Research Article

Accelerated Road Transport Duration Affects Physiological Condition, Muscle Physiology, and Body Weight in Leumosin Breed Bulls (LBB)

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Abstract | Animal transport is the primary means of distributing livestock for fresh meat supply, especially in Indonesia. Sixty LBB were used as samples in this study, with a body weight of 607 kg ± 17 kg and aged 24–27 months, were divided into three groups, each with a transportation duration of 10 hours (T1), 12 hours (T2) and 14 hours (T3), covering the same distance of 560 km, using trucks with dimensions of length, width and height of 610, 238 and 232 cm. Physiological conditions (respiration rate, venous pulse, rectal temperature, and body surface area), muscle physiology (metabolites indicative of muscle energy metabolism), and body weight loss have been measured during this study. The results of this study indicate that the duration of transportation affects the physiological conditions, muscle energy metabolism and body weight loss of LBB. The 560 km distance with a 10-hour duration (T1) appears better than the 12- and 14-hour transport durations. Physiological conditions and muscle physiology were better with a 10-hour duration, resulting in the lowest body weight loss of 30.55 kg (5.00%) after transportation.

Keywords | Bull, Transportation, Stress, Energy, Physiological condition

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INTRODUCTION

Animal products result from various physiological processes within the animal's body. Optimal animal products can be maintained under normal conditions and physiological processes. Each physiological process is a product or result of complex activities of tissues, organs, and organ systems, which are greatly influenced by the genetic abilities or potential of the animal in question. The animal controls physiological processes within a framework that maintains an internal condition comfortable for the animal. All physiological processes that take place in the animal's body aim to safeguard the internal environment, maintaining a balanced state, whether chemical or physical, commonly referred to as homeostasis (Teke *et al*., 2014).

Transportation is an essential component in the animal logistics chain. However, transportation can also cause stress for animals and result in economic losses. One major factor that can induce stress is the duration of the transport. Transportation increases stress in cattle; the longer the transport, the more stressed the animals (Aditia *et al*., 2022; Muhammad *et al*., 2023). According to the Indonesian Ministry of Agriculture, on the protection of animals during transport, transport should be limited to 12 hours to ensure animal welfare. The company PD Akas Jaya has expedited animal transport from East Java to West Java, reducing transport time from approximately 12 hours. However, the long-lasting effects of transport vary; the previous studies suggest a 10-hour transport or one that is 2 hours shorter (Cramer *et al*., 2024). Based on experience, this is the fastest transport time, given factors like speed and safety that are still manageable. The author also compares different transport durations, such as 14 hours or 2 hours longer.

One type of transport is short-distance transport. According to government regulations issued by the Indonesian Ministry of Agriculture on the protection of animals during transport, transport for less than eight hours is categorised as short-distance transport. Transport activities such as preparation, loading, transport, and unloading of animals can generally cause stress (D'Oliveira *et al*., 2014). Stress and its effects on cattle during transportation are measured using various physiological, behavioural, performance, and genetic factors (Dudi *et al*., 2023). Changes from the comfort zone to critical conditions in animals can alter their physiological status, potentially leading to decreased performance (Aritonang *et al*., 2025). A previous report also showed that the physiological responses of cattle to stress include increased heart rate (Damtew *et al*., 2018; Li *et al*., 2019) and respiratory rate (Kharazi *et al*., 2022), and decreased feed intake (Adriani *et al*., 2024a). Damtew *et al*. (2018) showed that stress can persist for a long time and suppress immune function, potentially leading to death (Mushawwir *et al*., 2010; Pagliasso *et al*., 2023).

Transport stress in animals can occur due to various factors, including duration, transport density, distance, and poor road conditions. Environmental conditions also contribute to stress levels (Tanuwiria *et al*., 2022; Rosiyanti *et al*., 2025), including temperature, humidity, noise, ventilation, lighting, and treatment during transport (Price *et al*., 2015). Several factors can cause cattle to become stressed, including rough handling during loading and unloading, mixing with unfamiliar animals of different ages, lack of feed and drinking water, transportation conditions and poor road quality. These include high load density, inadequate ventilation, extreme temperatures, humidity, and wind speed (Tanuwiria *et al*., 2022; Reichhardt *et al*., 2025).

Recent research indicates that stress is the primary cause of weight loss as a physiological, psychological, and behavioural response in animals (Tanuwiria *et al*., 2022; Adriani *et al*., 2024b), which attempts to adapt and manage internal and external pressures. Various factors can affect stress levels in animals, including drastic changes in habits such as eating and drinking patterns, long-distance transport, cage and habitat relocation, the presence of predators, rough handling, and climate change. Environmental conditions also contribute to stress levels, including temperature, humidity, noise, light, and handling during transport (Tanuwiria *et al*., 2023; Teke *et al*., 2014).

The LBB is typically shipped from production centres in East Java by truck on the Trans Java Toll Road. Currently, PD Akas Jaya requires 12 hours to transport cows from East Java to West Java, with two rest periods. Besides affecting carcass quality, transportation stress also induces physiological changes that alter blood counts (Mushawwir *et al*., 2010). Several studies have indicated that transportation activities, such as preparing for transit, loading, transporting, and unloading animals, conducted by animal entrepreneurs using trucks, ships, or other means generally result in stress (Li *et al*., 2019; Damtew *et al*., 2018; Cramer *et al*., 2024).

The type of transport truck used to transport animals is primarily determined by the animal being transported. Cattle can be transported in Colt Diesel trucks, which hold 10–13 head, while Fuso trucks hold 13–18 head. Animal transport is the process of moving animals by one or more means of transport, including loading, movement, rest, and unloading at the destination (Adriani *et al*., 2024b; Kharazi *et al*., 2022). Previous studies have shown that transport can affect animal stress levels. Stress during transport includes: 1) pre-loading (preparation), namely prolonged restraint and confinement, 2) during loading, namely handling methods and forcing animals into the means of transport, 3) during transport, namely distance and duration, vibration/shaking, jolts due to uneven roads (Pagliasso *et al*., 2023), noise, wind speed, livestock density, which further triggers stress (Price *et al*., 2015), mixing of livestock, and climate, temperature, and humidity (Damtew *et al*., 2018). 4) automatic and manual unloading (Melendez *et al*., 2020). Transport stress affects animal welfare and mortality, weight loss, and meat and carcass quality (Teke *et al*., 2014). Transportation system engineering has been reported by Nicholson *et al*. (2013), showing that transportation time affects weight loss; however, in this study, different transportation durations were due to different transport destinations. The same research results show a decrease in the risk of weight loss and stress with shorter transport distances (Li *et al*., 2019). The administration of additives during transport also shows a risk of stress and weight loss (Goetz *et al*., 2022).

Specifically, the transport of animals on the island of Java, Indonesia, from their place of origin to the slaughterhouse takes an average of 12 hours. As reported by previous researchers, longer transport times are associated with greater weight loss and reduced immunity. Increasing transport speed is a good strategy. This means reducing standing loads to improve energy efficiency for supporting the body. Based on this phenomenon, it can be inferred that the shorter the transport time for a given distance, the lower the risk of stress and weight loss. The cattle ware stopped accurate data on the physiological condition and weight loss of animals transported over the same distance but with different transport times.

MATERIALS AND METHODS

Animal samples, experimental design

Sixty LBB, with a body weight of 607 kg ± 17 kg, aged between 24 and 27 months, were selected as samples in this study. The animal transported came from village Dali, Alastuwo Village, District Poncol, Magetan Regency, East Java, and was transported to the Cijawura RPH, Cijawura Village, Buahbatu District, Bandung City, West Java, Indonesia. The distance between the two locations, or transport distance, was 560 km. Wet-bulb and dry-bulb thermometers and anemometers were installed in all trucks during transport to measure temperature, humidity, and wind speed inside the trucks. The average temperature, humidity, and wind speed were relatively the same: 28.25 ˚C, 75.36%, and 15 km/h, respectively.

Transport trucks with dimensions of 610, 238, and 232 cm, respectively, were used in this transportation study. Sixty samples were divided into three groups: Group 1 (T1), with a transport time of 10 hours; Group 2 (T2), with a transport time of 12 hours; and Group 3 (T3), with a transport time of 14 hours. Each group consisted of 20 samples and used two trucks, so each car contained 10 LBB samples. Each truck was conditioned to ensure comfortable, uncrowded transport of animals with adequate air circulation.

Sample measurement and analysis

The observed variables included physiological status, muscle physiology, and body weight loss in the cattle. The body weight of all samples was measured using a digital scale before and after transportation. All LBB samples have been fitted with ear tags as individual markers to prevent cross-contamination of measurement data.

Physiological status checks (rectal temperature, body surface temperature, respiratory rate, pulse rate) are carried out before and after transportation, specifically for body surface temperature checks, which are carried out before, during transport and afterwards, the cattle were stopped (after reaching a distance of 450 km, for 60 minutes) to measure body surface temperature and take blood samples.

The T600 digital infrared thermometer has been used to determine body surface temperature. Infrared rays are emitted from a distance of approximately 15 cm from the surface of the body being measured. Blood samples were prepared before determining muscle physiological marker levels. Blood samples were collected from the coccygeal vein using a sterile venojet and a 3 mL EDTA tube. To obtain plasma, a centrifugation method was used at 3500 rpm for 15 minutes. All muscle physiological marker metabolites were determined based on the analysis protocol in accordance with the Randox KIT instructions (Mushawwir *et al.*, 2023). A summary of the study implementation is shown in Figure 1.

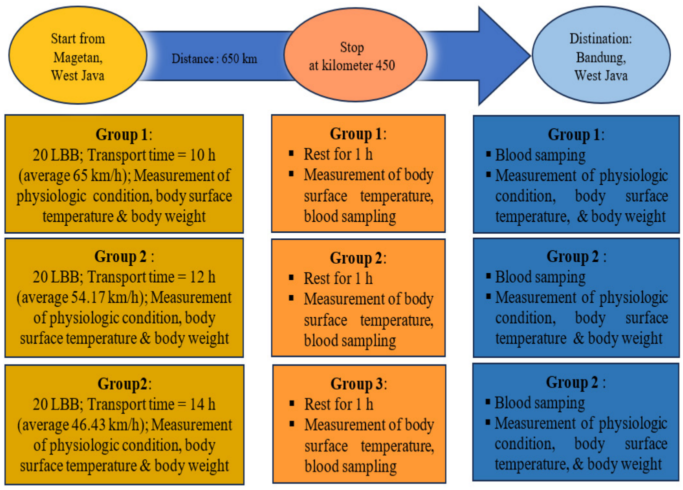

Figure 1: The summary of the study implementation.

Data analysis

Many factors involved in this experiment could not be controlled, including different truck speeds. Therefore, this experiment was analysed using a semi-quantitative statistical method. All data were collected and tabulated using MS Excel 2016. To ensure the accuracy and validity of the data analysis, all experimental effects on the measured parameters were determined using the Kruskal-Wallis test. To determine differences between groups, the Mann-Whitney analysis was used. IBM SPSS 20 software was used to analyse all experimental data.

RESULTS AND DISCUSSION

The influence of transportation duration on the physiological status

Changes in physiological status (rectal temperature, body surface temperature, respiratory rate, and heart rate) during travel are indicators of the level of stress and strain caused by transportation. Average physiological conditions and the results of the Kruskal-Wallis test are shown in Table 1.

Table 1: Physiologic condition of LBB with duration of transportation and period of measurement.

Parameters	Duration of Transportation – Period of Measurement					
	T1		T2		T3	
	BT	AT	BT	AT	BT	AT
Venous Pulse (f/m)	66.0±2.94^{aA}	72.0±0.4^{bA}	65.0±0.33^{aA}	75.0±2.80^{bB}	65.0±1.03^{aA}	85.0±1.94^{bB}
Rectal Temperature (°C)	39.4±0.08^{aA}	38.9±0.17^{aA}	39.7±0.96^{aA}	38.9±0.14^{aA}	39.2±0.76^{aA}	39.2±0.66^{aA}
Respiration (f/m)	26.0±0.81^{aA}	31.0±2.21^{bA}	26±1.23^{aA}	36±1.94^{bB}	27.0±1.03^{aB}	46.00±2.44^{bC}

BT=Before Transportation; AT=After Transportation; f/m=frequency/minute; ^{a,b} The average at the same transportation duration, followed by different lowercase letter notations, indicate significant differences (P<0.05). $^{A, B}$ The average between transportation durations in the same measurement period, followed by different capital letter notations, differt significantly (P<0.05)

Rectal temperature reflects the balance between heat produced and heat released. Based on Table 3, the results of rectal temperature measurements before the trip at P1 (39.4±0.08 °C), P2 (39.7±0.96 °C) and P3 (39.2±0.76 °C), and after transport, P1 (38.9±0.17 °C), P2 (38.9±0.14 °C) and P3 (39.2±0.66 °C). The results of the Kruskal-Wallis test in Table 1 indicate that P1, P2, and P3 do not differ significantly in rectal temperature after transportation (P>0.075). The results of this study indicate that cattle can maintain a constant body temperature (homeostasis). The normal temperature range for animals in tropical areas is 38-39.2 °C (Manin *et al*., 2024). This shows that, under normal conditions, the rectal temperature of cattle measured is 38.9-39.2 °C. The rectal temperature that did not differ between Bulutanah Village and Kalero Village is in line with research (Goetz *et al*., 2022), which stated that there was no difference in the rectal temperature of Bali cattle compared with Limousin and Simmental cattle, even though the range in that study was higher, namely 38.00-39.20 °C.

Rectal temperature in animals can be influenced by environmental temperature, activity, feed intake, water intake, and digestion. The body indirectly controls production; it depends on the food it receives and the amount available in the digestive tract (Adriani *et al*., 2024a; D'Oliveira *et al*., 2014). The high body temperature of Limousin crossbred cattle is thought to be due to the breed's greater difficulty dissipating heat through its skin compared to Bali cattle. According to Fazio *et al*. (2025), the Boss Taurus has difficulty dissipating body heat through the skin, which is characterised by lower sweat levels than those of the bull of *Boss sondaicus* (Bali cattle).

Respiratory frequency is an effort by cattle to reduce heat stress from the environment (Melendez *et al*., 2020; Adriani *et al*., 2024b). Based on Table 1, the results of respiratory frequency measurements before the trip at P1 (26±0.81 f/m), P2 (26±1.23 f/m) and P3 (27±1.03 f/m), and after transportation, P1 (31±2.21 f/m), P2 (36±1.94 f/m) and P3 (46±2.44 f/m). The test results, as shown in Table 1, indicate that P1, P2, and P3 have significantly different respiration frequencies after transportation (P<0.075). This suggests that the respiratory frequency in cattle after transportation has increased compared to the normal respiratory frequency. The high respiratory frequency of LBB after transportation indicates that the animal is experiencing stress.

The results showed that animals transported for 14 hours had higher respiratory rates. This indicates that the animals were more active in releasing body heat through respiration. The increase in respiratory rate occurred because the cow is experiencing an excess heat load from metabolic activity. To maintain its body heat balance, the cow attempts to dissipate heat by increasing its breathing rate. This indicates that cattle exposed to greater heat stress will try to dissipate the heat they receive by greater means (Mushawwir *et al*., 2010; Pagliasso *et al*., 2023). Frequency breathing is influenced by Several factors, including body size, age, physical activity, anxiety, environmental temperature, pregnancy, digestive tract disorders, animal health conditions, and animal position (Li *et al*., 2019; Aditia *et al*., 2022). Respiratory frequency varies depending on physical condition, activity, environmental temperature, and body size (Nicholson *et al*., 2013).

Heart rate reflects cardiac performance. Increases and decreases in heart rate are closely related to heat load, which produces good in-process metabolism in the body, and to heat load received from the external environment. Frequency pulse influenced by factors such as age, body size, environmental conditions, measurement time, and animal activity (Mushawwir *et al*., 2023; Tanuwiria *et al*., 2022).

Based on Table 1, venous pulse measurements were made before transportation on P1 (66±2.94 f/m), P2 (65±0.33 f/m), and P3 (65±1.03 f/m), and after transportation, P1 (72±0.41 f/m), P2 (75±2.80 f/m), and P3 (85±1.94 f/m). The results show that LBB transported for 14 hours had a higher respiratory rate, specifically 85 frequency per minute, while the normal range according to Mushawwir *et al*. (2010) is 36-80 frequency per minute in beef cattle. These findings suggest that European crossbred breeds (Limousin) are less adaptable to tropical regions than

Bali cattle. This aligns with the opinion of Melendez *et al.* (2020), who state that Limousin cattle are less able to adapt to tropical conditions. The physiological changes shown in Table 1 indicate that the duration of transport causes stress. These physiological changes are a standard mechanism by which cells maintain homeostasis (Mushawwir *et al.*, 2010), even though they increase energy requirements. Heat release resulting from increased energy metabolism requires a higher heart rate (Melendez *et al.*, 2020), and vasodilation of blood vessels occurs simultaneously (Hong *et al.*, 2019). Another mechanism, evaporation through respiration, is also an effective way to dissipate body heat (Kharazi *et al*, 2022).

Measuring the surface temperature of LBB (Table 2) using an infrared thermometer is a non-contact method that can minimise stress in cattle. According to Goetz *et al.* (2022), the results coverage. The transmit power of an infrared thermometer's sensor varies with height. Maximum transmittance occurs at a sensor height of 150 cm from the floor. Furthermore, the results of body temperature measurements using an infrared thermometer depend on the position of the transmittance on a specific body part (Teke *et al.*, 2014).

Table 2: Surface body temperature of LBB with duration of transportation and period of measurement.

Body surface	Duration of transportation	Period of measurement*		
		Before transportation	During transportation	After transportation
	T1	33.0[a]	34.3[a]	31.6[a]
Orbital	T2	33.2[a]	32.2[a]	31.7[a]
	T3	32.8[a]	32.8[a]	30.2[a]
	T1	24.9[a]	29.1[a]	26.4[a]
Frontal	T2	26.0[a]	30.2[a]	27.8[a]
	T3	25.4[a]	29.9[a]	27.2[a]
	T1	31.6[a]	33.2[a]	28.4[a]
Cheek	T2	31.4[a]	32.0[a]	29.7[a]
	T3	30.8[a]	31.2[a]	28.2[a]
	T1	32.3[a]	33.7[a]	30.2[a]
Shoulder	T2	33.3[a]	31.9[a]	31.5[a]
	T3	31.6[a]	33.1[a]	30.8[a]
	T1	32.5[a]	32.9[a]	29.3[a]
Abdomen	T2	33.2[a]	31.4[a]	31.9[a]
	T3	32.4[a]	33.5[a]	31.6[a]
	T1	31.1[a]	32.8[a]	29.7[a]
Femur	T2	31.2[a]	30.6[a]	31.5[a]
	T3	30.9[a]	32.3[a]	29.0[a]
	T1	28.8[a]	31.9[a]	26.2[a]
Tibia	T2	30.0[a]	30.6[a]	26.9[a]
	T3	27.8[a]	29.9[a]	27.6[a]

*There were no significant differences (P>0.05).

The average body surface temperature results are shown in Table 2. The measurements show the average for each part of the cow's body surface. The results of this study indicate that body surface temperature before, during, and after transport did not differ significantly (P>0.05). Nevertheless, orbital temperature in all treatment groups was higher than that of other body surfaces. According to Price *et al.* (2015), the eye area has a large number of capillaries, which are innervated by the nervous system. These capillaries respond to changes in blood flow, allowing the eye area to serve as an indicator of stress because blood flow to the eyes is closely related to sympathetic activity. Body surface measurements can confirm the heat load borne by livestock. Body surface temperatures that do not differ may indicate that the heat load from transport stress can still be managed by evaporative cooling through respiration (as shown in Table 1). Body surface temperature is an alternative means of heat release (Nielsen *et al.*, 2022). Heat dissipation through the skin occurs if evaporation through respiration is unable to manage the heat load of body tissues (Reichhardt *et al.*, 2025).

The effect of transport duration on muscle physiology markers

Several metabolites that can indicate the physiological and biochemical conditions of muscles as a result of transport duration are shown in Table 3.

Table 3: Muscle Physiology marker levels (metabolite state after reaching a distance of 450 km).

Marker	Transport duration		
	T1	T2	T3
Creatine Kinase (mg/dL)	1.76±0.06 [a]	3.05±0.07 [b]	6.61±0.25 [c]
Creatinine (mg/dL)	5.23±0.19 [a]	7.62±0.18 [b]	11.57±0.16[c]
Pyruvate (mg/dL)	14.45±1.07[a]	12.45±1.05[b]	7.52±0.24 [c]
Lactate (mg/dL)	2.16±0.02 [a]	3.73±0.15 [b]	3.73±0.15 [b]
Lactate dehydrogenase (mg/dL)	1.35±0.52 [a]	2.63±0.11 [b]	3.05±0.08 [c]

[a,b] Means within a row with different superscripts differ significantly (P<0.05

Table 3 shows that the average levels of blood plasma metabolites, which can serve as markers of muscle physiological condition, were significantly different (P<0.05) between the experimental groups. Overall, the current research results confirm that muscle metabolic stress for energy supply increases with the duration of transport.

During transport, the sample animals (LBB) were standing. The energy required to support this activity was supplied by the anaerobic glycolysis pathway (Nielsen *et al.*, 2022; Manin *et al.*, 2024). This pathway was achieved by degrading pyruvate to lactate, catalysed by lactate dehydrogenase. This pathway can produce 1 mol of ATP for every 1 mol of pyruvate breakdown (Fazio *et al*., 2025; Firmansyah *et al*., 2024). The results of this study showed that the transport duration of up to 14 hours (T3) led to higher levels of this metabolic pathway, resulting in lower blood pyruvate levels (7.52 mg/dL), which were lower ($P<0.05$) than plasma levels in LBB in groups T1 and T2. Conversely, lactate production and enzyme activity (lactate dehydrogenase) were highest in group T3, namely 6.95 and 4.05 mg/dL, respectively; these levels were higher ($P<0.05$) than in T1 and T2.

Energy stress, especially in the LBB group with T2 and T3 duration, also seems to take an alternative energy supply other than anaerobic glycolysis, namely by the mechanism of converting creatine to creatinine, which is catalysed by creatine kinase (Mushawwir *et al*., 2010; Goetz *et al*., 2022; Rosiyanti *et al*., 2025). The increase in creatine kinase and blood plasma creatinine, as seen in the T3 group (6.61 and 11.57 mg/dL, respectively), is a strong indication that LBB transported with T3 duration requires higher energy. Previous research has shown that the energy supply pathway involving the conversion of creatine to creatinine is used by animals experiencing energy stress (Tanuwiria *et al*., 2023; Pagliasso *et al*., 2023; Mushawwir *et al*., 2010). This pathway is considered an effect of the lack of energy precursors from pyruvate (Melendez *et al*., 2020; Tanuwiria *et al*., 2022). This pathway is also shown by Hong *et al*. (2019) in dairy cattle experiencing heat stress, and sea (Reichhardt *et al*., 2025) and land (Li *et al*., 2019) transportation stress.

Effect of transportation duration on body weight loss

Body weight loss can be caused by stress experienced by animals during delivery. Stress levels is not the sole cause of weight loss, distance and transport duration also contribute. The average presentation and the Kruskal-Wallis test comparison of weight loss by body weight for each treatment are shown in Table 4.

Table 4: Presentation average body weight loss of LBB after transportation with different durations.

Transport duration	Average body weight loss	
	Kg	%*
T1	30.55 [a]	5.00
T2	39.70 [b]	6.80
T3	50.35 [c]	8.50

[a,b] Means followed by different superscripts in the same column indicate significant differences ($P<0.05$); * % loss calculated relative to initial body weight.

Based on Table 4, the average body weight loss from highest to lowest is P3 (8.50%), P2 (6.8%), and P1 (5%). The results of the Kruskal-Wallis comparison test in Table 2 show that P1, P2 and P3 have significantly different results ($P<0.075$) on the percentage of body weight loss of transported cattle. The results of this study indicate that transportation distance affects body weight loss. The survey by Stojkov *et al*. (2020) found that stress in beef cattle transported for 7 hours resulted in a 5.41% loss in body weight. A study (Teke *et al*., 2014) found that transportation for 7-8 hours resulted in a 5.26% loss in Simmental-Limousin crossbred cattle. Another report (Stojkov *et al*., 2020) states that the longer the cattle are transported, the greater the weight loss.

The duration of transport in this study indicates that transport time affects the weight loss of transported animals. Previous studies have shown that animals transported for 10 hours exhibit lower weight loss compared to those transported for 12 or 14 hours. This indicates that transporting animals for 10 hours can reduce stress levels, tension, and fluid loss, which ultimately helps maintain body weight. Pagliasso *et al*. (2023) demonstrated through their research that stress is the leading cause of weight loss in animals, with factors such as fatigue or excessive movement also contributing. The longer the transport duration or the wider the range of animals transported, the greater the impact on immunity, carcass quality, and body weight (Tanuwiria *et al*., 2022).

Several factors, including handling during selection, weighing, treatment administration, and unloading animals from vehicles, can cause stress (Muhammad *et al*., 2023). Animals must adapt to new weather conditions and environments, and endure shocks during transportation. Generally, animals experience anxiety due to their inability to maintain homeostasis (Noriega *et al*., 2020). In general, animals experience stress as a result of their metabolic and physiological activities aimed at maintaining homeostasis (Noriega *et al*., 2020). This includes the conversion of non-carbohydrate precursors, such as muscle creatine into creatinine, to produce ATP (see also Table 3), which is why changes in the profile of these metabolites occur. Previous studies have also reported that Nicholson *et al*. (2013) found that the stress experienced was influenced by handling, loading, movement or transport turbulence. Their research results showed that short transport times can reduce the risk of adverse effects on animal performance.

CONCLUSION

Current research indicates that transport duration impacts the physiological state, muscle energy metabolism, and body weight loss in LBB. A 560 km journey lasting 10 hours (T1) seems preferable over 12 and 14 hours. In this case, physiological and muscle parameters were more favourable, leading to the least body weight loss of 30.55 kg (5.00%) after transit.

The results of this research can inform the development of road infrastructure to reduce economic losses from transport, for example, by building dedicated roads for animal transport to shorten transport times. Research on the quality of post-transportation LBB meat could also be an interesting idea, using a molecular approach to rigor mortis physiology.

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NOVELTY STATEMENT

Previous researchers have reported on transportation techniques and their impacts, spanning diverse subjects and outcomes. Previous studies has examined studies on transportation duration have been conducted for varying distances, yielding different results. The current research focuses on engineering animal transportation by shortening and lengthening the duration of transport over the same distance while increasing transport speed. Additionally, it highlights changes in muscle physiology markers during transportation.

AUTHOR'S CONTRIBUTION

The authors listed in this article are members of the research team, each contributing equally based on their expertise. Similarly, the writing, processing, and analysis of data, as well as the refinement of this article, were carried out collaboratively with equal contributions and roles.

Ethical approval

All procedures and the implementation of this experiment have been carefully reviewed by the Animal Research Ethics Board, National Research Institute, under the authority of the Directorate of Animal Production and Animal Health, Republic of Indonesia, with decision number No. 1052/KP-R-443/SK/05/2025.

Generate AI and AI-assisted technology statement

The authors declare that we did not use AI or similar technology in any way during the writing or editing of this manuscript.

Conflict of interest

The author states truthfully that this research and publication have no potential for conflict with any party in any aspect.

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