Research Article

Performance and Blood Biochemistry of Friesian Holstein Dairy Calves with Different Types of Fodder as Forage Starter

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Abstract | High calf mortality (up to 35%) is often linked to poor feed quality and quantity. While elephant grass is commonly used to meet fiber needs, its high crude fiber (32.6%) exceeds the 16% limit young calves can digest, risking digestive issues. This challenge is worsened during the dry season due to limited forage availability. Hydroponic fodder presents a promising alternative, offering lower crude fiber, higher crude protein, fast growth, and year-round accessibility. This study aimed to evaluate the performance and blood biochemistry of weaned Friesian Holstein dairy calves fed various types of hydroponic fodder specifically corn, sorghum, and rice. The research involved 16 calves aged 2 to 3 months, assigned to four forage starter treatments: elephant grass (as the control) and three types of hydroponic fodder. The parameters analyzed included dry matter intake (DMI), body dimensions (shoulder height, body length, and chest circumference), and average daily gain (ADG), as well as blood biochemical markers such as total protein, albumin, globulin, glucose, urea, alanine aminotransferase (ALT), aspartate aminotransferase (AST), and alkaline phosphatase (ALP). The results showed that the treatments had no statistically significant effect on DMI or ADG ($P > 0.05$). However, calves fed hydroponic fodder exhibited a tendency toward improved DMI and ADG, with a particularly significant increase in chest circumference compared to the control group ($P < 0.05$). Importantly, the use of hydroponic forage starters did not adversely affect blood biochemical parameters, indicating that these feed sources are safe and do not compromise animal health. In conclusion, the findings provide evidence that hydroponic fodder corn, sorghum, and rice can be effectively used as forage starters for post-weaning dairy calves. This strategy presents a sustainable and promising approach to improving livestock nutrition and addressing challenges in animal production systems.

Keywords | Blood biochemistry, Forage starter, Friesian Holstein, Hydroponic fodder, Performance, Weaned calves

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INTRODUCTION

In Indonesia, the mortality rate among weaned dairy calves remains significantly high, approximately 35%. This elevated calf mortality can often be attributed to inadequate feed management (Djegho *et al*., 2020). As highlighted by Fentie *et al*. (2020), effective feed management is essential for producing quality replacement stock. These replacement calves are expected to yield milk that is both high in quality and quantity in the future. A critical phase for calves occurs during the feed transition stage, when their diet shifts from liquid (breast feeding) to solid (forage and concentrates). According to Nikkhah and Alimarzaei (2022) and Doolatabad *et al*. (2020), the consumption of solid feed is vital in providing energy and protein for the growth of calves. To promote the development of the rumen epithelium in weaned calves, easily fermentable carbohydrates are necessary. Additionally, Xiao *et al*. (2020) noted that providing starter forages can enhance rumen development in weaned calves.

The digestion process in weaned calves must adapt to the provided feed. Feeding them diets high in crude fiber (CF) can hinder digestion, as the rumen in calves, as observed in this study, is not yet fully developed (Izadbakhsh *et al*., 2024). Weaned calves require forage to stimulate their rumen growth and development. However, on smallholder farms, the forage typically available has a high CF content of 32.60% (Rustiyana *et al*., 2016). In contrast, calves can only tolerate a maximum of 16% CF in their feed (BSN, 2024). The high CF content in forage, such as elephant grass, negatively affects calf digestibility. Starter feeds are essential for promoting rumen development, which, in turn, supports the rumen fermentation process and enhances calf performance. Additionally, the availability of forage is often limited, especially during the dry or lean seasons. Therefore, there is a need for alternative forage sources to replace high CF forage. This research proposes hydroponic fodder made from various grains as a viable alternative.

Hydroponic fodder presents a sustainable alternative for providing quality forage to ruminants. This innovative technology has gained traction in various countries (Girma and Gebremariam, 2019). Hydroponic fodder offers numerous benefits for animal health, being rich in protein, vitamins, fiber, and minerals (Ibarruri *et al*., 2021). Additionally, hydroponic feeding enhances the digestibility of nutrient rations, contributing to increased milk production. The source of this fodder can include grains such as corn, sorghum, rice, wheat, and barley. Hydroponic fodder can be harvested in a relatively short time of 6 to 10 days after seeding and can be produced year-round (Ghorbel and Kosum, 2022). The nutritional profile of corn fodder includes crude protein (CP) at 13.30%, dry matter (DM) at 90.93%, and CF at 6.37% (Naik et al., 2014; Rayani *et al*., 2021). For sorghum fodder, the nutritional values are CP ranging from 8.9% to 9.5%, DM between 92.50% and 92.78%, and CF from 2.70% to 2.80% (Iqbal and Asif, 2015). Rice fodder has a CP content of 8.55%, DM of 93.55%, and CF of 14.62% (Rayani *et al*., 2021). While the nutritional content of these various fodder types is suitable as a forage starter, their effectiveness must be assessed through blood biochemical levels as indicators of calf health. Consequently, this research was conducted to evaluate the performance and blood biochemistry of weaned Friesian Holstein dairy calves fed various types of hydroponic fodder specifically corn, sorghum, and rice.

MATERIALS AND METHODS

Site of research

This study was conducted in Enrekang Regency, South Sulawesi Province, Indonesia. Blood samples were tested at the Makassar Health Laboratory Center located at Jalan Perintis Kemerdekaan No. 11, Tamalanrea, Tamalanrea District, Makassar City.

Research material

This study involved four Friesian Holstein dairy calves aged 2 to 3 months (during weaning), with an average body weight ranging from 60 to 80 kg. The calves were provided with elephant grass (*Pennisetum purpureum*) as a control forage, along with a fodder mixture (comprising sorghum, corn, and rice) constituting 10% of the calves body weight.

Research design

The study was conducted using a Latin square design, involving four treatments and four periods to account for variation and ensure reliable replication. The treatments consisted of different types of hydroponic fodder used as forage starters for Friesian Holstein dairy calves. Each treatment was designed to assess the effects of a specific hydroponic fodder type on calf growth and overall health.

The four forage starter treatments were as follows:

EG= Elephant grass (Pennisetum purpureum) – Control group
CF= Corn Fodder (Zea mays L.) – Hydroponic
SF= Sorghum fodder (Sorghum bicolor L. moench) – Hydroponic
RF = Rice fodder (Oryza sativa) – Hydroponic

The nutrient composition of each type of hydroponic fodder is presented in Table 1.

Table 1: Nutrient content of each type of hydroponic fodder.

Treatment	Ash	CP	GE	ADF	NDF	LIG	CEL	DMD	CPD	OMD	GED
EG	14.63	18.38	3451	32.44	50.76	3.06	21.76	66.47	70.12	68.89	62.58
CF	6.71	18.35	3881	10.03	26.93	1.30	9.03	79.96	76.34	78.15	74.64
SF	10.09	22.83	4082	28.79	44.03	10.89	17.30	60.57	65.78	56.52	53.85
RF	7.53	19.92	3795	30.88	52.07	4.93	23.41	57.53	63.07	56.21	50.48

Description: Crude protein (CP); Gross Energy (GE); Acid Detergent Fiber (ADF); Neutral Detergent Fiber (NDF); Dry Matter Digestibility (DMD); Crude Protein Digestibility (CPD); Organic Matter Digestibility (OMD); dan Gross Energy Digestibility (GED); Elephant Grass (EG); Corn Fodder (CF); Sorghum Fodder (SF); Rice Fodder (RF).

Research implementation

Hydroponic fodder production involves the use of various types of seeds, including corn, sorghum, and rice. The seeds are thoroughly washed and soaked in clean water for 12 hours. Sorghum seeds are then spread on trays at a density of 0.38 g/cm^2 (Wahyono et al., 2019), while corn seeds are distributed at a density of 0.45 g/cm^2 (Harwanto *et al*., 2022), and rice seeds are spread at a density of 0.14 g/cm^2 (Rayani *et al*., 2021). The seeds are irrigated with liquid organic fertilizer, and all treatments are arranged on racks exposed to sunlight. Watering of the fodder occurs every 3 hours. The fodder is harvested after 14 days and is provided to calves. The process of producing hydroponic fodder is illustrated in Figure 1.

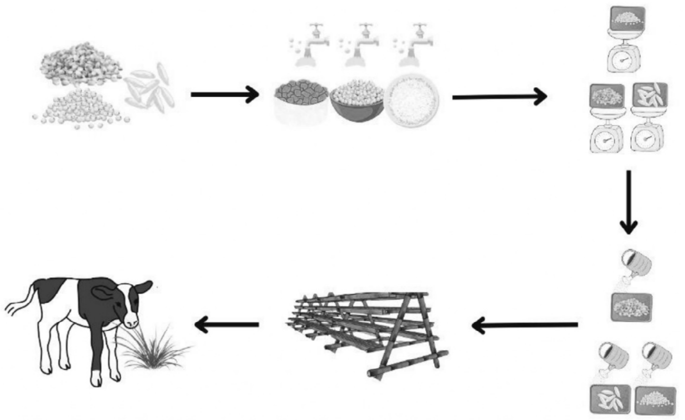

Figure 1: Flow of hydroponic fodder production.

The feeding of hydroponic fodder to the calves was carried out over a period of 10 days, which included 3 days for habituation, followed by 7 days of observation. The calves were fed three times daily at 07:00 AM, 11:00 AM, and 04:00 PM. The quantity of fodder administered was set at 3% of the calf's body weight. Fresh drinking water was provided *ad libitum.*

The study involved a comprehensive assessment of dry matter intake (DMI) and calf performance, which included detailed measurements of body dimensions such as shoulder height, body length, and chest circumference. These measurements were conducted using observational methods that entailed direct assessment at the research site, ensuring accuracy and reliability. Additionally, the analysis of blood biochemical levels was performed at the Laboratory of the Center for Health in Makassar, where precise methodologies were employed to obtain vital insights into the health and development of the calves.

Observed parameters

Dry Matter Intake (DMI) was calculated using the formula Kearl (1982):

$$\text{Feed Consumption (DM)} = \frac{\text{Total Feed (g DM)} - \text{Total Resiudal Feed (g DM)}}{\text{Duration of Study (Days)}}$$

Average daily gain (ADG) calculated using the formula Winter (1961):

$$\text{ADG} = \frac{\text{Final Weight} - \text{Initial Weight (Kg)}}{\text{Duration of Study/Treatment (Days)}}$$

Shoulder height was determined by measuring the perpendicular distance from the ground to the highest point of the shoulder, positioned behind the hump and parallel to the front foot, using a yardstick. Body length is measured from the left side of the cattle by calculating the distance between the shoulder point (the lateral tuberosity of the humerus) and the thigh bone (tuber ischii). Chest circumference is recorded by wrapping a measuring tape around the chest, situated behind the hump (Goe *et al*., 2001).

On the tenth day of treatment, blood samples were collected to evaluate the blood biochemical profile. A total of 3 mL of blood was drawn from the jugular vein of each calf using a sterile syringe and needle holder. The samples were then left at room temperature for 30 minutes to allow clotting. Subsequently, they were centrifuged at 3,000 rpm for 10 minutes to separate the serum. The resulting serum was transferred into labeled microtubes and stored in a cooler to maintain sample integrity during transportation to the laboratory for blood biochemical analysis. Blood biochemistry parameters, including total protein, albumin, globulin, urea, glucose, calcium, alanine aminotransferase (ALT), aspartate aminotransferase (AST), and alkaline phosphatase (ALP), were analyzed using a photometric method with an autoanalyzer. Total protein was determined by the Biuret method (Gornall *et al*., 1949), while albumin levels were measured with the Bromocresol Green reagent (Doumas et al., 1997). Globulin levels were calculated indirectly as the difference between total protein and albumin. Urea was assessed using the urease-glutamate dehydrogenase method (Sampson and Baird, 1979). Glucose was analyzed through the enzymatic glucose oxidase-peroxidase method (Müller, 1925; Heller and Ulstrup, 2021). Calcium was measured using the Arsenazo III colorimetric method (Savvin, 1959). Both ALT and AST were analyzed according to the International Federation of Clinical Chemistry method, without the use of a pyridoxal phosphate activator (Lustig *et al*., 1988).

Blood protein and albumin levels were rigorously assessed using the established biuret and bromocresol green methods. Additionally, blood serum globulin concentrations were calculated by employing the formula: Total protein minus albumin (Orhue *et al*., 2005).

Data analysis

Data were analyzed utilizing the General Linear Model

(GLM) procedure within the Analysis of Variance (ANOVA) framework, employing SPSS software for Windows version 26.0, obtained from Chicago, IL, USA. A 95% confidence level was established for the analysis. Duncan's test was applied when the mean values of the treatments indicated a significant effect (P<0.05).

RESULTS AND DISCUSSION

Growth performance

The growth performance data of weaned calves fed with different types of fodder as forage starter presented in Table 2. Dry matter intake and ADG showed no significant effect (P>0.05) on the various fodder types used as forage starters. However, DMI and ADG tended to be greater in the CF treatment compared to the other treatments. Additionally, while body dimensions such as shoulder height and body length did not significantly differ (P>0.05) among the treatments based on fodder type, chest circumference displayed a significant effect (P<0.05) when comparing the CF and RF treatments, both of which were notably larger than EG. Notably, chest circumference in the CF treatment tended to be higher than in the other treatments. DMI, ADG, and chest circumference generally favored the CF treatment over the others. The elevated ADG observed in the CF treatment can be attributed to the high digestibility of protein, energy, and fiber present in corn fodder, making it easier for weaned calves to digest. This aligns with the research conducted by Terefe and Mengistu (2022), which indicated that hydroponic corn as a substitute for early calf feed can enhance dry matter intake and body weight gain. Furthermore, Arif *et al.* (2023) noted that substituting feed with corn fodder can lead to increased feed consumption. Enhanced digestibility and feed consumption are critical factors in improving the nutritional value of forage. In line with this, Naik *et al.* (2016) pointed out that hydroponic fodder has a soft texture and easily digestible fibers, which promote better digestion and nutrient absorption. Seymour *et al.* (2019) emphasized that DMI is a key factor in assessing feed efficiency in livestock and evaluating growth and production efficiency. Barlett *et al.* (2024) further stated that DM consumption is positively correlated with livestock body weight gains, where an increase in feed consumption corresponds to an increase in body weight.

In this study, the observed increase in ADG corresponded with an increase in DMI (Table 2). The high digestibility of feed in corn fodder positively influences nutrient sufficiency, thereby enhancing the body weight gain of the livestock. Although the effect was not statistically significant, calves fed with CF tended to exhibit higher ADG. This tendency is attributed to the higher digestibility of CF compared to other treatments (Table 1). Feed digestibility is a critical indicator for determining the amount of nutrients and feed components that can be absorbed in the digestive tract, as feed quality is influenced not only by its nutrient content but also by its digestibility. Providing feed with high nutrient content but low digestibility may result in nutritional deficiencies in dairy calves. Conversely, highly digestible nutrients positively contribute to improved ADG, as they ensure adequate nutrient availability to support post-weaning growth (Utamy *et al.*, 2025).

Conversely, inadequate nutrient sufficiency can lead to low growth performance, as noted by Wang *et al.* (2024). A low DMI suggests that livestock are receiving fewer nutrients, which can impede their growth rate. Utamy *et al.* (2021) further explained that a reduction in DMI may be attributed to high fiber content, resulting in decreased productivity in livestock. Notably, corn fodder exhibited the highest digestibility values among all treatments, with a dry matter digestibility (DMD) of 79.95%, crude protein digestibility (CPD) of 76.33%, organic matter digestibility (OMD) of 78.15%, and gross energy digestibility (GED) of 74.64% (Table 1). Additionally, Rani *et al.* (2019) indicated that calves fed hydroponic corn did not experience negative effects on nutrient digestibility and exhibited an increase in body weight growth.

The use of corn and rice fodder positively influenced chest girth gain, demonstrating superior results compared to sorghum fodder and elephant grass (Table 2). This is attributed not only to their higher nutrient content, better palatability, and enhanced digestibility but also to their

Table 2: Growth performance of weaned calves fed with different types of fodder as forage starter.

Parameters	**Treatment**				**Sig**
	EG	**CF**	**SF**	**RF**	
DMI (kg/day)	1.10±0.22	1.61±0.59	1.05±0.21	1.55±0.40	0.25
ADG (kg/day)	0.26±0.07	0.50±0.09	0.28±0.15	0.44±0.10	0.06
Body dimensions (cm)					
Shoulder height	0.21±0.08	0.17±0.07	0.14±0.03	0.15±0.03	0.39
Body length	0.14±0.03	0.21±0 .08	0.17±0.07	0.21±0.08	0.21
Chest circumference	0.12±0.20^{b}	0.20±0.04^{a}	0.16±0.02^{ab}	0.17±0.04^{a}	0.04

Description: Dry Matter Intake (DMI); Average Daily Gain (ADG); Elephant Grass (EG); Corn Fodder (CF); Sorghum Fodder (SF); Rice Fodder (RF).

Table 3: Blood biochemical levels of weaned calves fed with different types of fodder as forage starter.

Parameters	Treatment				Sig
	EG	CF	SF	RF	
Blood protein (g/dL)	5.50±0.34	5.52±0.68	5.46±0.69	5.60±0.34	0.98
Albumin (g/dL)	2.60±0.18	2.62±0.34	2.53±0.37	2.62±0.23	0.97
Globulin (g/dL)	2.90±0.43	2.90±0.69	2.93±0.40	2.97±0.55	0.99
Glucose (mg/dL)	76.66±13.57	79.66±11.11	80.75±9.46	76.25±19.18	0.83
Urea (mg/dL)	10.00±2.44	7.25±4.27	6.50±4.27	10.66±2.05	0.25
ALT (U/L)	26.25±5.56	26.50±8.69	28.33±7.84	29.66±3.85	0.91
AST (U/L)	78.66±6.23	88.55±13.24	78.00±13.95	77.75±13.52	0.72
ALP (U/L)	200.25±62.21	247.00±82.00	166.50±33.39	202.00±91.56	0.70

Description: Alanine transaminase (ALT); Aspartate aminotransferase (AST); Alkaline phosphatase (ALP); Elephant Grass (EG); Corn Fodder (CF); Sorghum Fodder (SF); Rice Fodder (RF).

optimal energy efficiency, which supports livestock growth. Li *et al.* (2024) reported that high-quality feed provided in adequate amounts facilitates rapid growth in livestock; conversely, poor feed quality hampers growth. In this study, an increase in chest circumference was observed alongside growth in body weight, as noted by Oliveira *et al.* (2025) and Silva *et al.* (2024), who established a positive correlation between chest circumference and body weight gain. The chest cavity, which houses the heart and lungs, develops with the livestock, and as chest circumference increases, so does body weight, reflecting associated bone and muscle development. Firdaus *et al.* (2023) further emphasized that chest circumference size increases in tandem with muscle tissue growth in the chest area. Moreover, Ghorbel and Kosum (2022) highlighted hydroponic fodder as a sustainable alternative for providing quality starter forage for calves, particularly during feed shortages in the dry season. Fodder offers numerous health benefits for animals, being rich in protein, fiber, vitamins, and minerals. Santoso *et al.* (2021) underscored the importance of quality feed in fulfilling the nutritional needs of calves as replacement stock. Additionally, Nguyen *et al.* (2024) and Tabun *et al.* (2022) noted that the availability of feed significantly impacts the growth of shoulder height, body length, and chest circumference, whereas feed deficiencies can inhibit growth and prevent calves from reaching their full potential.

Blood biochemical profile

Blood biochemical levels in weaned calves fed with different types of fodder as forage starter can be seen in Table 3. The analysis of blood biochemical levels in weaned calves showed that using different types of hydroponic fodder as forage starters had no significant effect (P>0.05). The levels of blood protein, albumin, globulin, glucose, urea, ALT, AST, and ALP remained within normal ranges. These findings are consistent with previous studies: protein and albumin levels align with Motta *et al.* (2023); globulin with Mehrez *et al.* (2018); glucose with Roadnight *et al.* (2021); urea levels (6.50–10.66 mg/dL) with Sharma *et al.* (2021); AST with Yu *et al.* (2019); and ALT, AST, and ALP with Hata *et al.* (2021).

Blood parameters are important indicators of livestock health. Blood tests offer insights into physiological status, metabolism, nutrition, and possible infections or diseases. According to Puay *et al.* (2023), total protein, albumin, globulin, glucose, and urea levels reflect how well nutrients are digested and absorbed into the bloodstream. Blood glucose specifically shows the energy available to the body. Gorski and Saba (2012) stated that blood protein levels indicate nitrogen metabolism, which can vary depending on dietary protein and energy intake. Sudarman *et al.* (2019) added that changes in total protein are influenced by albumin and globulin levels. Albumin plays key roles in maintaining blood pressure and transporting substances (Throop *et al.*, 2004; Orhue *et al.*, 2005). Low albumin levels may result from poor absorption, reduced liver synthesis, or increased protein loss through the intestines or kidneys.

Hydroponic fodder offers several benefits for weaned calves, including improved nutrient digestibility, high nutritional content, enhanced productivity, and overall health advantages (Girma and Gebremarium, 2019). Abdula (2022) noted that this technology also addresses forage shortages during the dry season and allows for quality feed production even on limited land. According to Welboren et al. (2021), blood glucose levels are influenced by dietary carbohydrates, such as structural carbohydrates and BETN, and by the animal's age. Calves tend to show a stronger glucose response due to higher energy demands. Utamy *et al.* (2025) explained that blood urea levels are affected by dietary protein, as urea is mainly formed from protein breakdown. Peng *et al.* (2021) added that urea is a nitrogenous waste product of protein metabolism, produced in the liver and excreted by the kidneys. Enzymes such as ALT, AST, and ALP are involved in protein metabolism and serve as indicators of liver health. When liver cells are damaged, ALT and AST are released into the bloodstream, increasing their activity levels. Boudjellaba *et al*. (2018) identified these enzymes as markers of liver cell damage, with AST also serving as an indicator of fat accumulation in the liver. Mohsin *et al*. (2022) noted that ALT, primarily found in the cytoplasm, increases in plasma during fatty liver conditions.

CONCLUSION

This study found that using hydroponic fodder as a forage starter for Friesian Holstein calves positively influenced growth and performance. Corn-based hydroponic fodder resulted in the highest average daily gain and dry matter intake, likely due to its high digestibility. Calves fed hydroponic fodder also showed greater increases in chest circumference compared to those fed elephant grass. Moreover, hydroponic fodder had no significant effect on blood biochemical parameters, suggesting it is safe for calf health. Therefore, hydroponic fodder presents a sustainable alternative in modern livestock systems to enhance feed efficiency and productivity.

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NOVELTY STATEMENT

This preliminary study investigates the impact of different types of hydroponic fodder such as corn fodder, sorghum fodder, and rice fodder used as starter feed on the performance and blood biochemistry of weaned Friesian Holstein calves. The novelty of this research lies in the application of a hydroponic system as an alternative source of high-nutrient feed during the post-weaning transition phase, which is widely recognized as a critical period in calf development. Unlike previous studies that primarily focused on feed productivity or responses in adult livestock, this study emphasizes the growth performance and blood biochemical profiles of weaned calvesin response to various hydroponic fodder types. Notably, in Indonesia, particularly inEnrekang Regency, the implementation of hydroponic fodder systems has never been carried out, highlighting the originality and practical relevance of this research.

AUTHOR'S CONTRIBUTION

Andi Fitri Nurbina: Designed and set up experiments, conducted fieldwork, compiled and analyzed data, and contributed to the writing and preparation of the manuscript.
Renny Fatmyah Utamy: Designing and organizing experiments, supervising the research process, and providing tec hnical guidance at each stage were integral components of this study.
Ambo Ako: Designing and organizing experiments, supervising the research process, and providing technical guidance at each stage were integral components of this study.

Ethical approval

This research was conducted in accordance with the approved protocol and did not violate animal welfare standards. Ethical approval was granted by the Research Ethics Commission of Hasanuddin University under certificate number 018/UN4.12/EC/II/2025.

Generative AI and AI-assisted technology statement

Generative AI and AI-assisted technologies were utilized solely to improve language clarity and grammar during manuscript preparation. No AI tools were employed for data analysis, interpretation, or generation of scientific content. The authors take full responsibility for the integrity, accuracy, and originality of all scientific content presented in this manuscript

Conflict of interest

The authors have declared no conflict of interest

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