, cow age, and lactation phase (Hartanto *et al.*, 2020). The lactation phase is an internal factor that affects milk yield, performance, and physiological value

in dairy cows (Dillania *et al.*, 2021). Lactation is divided into three stages: early lactation, mid-lactation, and late lactation (Adi *et al.*, 2020). The lactation period lasts for ten months or 305 days (Sehested *et al.*, 2019). Milk yield in each lactation phase fluctuates, with the highest yield occurring in mid-lactation (Hartanto *et al.*, 2020; Dillania *et al.*, 2021).

Holstein Friesian cows tend to perform differently during

different lactation phases. Generally, dairy cow's milk yield increases during the first few weeks of lactation (early lactation phases) and then gradually decreases until the late of lactation phase. During early lactation, dairy cows have a negative energy balance (NEB), which can lead to weight loss and other health issues. The occurrence of NEB in dairy cows happens when the energy used for milk yield and postpartum recovery exceeds the energy obtained from feed intake, leading to a decline in the dairy cows' performance (Jóźwik *et al.*, 2012; Mekuriaw *et al.*, 2023). NEB arises from nutritional imbalances, causing the mobilization of lipid, glycogen, and protein reserves in the body to meet these energy demands (Xu *et al.*, 2018). These energy reserves are catabolized in the liver into Beta-Hydroxybutyrate (BHB). There is a positive correlation between NEB and blood BHB levels, with higher BHB levels indicating a more severe NEB. This increased BHB can lead to fat accumulation in the liver (ketosis) (Xu *et al.*, 2020a; Zhang *et al.*, 2020). NEB can impact the performance of the mammary glands, consequently affecting milk quality (Xu *et al.*, 2020b). Additionally, NEB can restrict milk synthesis, reduce reproductive performance, and delay postpartum recovery (Zhang *et al.*, 2020; Mekuriaw *et al.*, 2023). As lactation progresses, dairy cows may regain their body condition and produce milk more efficiently. Proper nutrition and management practices are crucial for maintaining the health and productivity of Holstein Friesian dairy cows during all lactation phases. The late of the lactation phase is essential for repairing mammae tissue and increasing milk yield during the subsequent lactation period. (Ginantika, *et al.*, 2021).

After about three months of postpartum, dairy cows are prepared for estrus postpartum. When dairy cows are pregnant, the pregnancy process can affect their production performance and physiological status. As cows age during pregnancy, their milk yield tends to decrease until they enter the late lactation phase and dry period, as the nutrients they consume are used for the growth and development of their fetus (Roche, 2003). Therefore, this study aimed to assess the performance, physiological status, and heat tolerance of dairy cows during each lactation phase.

MATERIALS AND METHODS

EXPERIMENTAL SITE

The research was conducted in Hamlet Baba, Village Cendana, Enrekang district, South Sulawesi Province.

PROCEDURES

The study was designed using a complete random design (CRD) with 3 treatments and 5 replications. The study required 15 Holstein Friesian dairy cows, aged 4–5 years old, with an average weight of 500 kg. The cows were categorized into three experimental, each representing a different

stage of lactation. The first experiments consisted of cows in the early lactation phase (1–3 months) postpartum, the second included dairy cows in the mid-lactation phase (4–6 months) postpartum, and the third comprised dairy cows in the late lactation phase (7–10 months) postpartum. Their feed was 3% dry matter (DM) of their body weight, which comprised 80% elephant grass (*Pennisetum purpureum*) and 20% concentrate. The concentrate included rice bran, tofu dreg, palm kernel cake meal, and a commercial minerals. The composition and nutrient content of the concentrate are detailed in Table 1. The formulation of the concentrate was designed to ensure a 16% Crude Protein (CP) adequacy and a 70% Total Digestible Nutrient (TDN) content. Throughout the study, the dairy cows had unlimited access to drinking water.

Table 1. Composition of Holstein Friesian dairy cow concentrate.

Feedstuff	Composition (%)	Crude Protein (%)	TDN (%)
Rice bran	50	6.45	35.03
Tofu dregs	19	5.13	14.80
Palm kernel cake meal	30	4.62	21.60
Commercial minerals	1	0.00	0.00
Total	100	16.20	71.43

PARAMETER

$$THI = (1,8 \times Ta + 32) - [(0,55 - 0,0055 \times RH) \times (1,8 \times Ta - 26)]$$

The Temperature Humidity Index (THI) is a calculation of dairy cow comfort based on temperature and humidity using the formula developed by Thompson and Dahl (2012). The THI can help determine how comfortable dairy cows are in their environment:

Where Ta is Ambient Temperature (°C) and RH is Relative Humidity (%). Dry matter intake (DMI) is measured between the different feed offers and the remaining feed the next day according to Mustabi *et al.*, (2020). Milk yield is measured twice, in the morning and the afternoon (Dalmayanti *et al.*, 2020). Feed Conversion Efficiency (FCE) is measured by the accumulation between the amount of milk yield divided by the quantity of DMI (Arndt *et al.*, 2015), with the following formula:

$$FCE = \frac{\text{Milk yield (Kg)}}{\text{Dry matter intake (Kg)}}$$

The body condition score (BCS) is a crucial measure used to evaluate the health and well-being of dairy cows. This assessment is typically based on a subjective assessment and physical examination. The BCS is determined by evaluating eight key points, including the spinous processes,

the space between the spinous and transverse processes, the transverse processes, the overhanging shelf (rumen fill), tuber coxae (hook), tuber ischia (pinch), the area between the pinch and hook, and the area between the hook and the tail head. Evaluating BCS through inspection involves placing the cows on a flat surface, while the assessor stands 2 meters away, observing the cows from the side, front, and rear. According to Edmonson *et al.* (1989), the BCS is rated on a scale of 1-5, representing emaciated (1) (Figure 2), thin (2), moderate (3), fat (4), and very fat (5). Additionally, intermediate values of 0.25, 0.5, and 0.75 can be used for a more precise assessment of cattle BCS (Mulyanti and Keraf, 2021).

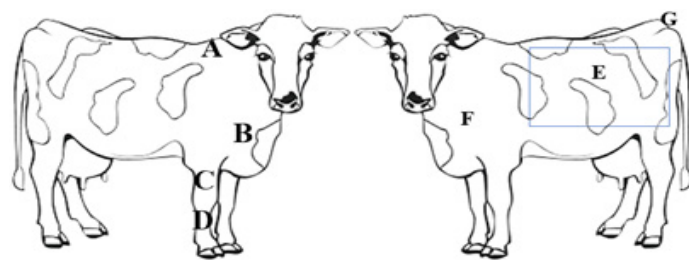


Figure 1: Measurement points of physiological values.

The physiological levels measured in this study are respiratory frequency, heart rate, and skin temperature (Figure 2).

Where is dairy cows back temperature measurement point (A); chest temperature measurement point (B); upper leg temperature measurement point (C); lower leg temperature measurement point (D); respiratory frequency measurement area (E); heart rate measurement area (F); and

rectal temperature measurement area (G).

To measure the respiratory frequency of dairy cows, one needs to observe their flanks and ribs movements during inhalation. This is done for one minute, repeated three times, and then summarized. The measurement is done three times a day, in the morning (08.00–09.00 a.m.), mid-day (01.00–02.00 p.m.), and late afternoon (04.00–05.00 p.m.) (Frans *et al.*, 2020). To measure heart rate, a stethoscope is used, placed close to the left axillary bone for one minute with three repetitions, Following Sulistyowati *et al.* (2019), each pulse detected via the stethoscope will be tallied with a manual tally counter. Skin temperature will be assessed using an infrared thermometer directed at specific areas of the skin. The skin surface temperature will be measured at four locations: back (A), chest (B), upper limb (C), and lower limb (D), as per the guidelines presented by McLean *et al.* (1983). Three measurements will be taken at each location and then averaged.

$$T_s = 0.25 (A + B) + 0.32 C + 0.18 D.5.$$

Heat tolerance was calculated by using the formula of Rhoad (1944) and Benezra (1953) which has been modified by Soeharsono (1978).

Rhoad's formula; $HTC = 100 - 10 (T_f - T_i)$; which HTC = Heat Tolerance Coefficient (Rhoad Coefficient); T_f = Average of body temperature at noon ($^{\circ}C$); T_i = Average of body temperature in the morning ($^{\circ}C$); 100 = The number of perfect coefficient on T_i ; and 10 = Constant

	SCORE	Spinous processes (SP) (anatomy varies)	Spinous to Transverse processes	Transverse processes	Overhanging shelf (rare - rumen fill)	Tuber coxae (hook) & Tuber ischia (pinch)	Between pins and hooks	Between the hooks	Tailhead to pins (anatomy varies)
SEVERE UNDERCONDITIONING (emaciated)	1.00	individual processes distinct, giving a saw-tooth appearance	deep depression	very prominent, > 1/2 length visible	definite shelf, gaunt, tucked	extremely sharp, no tissue cover	severe depression, devoid of flesh	severely depressed	bones very prominent with deep "U" shaped cavity under tail
	1.25								
	1.50								
FRAME OBVIOUS	1.75			1/2 length of process visible					
	2.00	individual processes evident	obvious depression	between 1/2 to 1/3 of processes visible	prominent shelf	prominent	very sunken		bones prominent "U" shaped cavity formed under tail
	2.25								
FRAME & COVERING WELL BALANCED	2.50	sharp, prominent ridge		1/3 - 1/4 visible	moderate shelf		thin flesh covering	definite depression	first evidence of fat
	2.75								
	3.00		smooth concave curve	< 1/4 visible	slight shelf	smooth	depression	moderate depression	bones smooth, cavity under tail shallow & fatty tissue lined
FRAME NOT AS VISIBLE AS COVERING	3.25			appears smooth, TP's just discernable					
	3.50	smooth ridge, the SP's not evident	smooth slope	distinct ridge, no individual processes discernable		covered	slight depression	slight depression	
	3.75								
SEVERE OVERCONDITIONING	4.00	flat, no processes discernable	nearly flat	smooth, rounded edge	none	rounded with fat	fat	fat	bones rounded with fat and slight fat-filled depression under tail
	4.25								
	4.50			edge barely discernable		buried in fat			bones buried in fat, cavity filled with fat forming tissue folds
	4.75								
	5.00	buried in fat	rounded (convex)	buried in fat	bulging		rounded	rounded	

Figure 2. The body condition score of dairy cows. Source: Edmonson et al., (1989).

Benezra's formula :

$$BC = \frac{Tf}{Ti} + \frac{Rf}{Ri}$$

Where BC = Benezra coefficient; Tf = Average of body temperature at noon (°C); Ti = Average of body temperature in the morning (°C); Rf = Average of respiratory rate at noon (breaths/minute); and Ri = Average of respiratory rate in the morning (breaths/minute).

STATISTICAL ANALYSIS

The data underwent analysis of variance (ANOVA) using the General Linear Model (GLM) procedure in SPSS software for Windows ver. 16.0 (Chicago, IL, USA) with a confidence level of 95%. Duncan's test was utilized if the experimental diet means exhibited a significant effect ($P < 0.05$). The mathematical model is as follows:

$$Y_{ij} = \mu + U_i + \Sigma_{ij}$$

Remarks:

Y_{ij} : response variable

μ : general mean

U_i : effect of dietary treatments

Σ_{ij} : random error

RESULTS AND DISCUSSION

MICROCLIMATE CONDITIONS OF THE RESEARCH SITE

Microclimate conditions in the cowshed can affect dairy cow productivity and physiology. The temperature-humidity index (THI) reflects the dairy cow's comfort level. Based on ANOVA, the cage temperature, humidity, and THI values were significantly different ($P = 0.00$), Table 2 presents microclimate data.

Table 2. Cowshed microclimate conditions.

No	Parameter	Measurement time		
		Morning	Midday	Late Afternoon
1.	Ta (°C)	24.76±0.70	31.12±0.90	26.86±2.89
2.	RH (%)	87.44±0.57	57.00±5.56	57.00±4.58
3.	THI	75.26±1.13	80.81±0.41	80.26±1.67

Description: Ta: Ambient Temperature; RH: Relative Humidity; THI: Temperature Humidity Index

Based on the study, there were differences in the microclimate values of the cowshed throughout the day, the temperature fluctuates within the range of 24.76–31.46 °C, while the humidity levels span from 57.00% to 87.33%. The Thermal Heat Index (THI) falls between 75.26 and 80.81. According to this study, it can be inferred that live-stock are highly susceptible to heat stress during daytime hours with the highest values observed during midday.

The environmental conditions during the study were also generally high, with temperatures ranging from 24–31 °C and humidity ranging from 57–87%, which caused mild to moderate damage to the dairy cows. The ideal ambient temperature for Holstein Friesian dairy cows to achieve the best production performance is 18.3 °C with a humidity of 55%. Any increase in temperature can cause physiological adjustments in dairy cows, leading to discomfort and lower productivity. To improve the THI value and make dairy cows more comfortable, measures such as improving air circulation and using roof materials that can suppress heat can be implemented (Suherman et.al., 2017; Kartiko et.al., 2019).

The microclimate conditions in the cowshed, such as temperature, humidity, and THI, are influenced by various factors such as solar radiation and wind speed as pointed out by Haider *et al.*, (2017). If the cowshed microclimate conditions are inappropriate, it can have adverse effects on the cows, leading to decreased milk yield and feed consumption, as stated by Marumo *et al.* (2022). In a recent study, it was found that the THI was between 75 and 80, which is categorized as a moderate heat level. Atrian and Shahryar (2012) have classified heat levels based on THI values into four groups e.i., light heat (72–78), medium heat (79–88), heavy heat (89–98), and very heavy heat (>98).

PERFORMANCE OF HOLSTEIN FRIESIAN ON DIFFERENCE LACTATION PHASE

The performance of Holstein Friesian dairy cows is different in each lactation phase. The ANOVA revealed that the BCS values showed a significant difference with a P-value of 0.04. However, the consumption of forage DM, concentrate DM, total DM, milk yield, and feed conversion efficiency (FCE) had no significant effect ($P > 0.05$), as presented in Table 3.

The lactation phase has a significant effect on various parameters related to dairy cows (Table 3). The daily DMI for dairy cows varies throughout the lactation phases: 11.30 kg/head/day in early lactation, 10.88 kg/head/day in mid-lactation, and 11.48 kg/head/day in late lactation. Each cow's feed consumption is tailored to their individual needs based on their physiological state. The nutrients obtained from the feed are vital for the dairy cows' energy and overall well-being (Erickson and Kalscheur, 2020). It's worth noting that Holstein Friesian dairy cows tend to consume more feed during the early and late phases of lactation compared to the mid-lactation phase. During early lactation, dairy cows require additional nutrients for milk yield and postpartum recovery. If the energy requirements surpass the nutrient intake from feed, the cows may get a negative energy balance (NEB) (Mekuriaw *et al.*, 2023). According to Vries and Veerkamp† (2000), NEB occurs as feed intake cannot provide enough energy for milk yield and recovery processes.

Table 3. Performance of Holstein Friesian on difference lactation phase.

No	Parameter	Lactation phase			P-Value
		Early- Lactation	Mid-Lactation	Late-Lactation	
1.	Dry Matter (DM) Intake, kg				
	DM intake of forage	8.56±0.82	8.16±0.21	8.88±1.03	0.37
	DM intake of concentrate	2.74±0.77	2.72±0.66	2.56±0.82	0.44
	Total DM intake	11.30±1.30	10.88±0.44	11.48±1.86	0.78
2.	Milk yield (kg/d/h)	10.73±3.16	11.68±2.42	9.46±1.32	0.37
3.	Feed Conversion Efficiency (Milk yield, kg/DM Intake, kg)	0.96±0.34	1.07±0.26	0.83±0.17	0.40
4.	Body Condition Score	2.70 ^a ±0.27	2.80 ^a ±0.44	3.35 ^b ±0.41	0.04

Table 4. Physiological status of Holstein Friesian dairy cows in different lactation phases.

No	Parameter	Lactation phase			P-Value
		Early- Lactation	Mid-Lactation	Late- Lactation	
1.	Heart rate (beats/min)	69.87±3.07	67.58±2.56	62.22±2.54	0.22
2.	Respiratory rate (breath/min)	33.99±3.19 ^{ab}	32.32±1.49 ^a	37.78±3.33 ^b	0.02
3.	Skin surface temperature (°C)	36.61±0.19	36.83±0.42	36.89±0.48	0.49

Similarly, in the late lactation phase, dairy cows require nutrition for the fetus and preparation for giving birth. The aim of providing nutrition to dairy cows is to ensure the supply of nutrients for fetal growth and development, optimize BCS during birth, and prepare milk yield in the early lactation phase (Marcondes et. al., 2023). During the mid-lactation phase, the dairy cows are in a stable condition, resulting in stable feed consumption. During lactation, the nutrients obtained from the feed are utilized for milk yield and live maintenance (Harder et. al., 2019). During mid-lactation, dairy cows adjust their feed intake to optimize milk yield, resulting in relatively lower feed consumption compared to other stages (Muktiani et al., 2017).

Milk yield in early lactation was 10.73 liters/head/day, in mid-lactation 11.68 liters/head/day, and in late lactation 9.46 liters/head/day. It has been observed that milk yield is highest during the mid-lactation phase as compared to other phases. This is due to peak lactation production during this phase, which increases feeding efficiency. After the peak lactation phase, the feeding efficiency decreases, leading to a rise in feed cost (Seymour et.al., 2021). The early lactation phase does not have optimal milk yield as dairy cows suffer from NEB, which requires most of the nutrients for recovery (Vries and Veerkamp†, 2000). Low blood glucose levels in dairy cows also contribute to low milk yield during this phase. NEB is a condition that arises after a cow gives birth due to the energy consumed exceeding the feed intake (Fenwick et.al., 2008).

As the age of dairy cows increases, milk yield decreases towards the late lactation phase, and the milking process

must be stopped as the cows prepare for the dry period. Pregnancy is affected by the decrease in milk yield, especially after the fourth or fifth month of pregnancy, as the nutrients are directed toward the growth and maintenance of the foetus (Penasa et.al., 2016). According to a study by Muktiani et al. (2017), milk yield gradually decreases by 0.717 liters per month after reaching its highest point during lactation. They found a correlation coefficient of 0.55, indicating a relationship between longer lactation periods and lower milk yields. Furthermore, Vijayakumar et al. (2017) discovered that milk yield initially increases as lactation length extends from 90-120 days, but then gradually declines. This pattern is affected by factors such as nutrient availability for milk yield, fluctuations in hormonal activity, and increased nutritional needs during the later stages of lactation, which coincide with pregnancy.

Feed Conversion Efficiency in the early lactation phase was 0.96, in mid-lactation 1.07, and in late lactation 0.83. The values FCE, which indicate the efficiency of feed utilization, depend on the pattern of feed consumption and milk yield. FCE is the amount of milk produced per 1 kg of dry matter. According to a study by Arndt et al., (2015), the highest FCE value is obtained in the middle phase of lactation. This is because of the high milk output but low feed intake in that phase, which means that the nutrients in the feed are mainly used to produce milk, resulting in a high FCE value. Furthermore, during the peak of lactation, milk yield increases, which in turn improves the efficiency of feeding. However, as Seymour et al. (2021) suggest, the feeding efficiency in the period after peak lactation decreases, increasing feeding costs. This means that it becomes more expensive to produce the same amount of milk.

Table 5. Resistance/heat adaptation of Holstein Friesian dairy cows in different lactation phases.

No	Parameter	Lactation phase			P-Value
		Early- Lactation	Mid-Lactation	Late-Lactation	
1.	Heat Tolerance Coefisien (HTC)	89.79±3.71	86.53±4.14	85.99±4.46	0.59
2.	Benezra Coefisien (BC)	2.62±0.68	2.33±0.11	2.54±0.50	0.64

In the early and late phases of lactation, the use of nutrients is focused on recovery and birth preparation, as suggested by studies conducted by Harder *et al.* (2019) and Marcondes *et al.* (2023).

Although FCE in early and late lactation tends to be lower, feeding in early lactation and late lactation still needs to be considered. At the beginning of lactation, feed is not only focused on the milk yield but also the postpartum recovery process (Sammad *et al.*, 2022) while at the end of lactation cattle are usually pregnant so feed is generally used for fetal development. The metabolic energy of livestock will increase as the gestation age increases, at 220 days of gestation the amount of metabolic energy is 5141 kcal/day which increases on day 280 to 7848 kcal/day (Sguizzato *et al.*, 2020). Therefore, the FCE values during these phases are expected to be lower than during the middle and peak phases of lactation. Overall, understanding FCE is important for dairy farmers as it can help them optimize their feeding strategies and improve the efficiency of milk yield, which can ultimately lead to increased profits.

Body condition scores at the early-lactation 2.70, at mid-lactation 2.80, and at the late-lactation 3.35. BCS levels in dairy cows increase as the lactation phase increases. During the early lactation phase, Holstein Friesian cows tend to decrease in BCS due to the energy used for partum. Moreover, producing colostrum for their calves at this stage may cause some cows to undergo NEB due to the large amount of energy required. A decrease in BCS indicates NEB, which is correlated with fat mobility during the early lactation phase (Vries and Veerkamp†, 2000). Post partus, cows get NEB, leading to a 30-40% decrease in fat reserves, which in turn lowers their BCS. This state persists until day 90 of lactation, according to Truman *et al.* (2022). As the recovery process ends, the mid-lactation phase of the BCS condition begins to improve, indicating a positive energy balance and improvement in dairy cows' performance (Harder *et al.*, 2019). Towards the end of the lactation phase, the nutrients are stored in the form of fat in the cow's body to prepare for birth, which makes them look fatter. According to Marcondes *et al.*, (2023), during the late lactation phase, dairy cows use nutrients from feed to optimize BCS, which helps in birth preparation and milk yield. Truman *et al.* (2022) proposed that dairy cows have an average BCS of 3.4 immediately after calving, which decreases as the duration of lactation extends. The lowest BCS value of 3.15 is observed between

the 40th and 90th day of lactation. Following this period, the BCS gradually increases, reaching 3.5 during the dry period before the next calving.

PHYSIOLOGICAL STATUS OF HOLSTEIN FRIESIAN DAIRY COWS IN DIFFERENT LACTATION PHASES

The physiological status of Holstein Friesian dairy cows throughout their lactation phases. This indicator gives insight into the overall health and comfort of dairy cows. By observing factors such as body temperature, heart rate, and respiration rate, it is easy to understand how dairy cows are adapting to their current conditions. This information can be used to identify adjustments to their environment or care to promote optimal health and well-being. Based on ANOVA, the frequency of respiration was significantly different ($P=0.02$), while heart rate and skin temperature had no significant effect ($P>0.05$), as presented in Table 4.

The lactation phase has a significant ($P=0.02$) effect on respiratory frequency values, but not on heart rate and skin temperature. With a heart rate range between 62.22-69.87 beats/min, respiration frequency between 32.32-37.78 beats/min, and skin temperature between 36.62-36.89°C. Dairy cows in the early lactation phase have a higher heart rate due to post-partum recovery and vulnerability to stress. However, this is a normal physiological response to maintain their body condition in a balanced state. The cows also attempt to regulate their skin temperature by increasing peripheral circulation to release body heat (Suprayogi *et al.*, 2017). Despite the higher heart rate in the early lactation phase, it is still within the normal range and does not affect dairy cow health. The average milk yield range in Indonesia is about 8-12 kg/day, which is still maintained even with the normal heart rate range. Heat stress is closely linked to cows' health and immune response, according to Cartwright *et al.*, (2023). Dairy cows in the mid-lactation to late phases have a lower heart rate because they have recovered and are more adaptive to stress.

The respiratory frequency of the late lactation phase tends to be higher compared to the early and mid-lactation. This is due at the end of lactation, the cow's fetus in the abdominal cavity has grown larger, causing the pulmonary cavity to be pushed upwards. This results in a decrease in the volume of air that can be stored, and to meet the oxygen requirements in the body, cows must increase their breathing volume. It is worth noting that during this time, pregnant cows may experience difficulty breathing due to bloating

and pressure on the diaphragm and chest cavity Jumaryoto *et al.*, (2020). According to Kaba *et al.* (2018), an enlarged abdominal cavity can lead to an increased respiration frequency, possibly up to 60 times per minute. Farmers should be cautious about the amount of CP administered during late lactation, as excessive amounts can lead to feed chlorogenicity, potentially elevating respiration frequency. Utomo *et al.* (2010) found that Holstein Friesian cows fed with 12% protein content exhibited higher respiration frequencies compared to those fed with 10% protein. Protein can raise oxygen demand due to heightened metabolism in dairy cows' bodies. The increase in oxygen demand needs to be balanced with an elevated respiration frequency to ensure that bodily processes operate as intended. The respiration rate is utilized as an indicator of heat stress, as it is associated with the decrease in CO₂ levels in body tissues and the inflow of oxygen through feed combustion, which generates heat (Nurmi, 2016).

The skin surface temperature at the early to late lactation phase increases, but it tends to remain within the normal range of 33.5–37.1°C, according to Tucker *et al.* (2008). Different skin surface temperatures at each lactating phase can be influenced by the milking process, as suggested by Bruckmaier and Blum (1998). Additionally, the release of oxytocin can lead to an increase in body temperature, as noted by Montes (2023) and Camerino (2021).

RESISTANCE/HEAT ADAPTATION OF HOLSTEIN FRIESIAN DAIRY COWS IN DIFFERENT LACTATION PHASES

The values of heat tolerance (HTC) and Benezra coefficients (BC) for Holstein Friesian vary at different lactation phases. These indicators are important for assessing the ability of dairy cows to cope with heat stress and adapt to changes in the environment. It's fascinating to see how these values change over time and how they can impact the overall health and productivity of the cow. HTC values in this study ranged from 85.99–89.79 and BC between 2.33–2.62.

However, it's worth noting that early lactation phases tend to have higher HTC values compared to the middle and late lactation phases. Mariana *et al.*, (2019) found that an HTC value approaching 100 means that there is no significant change in skin temperature neither in the morning nor late afternoon, and a good HTC value is close to 100. The higher the HTC value, the better the resistance of dairy cows to heat. Yetmaneli *et al.*, (2020), HTC is one of the physiological parameters used to evaluate the heat resistance of dairy cows to their environment. Both farmers and stakeholders need to be aware of the normal value of dairy cows' body resistance to assess their power against environmental heat for their survival in managing

the farm entrepreneur.

The Benezra Coefisien values can be used to assess the condition of a dairy cow during the lactation phase. Specifically, the BC values in the middle of the lactation phase tend to be lower than in the early and late phases. BC value that is close to the expected value of 2 is considered good, while a value that is further from 2 will require a lot of energy to maintain the body within the normal range (homeostatic) (Ominski *et al.*, 2002). Additionally, Yosi *et al.*, (2019) found that the BC value is strongly influenced by the conditions of the dairy cow, and mid-lactation cows can maintain their body state within the normal range due to the presence of heat.

CONCLUSION

Holstein Friesian dairy cows exhibit varying performance levels, physiological status, and resistance during lactation. In early lactation, dairy cows may show suboptimal performance, indicated by significantly lower BCS values. Furthermore, respiration frequency tends to increase with advancing gestational age toward the end of lactation. Negative energy balance during early lactation can affect performance and physiological indicators. Managing feed intake is crucial to address this issue, and adjusting nutritional intake based on the lactation phase is essential due to the varying performance and physiological indicators throughout the phases. Overfeeding can also have negative effects, as shown by an increased respiration frequency toward the end of lactation.

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AUTHORS CONTRIBUTIONS

R. F. Utamy: Conceived and designed the experiments, performed the field experiments, analyzed data, and wrote the paper; A. Ako and H. Hasbi: Conceived and designed the experiments, performed the field experiments, performed, and analyzed data, and wrote the paper; Z. Ramadan: Performed the data tabulation, analyzed data, and wrote the paper; A. A. Rahman and S. A. Sukri: Performed the field experiments and data tabulation.

CONFLICT OF INTEREST

The authors have declared no conflict of interest.

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