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RELATIONSHIP BETWEEN MATERNAL FACTORS, COLOSTRUM QUALITY, AND WEANING WEIGHT PERFORMANCE IN HOLSTEIN CALVES IN HIGH ANDEAN SYSTEMS IN ECUADOR.

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ABSTRACT: *Bovine colostrum quality plays a crucial role in the passive transfer of immunity and the early growth of calves. This research investigated how maternal factors, colostrum Brix percentage, and additional variables are associated with calf weaning weight in 34 Holstein in an altitude system in Tulcán, Ecuador. Colostrum samples were collected in the first two hours postpartum and analysed by digital refractometry. Non-parametric analysis and multiple linear regression were applied. 82.4% of the samples were classified as good quality. Surprisingly, a negative correlation was found between % Brix and weaning weight (ρ = -0.40, p = 0.02). Parity was significantly associated with colostrum quality (p = 0.0496). The regression model explained 84% of the variability in weaning weights, with birth weight, cow weight, and colostrum quality being significant. These results highlight the need for comprehensive colostrum evaluation beyond % Brix.*

KEYWORDS: Colostrum quality; passive immunity; weaning weight; brix refractometry; maternal factors.

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INTRODUCTION

The early intake of colostrum is a critical determinant of calf survival, as it supplies essential immunological and nutritional support during the initial hours of life. Several studies have documented the frequent inadequacies in both the volume and immunoglobulin content of colostrum in dairy cows (Luiza et al., 2020). For effective passive immunity transfer, it is recommended that calves ingest a quantity of colostrum equivalent to at least 10% of their body weight within the first few hours post-birth, preferably between 2 to 4 hours (Matamala, 2014; Tello & Zedeño, 2015; Yepes & Prieto, 2011). The quality of colostrum is determined by the concentration of immunoglobulin G (IgG) it contains. Thus, a good quality colostrum should contain at least 50 mg/ml of immunoglobulins (Lozic, 2013). Meeting these characteristics will help to harness the absorption potential of intestinal cells and, at the same time, decrease permeability to pathogenic microorganisms (Tello & Zedeño, 2015). The quality of ingested colostrum is another factor that conditions Ig levels in the blood, with 2 liters of colostrum after birth being the general rule for increasing Ig levels in the blood and depleting the absorption potential of the intestinal cells of macromolecules at an early stage, at the same time decreasing permeability to pathogenic microorganisms; It is also advisable to feed the same amount between 8 and 12 hours of age and to feed 10% of the calf's live weight with colostrum for several days after birth (Chacón 2009). Colostrum protects calves during the first weeks of life, reducing the risk of morbidity and mortality. It also stimulates the development of the gastrointestinal system, promoting the elimination of waste and the establishment of normal bowel movements. Colostrum contributes to the animal's long-term productivity by improving daily weight gain and feed efficiency, reducing age at first calving, improving production during the first and second lactation, and reducing the probability of culling during the first lactation. It is the first source of nutrition after birth and is fundamental to the process of thermogenesis in the calf in the first hours of life (Farooq et al., 2024; Yanuartono et al., 2022).

METHODOLOGY

Study area

The study was conducted at Hacienda Mavelita, situated in La Rancheria, Huaca Parish, Tulcán Canton, in the Carchi Province of Ecuador. This highland region lies above 3000 meters of altitude and has an average temperature of approximately 12°C. The data collection spanned from November 2024 through March 2025.

Experimental design

The study was an experimental, cross-sectional study, consisting of the evaluation of the quality of bovine colostrum by means of the reflectometry method. The cows subjected to the study were those that entered the lactation period (immediately after calving). The cows were fed on a grazing basis with ad libitum mineral salt supplementation. After data collection in the established period, the results are stratified by number of calvings, cow weight, calf weight at birth, calf weight at weaning, brix percentage, and colostrum quality.

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Sample Analysis

Thirty-four samples of 50 ml of colostrum were collected in the first 2 hours after calving and stored in a sterile plastic bottle for subsequent analysis using a digital refractometer to determine the percentage of Brix degrees.

Statistical Analysis

Statistical analysis was performed using R software. The Shapiro-Wilk test was applied to verify the normality of continuous variables. Variables that violated the normality assumption were examined using non-parametric methods. To assess differences in quantitative outcomes across categorical groups, such as parity and colostrum quality—the Kruskal-Wallis test was utilized. A multiple linear regression analysis was then conducted with weaning weight as the dependent variable, incorporating birth weight, maternal weight, colostrum quality, and calf sex as predictors. Model performance was evaluated using metrics such as adjusted R^2, AIC, BIC, and significance levels, with a threshold of $p < 0.05$ indicating statistical relevance.

RESULTS

A total of 34 calves born in the production unit were evaluated, of which 20 were males (58.8%) and 14 were females (41.2%). In terms of colostrum quality evaluated by Brix percentage, 3 samples (8.8%) were classified as low quality, 3 samples (8.8%) as medium quality and 28 samples (82.4%) as good quality (Figure 2).

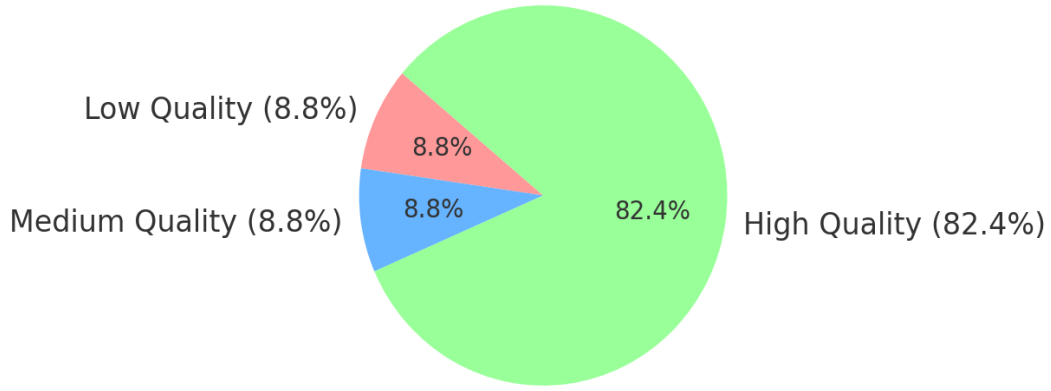

Figure 2: Colostrum Quality Based on Brix Percentage (N = 34)

Continuous variables showed a mostly normal distribution, with the exception of % Brix, which did not meet the assumptions of normality (Shapiro-Wilk test, $p < 0.05$). Therefore, non-parametric tests were applied to analyse this variable; Spearman's correlation analysis revealed a moderate and significant negative correlation between % Brix and weaning weight ($\rho = -0.40$, $p = 0$. On the other hand, the number of calvings of the cow was not significantly correlated with % Brix ($\rho = 0.10$, $p = 0.59$) (Figure 3 B) nor with weaning weight ($\rho = 0.24$, $p = 0.18$) (Figure 3 C).

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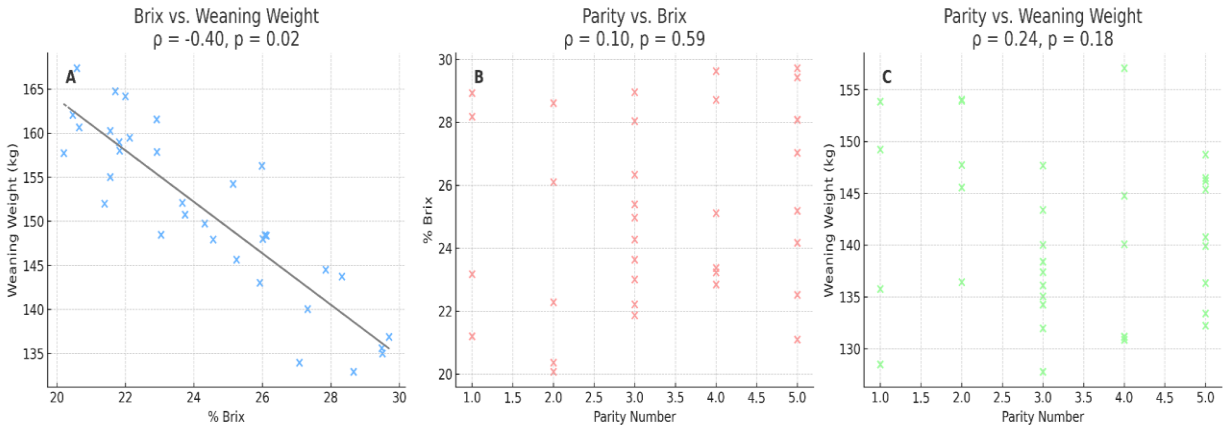

Figure 3: Spearman correlation analyses among colostrum quality (% Brix), calf weaning weight, and dam parity number.

Using the Kruskal-Wallis test, significant differences were detected in the number of calvings according to colostrum quality (H = 5.78, p = 0.0496). Cows with poor quality colostrum had lower parity (mean = 1.00), while those with medium and good quality colostrum had means of 2.67 and 3.68 calvings respectively.

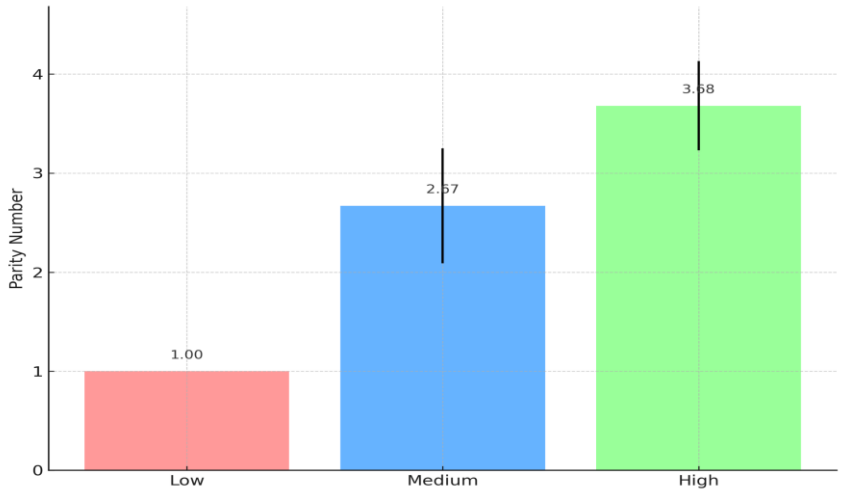

Figure 3: Parity Number by Colostrum Quality Kruskal-Wallis H = 5.78, p = 0.0496

Finally, the multiple linear regression model identified birth weight (β = 0.94, p < 0.0001), cow weight (β = 0.02, p = 0.0191), % Brix (β = -0.22, p = 0.0008), and low colostrum quality (compared to medium quality, β = -4.82, p = 0.0055) as significant predictors of weaning weight. The model had an excellent fit (R^2 = 0.84; adjusted R^2 = 0.81), explaining a high proportion of the variability in weaning weight.

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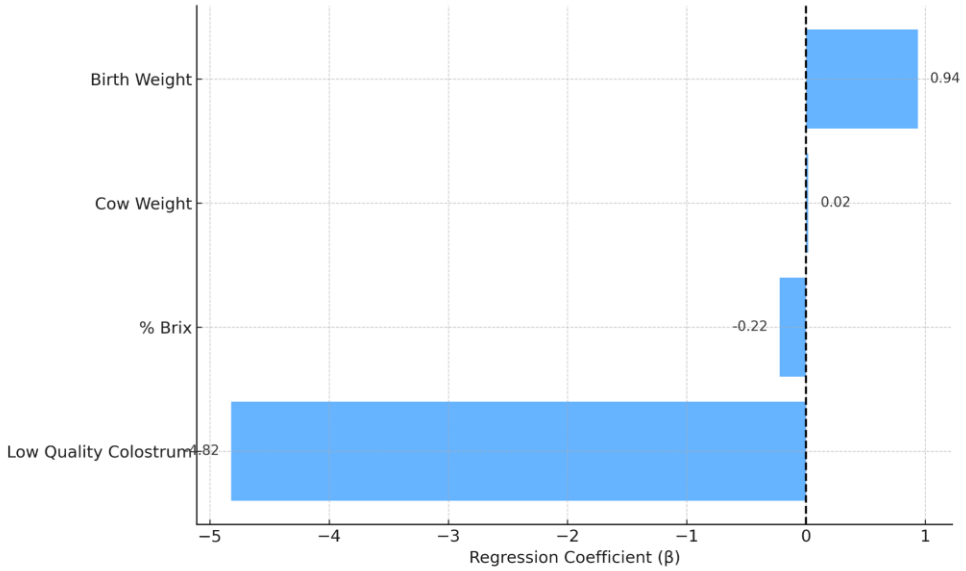

Figure 4: Multiple Linear Regression Predictors of Weaning Weight R^2 = 0.84; Adjusted R^2 = 0.81

DISCUSSION

The results of this study provide valuable information on factors associated with weight performance of calves at weaning, emphasizing the importance of both maternal and neonatal attributes, and provide information on colostrum quality through the analysis and interpretation of brix refractometry (Gamsjäger et al., 2020), this allows for colostrum to be categorized (Table 1), and according to the reported Brix percentage, its quality can be inferred (Dairy Australia, 2020).

Table 1: Refractometer rating scale

Categories	Brix Scale	IgG Concentration (mg/ml IgG)
Good Quality	> 22 ° Brix	> 50 mg/ml de IgG
Medium Quality	20 - 22 ° Brix	50 - 30 mg/ml de IgG
Low Quality	< 20 ° Brix	< 30 mg/ml de IgG

Fuente (Dairy Australia, 2022)

Birth weight was found to be positively associated with weaning weight, a finding consistent with those reported by Aytekin et al., 2019 and Lopez et al., (2020). There are several factors that could influence one of them according to Rooke et al., 2026 is the nutrition of the cow during maternal pregnancy significantly influences birth and weaning weights as calves born to cows fed a balanced diet showed higher birth and weaning weights compared to those fed grass silage. One factor according to Kiroski (2015) is the likelihood of adapting to environmental conditions which is critical during the first hours of life, this can be explained by the fact that a calf born with higher birth weight tends to have better vitality, suckling ability and adaptation to the extrauterine environment, which directly impacts its subsequent growth.

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While maternal cow weight, although of lesser impact than birth weight, was also positively associated with weaning weight (Ziegler et al., 2020), this could be due to higher nutritional and milk capacity in cows of larger body size. Heavier cows have been shown to have higher milk production volume during the first months postpartum (Santos et al., 2018), which is crucial for adequate calf weight development in systems where feeding is based on maternal milk and available forage (Hammon et al., 2020). Colostrum with a Brix % equal to or greater than 25% is of high quality and is essential for passive immunity transfer ('Evaluation of passive immunity absorption in Holstein Heifers', 2022). However, studies indicate that increased somatic cell count (SCC) in colostrum, which is often associated with lower quality, can paradoxically lead to higher initial serum IgG levels but poorer overall health outcomes; increased SCC in colostrum correlates with increased incidence of health problems, such as diarrhoea, which can negatively affect weight gain (Nia et al., 2010).

A particularly interesting and counter-intuitive result in this study was the negative relationship between colostrum Brix percentage and calf weaning weight. In principle, one would expect that higher colostrum quality reflected in higher soluble solids and immunoglobulin content would translate into better health and development indicators (Puppel et al., 2019); in this case, the opposite was found to be true. This apparent contradiction may have multiple influencing factors such as cows producing more concentrated colostrums, with Brix values above 25%, could be producing lower colostrum volumes, which is common in multiparous cows or certain breeds. This lower colostrum availability may limit the total amount of immunoglobulins ingested by the calf, even if the concentration is high.

Another possibility is that high-density colostrums may be more viscous or difficult for neonates to consume, which would limit their intake in the optimal window of intestinal absorption, negatively affecting the transfer of passive immunity. Furthermore, poor management of the timing of administration even with high quality colostrums can significantly reduce the efficiency of IgG absorption, which in turn can compromise subsequent health and growth. It is also noteworthy that, according to Nia et al. (2010), increased somatic cell counts (SCC) in colostrum - an indicator of mammary inflammation - may be associated with elevated levels of immunoglobulins, but also with increased incidence of health problems, such as scours. These adverse conditions can negatively impact weight gain, counteracting the expected benefits of high-quality colostrum. This is consistent with Zheng & Yepes (2021) finding that administration of high-quality colostrum does not necessarily translate into improved daily weight gain (ADG), which reinforces the idea that colostrum quality, while essential for passive immunity, does not act in isolation on calf growth. Factor such as volume, timing of administration, maternal health and the physiological state of the neonate significantly modulate this relationship. It is also important to note that the key to interpreting the negative relationship between colostrum Brix % and weaning weight is the nature of the indicator itself; the Brix refractometer estimates the total concentration of solids in colostrum, but does not distinguish between its specific components, such as immunoglobulins, fat, lactose or other proteins (Siqueira & Kalinouski, 2022). Therefore, a high Brix reading does not guarantee that colostrum is optimally balanced from a nutritional or immunological point of view. In fact, although Brix readings correlate with immunoglobulin G (IgG) concentrations, they can also be influenced by fat or lactose content (Hernandez et al., 2016). This could result in an inaccurate overestimation regarding the immunological or nutritional value of colostrum. In this regard, Brix-rich colostrums may not be promoting growth if the macronutrient profile is too fat or sugar heavy with too little functional IgG, an excess of fat or sugar, and inadequate

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IgG. Also, the dependency of calf performance on the colostrum's nutritional quality isn't colostrum's immunological quality isn't necessarily correlational. Other considerations, such as the child's immune condition, presence of undiagnosed infection, and even captivity stress may alter the dynamics of immunoglobulin intake and growth. (Soufleri et al., 2023). If the calf is immunocompromised or poorly fed, even high-quality colostrum might not yield the expected benefits. A more specific diagnostic tool such as ELISA or SDS-PAGE that allows quantification of the immunoglobulins gives a more accurate evaluation than Brix refractometry which cannot use colostrum's specific nutritional or immunological attributes (Hernandez et al., 2016). The other notable finding of this research was the difference in the number of calvings with respect to colostrum quality, which showed that primiparous cows tend to offer lower quality colostrum compared to multiparous cows, which was the observed outcome. This is consistent with abundant research which shows that the number of parities is one of the most important reasons that explains the immunological constituents of colostrum. It was shown in some studies that Djoharjani et al. (2020) & Salamończyk and Krysiak (2024) found that primiparous cows have lower concentrations of immunoglobulins in colostrum and lower Brix scores. One explanation for this is that first parity cows have not achieved full glandular development and have not been through a mer productive life which comprehensively exposes them to a large variety of antigens. In comparison to older, immune-experienced animals, the limited prior immunological experience set becomes difficult when having to transfer efficient humoral immunity to colostrum due to advanced age. Djoharjani et al. (2020) documented a progressive increase in the % Brix measures of colostrum quality from the second calving (26.88%) to the fifth (29.46%) reinforcing the notion that the accumulation of immunological exposures with each reproductive cycle enables the cow to enrich colostrum with immunoglobulins.

Salamończyk & Krysiak (2024) also documented Brix values as high as 24.2% for cows aged 4 to 7 years in lactation, further reinforcing the claim that multiparity is linked to better quality colostrum. Besides the amount of parity, dry period length prior to calving, as well as feeding management, have significant influence on the quality of colostrum. It has been noted that longer dry periods (between 46 and 59 days) are associated with better results in terms of immunoglobulin concentration (Salamończyk & Krysiak, 2024). On the contrary, mismanagement, particularly in prepartum nutrition, can drastically lower calving colostrum quality even in multiparous cows (Westhoff et al., 2023). These findings strengthen the notion that while multi parity remains as a primary physiological factor determining colostrum quality, there is essence of other factors involved such as meshed management and health conditions. Therefore, identification of first parity cows as a risk group for poor quality colostrum production is critical to implement specific strategies, such as more rigorous monitoring of their colostrum and eventual supplementation or use of better-quality reserve colostrum to ensure adequate immune transfer to the calf.

From a genetic improvement perspective, the results of the present study reinforce the importance of considering not only productive traits such as milk production or fat and protein content, but also maternal and immunological traits, which directly influence neonatal health and zootechnical development of the calf. Colostrum quality, associated with factors such as parity, maternal health and immune response, may itself be an indirect trait of genetic value, with significant impact on early survival and weight gain of the calf. A broad view on the improvement of animals genetically is well supported scientifically. As noted by Sasaki et al. (2024), the selection of cows based on maternal attributes like calving ease and neonatal

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activities can significantly reduce mortality rate and improve calf survival. Selection programs make use of calving ease, and it's associated great deal of genetic variance. Hence, there isn't much of a risk in implementing it and selection inclusion makes sense from productivity and welfare standpoint.

The immunological aspect is of growing importance towards the selection criteria for genetic improvement. The work by Mallard et al. (2015) showed that animals can be selected on the basis of how well their own immune response is, this results in healthier herds and reduced diseases which improves the growth rate of calves. Maternal health with respect to the newborn calf is directly related to the quality of the colostrum it is provided. In this context, Lynch et al. (2024) emphasized the possibility of improving calf immunity right from birth through genetic selection by getting better quality and intake of colostrum. This doesn't stop at the colostrum quantity, but the concentration of immunoglobulin provided acts as the determines the general health of the dam. Moreover, better reproductive and general health indices enable cows to produce healthier calves, as noted by Cushman et al. (2019), which shows that integration of several aspects of maternal phenotype – maternal health, welfare, and ability – is needed in selection schemes. This emphasizes the argument that a sustainable breeding strategy should integrate productive goals alongside welfare concerns of the animals. Not addressing these factors undermines not only the development and survival of calves but also the dairy system's reproductive and economic efficiency.

CONCLUSION

The variables of calf birth weight, cow weight, and colostrum quality cumulatively predicted weaning weight and explained 84% of variability. However, the corded concentration of soluble solids in colostrum (% Brix) was negatively linked to weaning weight, which suggests that better immunological quality does not equate to improved zootechnical performance.

Maternal parity significantly influenced colostrum quality, with multiparous cows producing better quality colostrum, reinforcing the need to monitor especially primiparous cows and optimize colostrum management to ensure adequate transfer of passive immunity.

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