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Research Article

Linking Colostrum-Derived Serum Proteins to Calf Growth and Health in Indonesian Dairy Farms

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Abstract | This study evaluated the effect of total serum protein (TSP) concentration at 24 hours post-birth on the growth performance and health of Holstein dairy calves. A total of 512 calves were monitored from birth to 180 days, with colostrum quality assessed using Brix refractometry and TSP levels measured at 24 hours. Results indicated that calves with higher TSP concentrations (>6.5 g/100 mL) had significantly greater ($P < 0.05$) birth weight, weaning weight, and average daily gain (ADG) compared to those with lower TSP levels. Furthermore, the incidence of diarrhea and pneumonia was significantly lower ($P < 0.05$) in calves with higher TSP, suggesting enhanced immune competence. These findings underscore the critical role of colostrum quality in achieving effective passive transfer of immunity and long-term calf performance. Optimizing colostrum management and monitoring TSP levels can improve calf health, boost growth efficiency, and contribute to more sustainable dairy production systems.

Keywords | Total serum protein, Colostrum quality, Growth performance, Immune response, Dairy calves

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INTRODUCTION

The timely administration of colostrum is crucial for neonatal calf health, providing essential immune components and nutrients that enhance disease resistance during early life (McGrath *et al*., 2016). Immunoglobulin G (IgG) is the dominant immunoglobulin in colostrum, constituting over 85% of total immunoglobulins (Dunn *et al*., 2017). The quality of colostrum, primarily determined by its IgG concentration, is directly linked to reduced pre-weaning morbidity (Puppel *et al*., 2019), lower mortality rates (Ahmann *et al*., 2021), and minimized economic losses due to calf diseases (Lopez and Heinrichs, 2022). Additionally, proper colostrum management has been shown to enhance calf growth, increase future milk production, and extend the productive lifespan of dairy cattle (Atkinson *et al*., 2017).

Various factors influence the efficiency of passive immune transfer (PIT), including colostrum quality, the volume administered within the first 24 hours postpartum, and hygienic handling to prevent bacterial contamination (Robbers *et al*., 2021). The IgG concentration in colostrum is commonly assessed using a refractometer, with a threshold of 21% Brix indicating high-quality colostrum (Quigley *et al*., 2013). Dairy industry guidelines recommend that neonatal calves receive at least 4 liters of high-quality colostrum containing >50 g/L IgG within the first few hours of life (Palczynski *et al*., 2020). To evaluate PIT success, total serum protein (TSP) levels are measured at least 24 hours post-colostrum administration using a refractometer, where TSP values below 5.5 g/dL indicate PIT failure (Moreira *et al*., 2024).

Total serum protein is widely recognized as an indirect yet reliable biomarker of passive immunity transfer, given that IgG constitutes the primary protein fraction in neonatal calf serum (Godden *et al*., 2019). TSP measurement is a practical alternative to direct IgG quantification and has been shown to strongly correlate with serum IgG levels (Morrill and Tyler, 2012; Thornhill *et al*., 2015). Several studies have validated the accuracy of refractometer-based TSP measurement, establishing it as a reliable field-based tool for assessing PIT success (Cuttance *et al*., 2019; Vogels *et al*., 2013). Hue *et al*. (2021) further confirmed that refractometry effectively evaluates colostrum intake and passive immune status in neonatal calves.

Beyond its role in assessing passive immunity, TSP has also been associated with early calf growth performance and health outcomes. Manriquez *et al*. (2018) categorized TSP levels into three groups: low (≤6.5 g/dL), moderate (6.6-7.4 g/dL), and high (≥7.5 g/dL). A notable study by Cortese *et al*. (2020) evaluated 39,619 neonatal dairy calves and found that TSP concentrations between 6.0 and 8.5 g/dL were associated with optimal health and growth. Specifically, calves within this TSP range exhibited reduced death, diarrhea, and pneumonia incidences. Conversely, calves with TSP concentrations below 5.0 g/dL or above 8.5 g/dL faced higher risks of adverse health events, emphasizing the importance of this threshold in calf survival. Furthermore, a systematic review by Lombard *et al*. (2020) found that calves with TSP ≥6.2 g/dL demonstrated optimal passive immunity transfer. These findings collectively indicate that maintaining higher TSP levels (>6.5 g/dL) is crucial for improved health status and enhanced growth performance during pre-weaning.

Although many studies have explored the relationship between TSP levels and early calf growth in various production systems, data specific to Indonesian dairy farms remain limited. Specifically, the relationship between TSP concentrations within the first 24 hours of life and key performance indicators such as body weight, average daily gain (ADG), and morbidity during the weaning phase. Given the significance of passive immunity in determining calf health and productivity, further research is warranted to establish evidence-based colostrum management strategies in Indonesia. Therefore, this study aims to evaluate the influence of TSP levels within the first 24 hours post-colostrum administration on the health and early growth performance of Holstein heifer calves in Indonesia. The findings are expected to inform practical strategies to enhance calf-rearing practices, reduce early-life morbidity, and improve growth performance, which contributes to increased productivity and profitability in the Indonesian dairy sector.

MATERIALS AND METHODS

Study location and animal care protocols

The study was conducted at PT. Greenfields Dairy Indonesia Farm 2, Blitar Regency, East Java, Indonesia. During the study period (January 2023 – January 2024), a total of 512 female Holstein dairy calves with an initial weight of 39.0±4.7 kg, without congenital abnormalities, born naturally without assistance, and showing normal breathing patterns that met the criteria for inclusion in the study. All calves were kept according to standard management protocol. Within 30 minutes after birth, the calves were separated from their mothers, weighed using a digital scale (Loadbar Sonic A12E), and got number identification. After that, the calves were placed in individual pens measuring 2.5 × 2 m with straw bedding.

Colostrum collection and administration

Colostrum was collected within 30 minutes to 1.5 hours after birth by full milking from all four quarters of the mother's udder. A 10 mL sample was then evaluated using a sterile milk tube. Colostrum quality was assessed using the refractometric method, using an optical Brix refractometer (brand: Atago Colustrum Refractometer PAL-Colustrum 3805) with a scale of 0–53% Brix. Colostrum was categorized as high quality if it had a content of more than 21% Brix, according to the standards set in reference (Quigley *et al*., 2013).

Colostrum was given in stages, starting with 4 L of colostrum using an Esophageal colostrum tube immediately after the calf was born (within 0 minutes to a maximum of 1 hour). After that, an additional 2 L was given within six hours after the first feeding (Godden, 2008). Thus, a total of 6 L of colostrum was given in two feeding sessions per day, which was gradually increased until it reached a peak intake of 12 L per day between days 22 and 46. From the first day, the calf was also introduced to solid feed in the form of calf starter, provided ad libitum. Between days 47 and 56, the milk volume was gradually reduced from 12 liters to zero, marking the weaning phase. During this transition, the intake of solid feed was increased to support the calf's nutritional shift from milk to solid feed.

Total serum protein (TSP) evaluation

After 24 hours postpartum, a 10 mL blood sample was taken from the jugular vein of each calf to measure total serum protein (TSP) as an indirect indicator of serum IgG concentration. TSP measurements were performed using a refractometer with the Atago Serum Proteins Refractometer PAL-11S brand (Thornhill *et al*., 2015). The TSP values obtained from calves were then grouped based on their TSP concentration at 24 hours of age: (1) TSP ≤6.5 g/100 ml, (2) TSP between 6.6–6.9 g/100 ml, and (3) TSP ≥7.0 g/100 ml (Aghakani *et al*., 2023). The resulting TSP value was used as a guideline for observing the growth and health of calves for 180 days.

Growth and health performance data collection

The parameters used for growth were body weight and pre-weaning average daily gain. The body weight was measured at birth (0 days), 56 days, and 180 days. For the average daily gain, it was calculated using a formula NAHMS (2007) as follows:

$$\text{average daily gain} = \frac{\text{weaning weight} - \text{birth weight}}{\text{age (in days) at weaning}}$$

The health was monitored individually twice daily (before feeding) for signs of illness such as weakness, decreased appetite, dehydration, fever, abnormal stool consistency, increased respiratory rate, and other signs of lethargy. Feces were scored daily according to the procedure of Habibi *et al*. (2019) and categorized as firm and well-formed (score 1), soft (score 2), loose (score 3), and liquid and splattered (score 4). Calves were considered to have diarrhea if their stool score was ≥3. If they had a stool score ≥3 and a cough or runny nose, the calves were examined by a veterinarian to confirm diarrhea or pneumonia (Habibi *et al*., 2019). Treatment procedures for diarrhea and pneumonia are implemented at Greenfields Dairy Indonesia. Treatment was stopped in calves that did not respond to treatment.

Data analysis

Body weight, average daily gain, and health disorders of dairy calves were analyzed using variance analysis (ANOVA). If there was a significant effect ($p<0.05$), the analysis was followed with Duncan's Multiple Range Test to test the difference between treatments using Genstat 12.2 software.

RESULTS AND DISCUSSION

Body weight and ADG performances after colostrum administration

The results of the descriptive analysis are presented in Table 1, showing the Brix value of colostrum, TSP concentration at 24 hours, birth weight, and body weight at 56 and 180 days of age in Holstein dairy calves. The average Brix value of the colostrum administered to newborn calves was 30.98 ± 4.83%, indicating a generally high-quality colostrum with sufficient immunoglobulin content to support passive transfer of immunity. At 24 hours after colostrum intake, calves had an average TSP concentration of 6.49 ± 0.65 g/100 ml, suggesting successful passive immunity transfer in most cases, as values above 5.5 g/100 ml are typically considered adequate. The average birth weight of Holstein calves was 35.93 ± 3.01 kg, while the average weaning weight at 56 days was 87.83 ± 7.17 kg. By 180 days of age, the calves reached an average body weight of 220.42 ± 28.91 kg, reflecting optimal growth in early life.

Table 1: Descriptive statistics of Holstein-Friesian calves used in the study.

Parameter	Mean	Max.	Min.
Brix colostrum (%)	30.98±4.83	51.5	22
Total serum protein at 24 h (g/100 ml)	6.49±0.65	8.6	4
Birth weight (kg)	35.93±3.01	64	28
Weaning weight at 56 day (kg)	87.83±7.17	110	70
Weight at 180 day (kg)	220.42±28.91	320	136

Statistical analysis (Table 2) indicated that TSP values at 24 hours had no significant effect ($P>0.05$) on the growth performance of Holstein dairy calves. However, calves with TSP ≤ 6.5 g/100 ml at 24 hours exhibited lower birth weight, weaning weight (56 days), and body weight (180 days) compared to those with TSP levels of 6.6–6.9 g/100 ml and ≥7.0 g/100 ml. Additionally, the average daily gain (ADG) during the 1–56 day and 57–180 days periods increased as TSP concentration increased.

Table 2: Effect of total serum protein measured 24 hours after colostrum administration on body weight of Holstein-Friesian calves.

Parameter	Total serum protein at 24 h (g/100 ml)			p value
	≤ 6.5	6.6-6.9	≥7.0	
Birth weight (kg)	35.19±2.97	35.88±3.14	36.03±2.21	0.488
Weaning weight at 56 day (kg)	87.40±6.87	89.58±8.18	90.12±7.03	0.506
Weight at 180 day (kg)	217.89±21.10	219.44±29.63	221.02±27.36	0.211
Average daily gain (g/day)				
1 – 56 day	914.51±127.30	943.47±120.03	946.82±116.70	0.065
57 – 180 day	1034.54±230.17	1054.91±225.80	1058.51±221.81	0.159

The growth performance of Holstein-Friesian calves between 58 and 180 days of life was positively influenced by TSP concentration measured 24 hours after birth. This suggests that higher TSP values following colostrum Brix administration contributed to increased body weight and ADG. These findings align with previous studies, such as Cordero-Solorzano *et al.* (2022), which reported a significant linear relationship between serum colostrum immunoglobulin (Ig) levels to ADG and body weight in 30-day-old buffalo calves. Similarly, studies by Elsohaby *et al.* (2019) and Robison *et al.* (1988) demonstrated that higher serum colostrum IgG concentrations were significantly correlated with increased body weight and ADG in dairy calves during the first 21 to 180 days of life. Additionally, Cuttance *et al.* (2018) found that for every 1.0 g/dL increase in TSP concentration, weaning weight increased by 0.4 kg. Stefańska *et al.* (2021) further observed that TSP concentration within the first 24 to 48 hours after birth was closely related to birth weight, with calves exhibiting higher TSP concentrations generally displaying higher birth weights and ADG up to 450 days of age.

In this study, calves were fed colostrum at a rate of 10% of their body weight, followed by transition milk, whole milk, and a consistent starter feed. The primary factor influencing TSP variation among calves was the quality of the colostrum Brix consumed, which ranged from 22% to 51.5%. These results are consistent with previous research on dairy calves, such as Deelen *et al.* (2014), which suggested that effective colostrum management can enhance passive transfer success. Using a Brix refractometer enables the estimation of IgG levels in both colostrum and calf serum, providing a valuable tool for optimizing colostrum feeding strategies (Deelen *et al.*, 2014). Colostrum contains various hormones and growth factors, including insulin, IGF-I, IGF-II, growth hormone, adiponectin, and leptin, which support digestive tract development and the production of digestive enzymes (Playford and Weiser, 2021). Therefore, adequate colostrum intake provides short-term benefits and long-term effects on growth, fertility, and milk production in dairy calves (Shivley *et al.*, 2018).

Health status of calves treated with different TSP concentrations

Observations in this study showed that the incidence of diarrhea and pneumonia in Holstein-Friesian calves from birth to 180 days decreased as TSP concentration increased (Table 3). The TSP concentration at 24 hours had a significant effect (P<0.05) on the risk of diarrhea and pneumonia in dairy calves. The highest incidence of diarrhea (20.83%) and pneumonia (10.42%) was observed in calves with TSP ≤ 6.5 g/100 ml at 24 hours. Conversely, calves with lower TSP concentrations were more susceptible to respiratory diseases such as pneumonia, which could inhibit growth. These findings align with those of Buczinski *et al.* (2021), who reported that calves with respiratory disease experienced a decrease in ADG of 0.067 kg/day, consistent with our study.

Table 3: Effect of total serum protein 24 hours after colostrum administration on the incidence of diarrheal disease and pneumonia in Holstein-Friesian calves during 180 days of rearing.

Disease	Total serum protein at 24 h (g/100 ml)			p value
	≤ 6.5	6.6-6.9	≥7.0	
Diarrhea (%)	20.83^{b}	14.53^{a}	7.72^{a}	0.042
Pneumonia (%)	10.42^{c}	5.18^{b}	1.26^{a}	0.006

Calf diseases significantly impact the economic sustainability of dairy farming, both through direct costs related to mortality and treatment and through long-term effects on herd performance. Calves with higher TSP concentrations exhibited lower incidences of diarrhea and pneumonia, likely due to the role of colostrum-derived immune cells in maintaining health. Colostrum contains not only immunoglobulins but also non-immunoglobulin factors such as cytokines, growth hormone (GH), and IGF-1, which interact with Ig concentrations or work independently to enhance immune function, metabolism, and overall growth in dairy calves (Ali and Sayed-Ahmed, 2020). Cuttance *et al.* (2018) found that calves with TSP <5.2 g/dL had a 1.68-fold higher risk of health disorders before weaning. This finding is consistent with our study and those of Donovan *et al.* (1998) and Stefańska *et al.* (2021), which reported correlations between TSP values and the incidence and severity of diarrhea. Additionally, pneumonia was significantly correlated with TSP values during the first six months of a calf's life (Khan, 2017). Virtala *et al.* (1996) reported that pneumonia can inhibit dairy calf growth, reducing weight gain by 0.8 kg and height by 0.2 cm in the first three months. Furthermore, calves with lower TSP levels in the first 30–60 hours post-birth exhibited increased haptoglobin levels, which were associated with higher gastrointestinal and respiratory morbidity and increased inflammatory reactions (Aghakhani *et al.*, 2023).

Calves with higher TSP levels tend to have a greater ability to combat infections and exhibit a more effective immune response than those with lower TSP, which must rely more on humoral immune mechanisms (Elsohaby *et al.*, 2019). Thus, preventing diseases, especially pneumonia, by increasing TSP levels in early life can improve ADG and structural growth. Our results, alongside previous studies, suggest that immune enhancement strategies and TSP optimization can improve calf health during weaning, regardless of the dairy cow management system employed.

Links Researchers

Brix levels in colostrum fed to calves ensure optimal growth and body development. In contrast, calves that experience failure in passive immunity transfer tend to suffer from impaired nutrient utilization and reduced feed intake (Silva *et al*., 2023). A study by Soberon *et al*. (2012) showed that an increase of 1 kg in ADG during the pre-weaning phase could increase first-lactation milk production by up to 1,550 kg. Based on these findings, it can be inferred that increasing TSP levels is an effective strategy for promoting first-lactation milk production by enhancing early feed intake, accelerating body growth, and increasing ADG during weaning. In line with this study, Stefańska *et al*. (2021) found that higher TSP concentrations were associated with increased height, earlier onset of estrus, improved reproductive efficiency, and higher milk yield during the first lactation.

In addition to colostrum management and TSP levels, several external environmental factors play a crucial role in determining calf health, particularly hygiene practices, housing conditions, and general farm management. In this study, calves were housed individually in calf boxes within a closed-house tunnel barn system, designed to reduce environmental stress and limit disease transmission. Prior to placing a new calf in a box, the unit was thoroughly washed with typol and sprayed with disinfectant to ensure a sanitary environment. The surrounding calf barn area was disinfected every two days to maintain a low pathogen load. These consistent sanitation practices are intended to minimize the risk of infection and promote a clean and controlled rearing environment.

Hygiene maintenance extended to regular cleaning routines and equipment sanitation. Every two days, barn floors and the undersides of the calf boxes were scrubbed to remove fecal matter and leftover milk residues that could harbor harmful bacteria. Feeding equipment, including milk bottles and buckets, underwent daily cleaning using a Cleaning-in-Place (CIP) system with hot water and alternating applications of acid and alkali to eliminate microbial contamination. Additionally, calf separators were cleaned twice during the rearing period, once at 15 days and again at 30 days of age, using Typol. These comprehensive hygiene protocols help reduce the risk of enteric and respiratory diseases, thereby contributing significantly to calf health and development alongside nutritional and immune management strategies.

Calf body weight growth is expected to occur in parallel with skeletal development, which is crucial as it is less influenced by body condition and digestive tract contents. Approximately 50% of a calf's height increase occurs within the first six months of life (Kertz *et al*., 1998), suggesting that calves with TSP >6.5 g/dL will experience faster growth in both body weight and skeletal size compared to those with TSP <6.5 g/dL (Aghakani *et al*., 2023).

CONCLUSION

To our knowledge, this study is the first in Indonesia to evaluate the effect of TSP at 24 hours on dairy calf growth. Our findings underscore the critical role of colostrum quality in achieving effective passive transfer of immunity and long-term calf performance. Optimizing colostrum management and monitoring TSP levels can improve calf health, boost growth efficiency, and contribute to more sustainable dairy production systems.

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NOVELTY STATEMENT

This study provides the first comprehensive evidence from Indonesia linking total serum protein (TSP) concentrations at 24 hours post-birth with both growth performance and health outcomes of Holstein dairy calves. While previous research has predominantly focused on Western production systems, our work uniquely integrates colostrum quality, TSP thresholds, and calf morbidity under Indonesian dairy farm conditions. By monitoring 512 calves over 180 days, this study not only validates TSP as a reliable biomarker for passive immunity in a tropical production setting but also establishes practical benchmarks to optimize colostrum management strategies, reduce early-life disease, and enhance calf productivity in emerging dairy industries.

AUTHOR'S CONTRIBUTION

W and LZ designed and coordinated the study. LH and AH supervised the experiment. W performed the experiment, analyzed the data, and drafted the manuscript. S, AW, and KK took part in preparing and critically checking this manuscript. All authors read and approved the final manuscript.

Ethical statement

The Ethics Commission of Muhammadiyah at Malang University approved this study, Number E.5.a/085/KEPK-UMM/III/2023.

Generative AI or AI-assisted Technology Statement

The authors declare that no Genrative AI was used in the creation of this manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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