The Effects of Colostrum Quality on Health and Development of Dairy Calves

by Madeline Kinsella

Understanding dairy calf growth and development is essential to ensuring a consistent supply of high-quality products to consumers throughout the nation. The antibody-rich milk—termed colostrum—administered to calves within their first 24 hours of life has become a key factor in increased calf health from birth through long-term development. This research analyzed the relationship between colostrum quality and passive immunity transfer proteins found in blood samples taken from calves between 48-72 hours after birth. Brix refractometry was utilized to measure protein content in these blood samples which were recorded as Brix scores. Another aspect of the project investigated new innovations for colostrum administration aimed at decreasing bacteria counts for higher-quality feeding to provide new data to farmers regarding more advantageous colostrum procedures. Blood samples were taken from 258 calves born over a seven-month period to find Brix scores, which were then compared with lab-tested total protein content and immunoglobulin levels from these blood samples, as well as recorded health events. Results expressed a significant positive correlation between Brix scores and lab-tested total protein content and immunoglobulin levels, as well as a significant correlation of higher Brix scores resulting in lower frequency of pneumonia contracted after 90 days of age. A newer colostrum procedure of administration through use of a single-use O-shaped bag resulted in a higher average Brix score than traditional methods of a reusable pitcher, suggesting that this innovation increases colostrum quality by decreasing the chances for bacteria replication. These results help provide dairy and beef farmers with essential information on the importance of good colostrum management and recommendations for procedures to improve their existing programs.

Introduction

Dairy calves are born with minimal immune systems due to the protective qualities of bovine placenta preventing transfer of vital immunoglobulins from dam to calf during gestation (Ahmann et al., 2021). A dairy calf's first source of immune protection develops entirely from the passive transfer of antibody-rich colostrum within the first few hours of life (Lorenz, 2021). Colostrum is effectively fed through use of esophageal tube feeders immediately after birth and then again twelve hours after birth (Godden et al., 2019). Once the first dose of colostrum is administered, absorption of maternal immunoglobulins (IgG) from colostrum within the small intestine occurs within the first 24 hours of life and protects the calf against disease until it develops its own immune system (Godden et al., 2019). Colostrum quality impacts long-term health in dairy calves, such as decreased mortality postweaning, increased development rates, reduced age at first calving, and increased milk production during first and second lactations (Godden et al., 2019). Good colostrum management increases colostrum quality on dairy farms, ensuring the development of strong and healthy calves. Factors influencing colostrum quality include cow and calf genetics, colostrum yield, equipment cleanliness, and procedure of how colostrum is administered to calves after birth (Soulfleri et al., 2021).

Brix refractometry has become one of the most common ways to effectively monitor colostrum management through passive immunity transfer found in pre-weaned dairy calves' blood samples (Giammarco et al., 2021). Brix refractometry works by passing light through a sample and measuring the amount of refraction to determine the solid content which is representative of various immunity factors. This measurement of solids has been shown to correlate with IgG levels, fat, protein, and lactose within dairy calf blood samples (Buranakarl et al., 2021). Brix percentages are evaluated on a quantitative scale from "poor" to "excellent" quality.

Poor blood serum Brix percentages are values below 8.1% refractive index in the liquid (Jaywant et al., 2022), with successive categories fair, 8.1–8.8%; good, 8.9–9.3%; and excellent, above 9.3% (Godden et al., 2019). Higher Brix scores should correlate with increased calf health and development through body growth, organ development, and resistance to infectious diseases, decreasing chances for calf morbidity and mortality (Lorenz, 2021).

Good colostrum management includes practices that ensure calves are administered clean colostrum at the appropriate times within the first few hours of life. The highest efficacy of colostrum absorption and maximum IgG levels are found when calves are fed their first feeding of colostrum 45 minutes after birth, and their second feeding within the first 12 hours of life, before the calf's gut becomes impermeable to colostrum immunoglobulins (Scott et al., 1979; Godden et al., 2019). Colostrum handling procedure—including how quickly the most recent donor cow colostrum is frozen and thawed through a water bath for feedings—has significant effect on colostrum quality. Recent studies have found that bacteria replication during heating and cooling of colostrum can decrease IgG concentration by 44% (Pfeiffer et al., 2010, as cited by Ahmann et al., 2021). A common practice of colostrum heating and cooling on dairy farms includes use of reusable plastic pitchers, first filled with colostrum then frozen in a freezer, and thawed through utilization of a hot water bath, before being fed to the calves with an esophageal tube feeder (Ashley Silva, Personal Communication). Recent innovations for this process have aimed at reducing the time needed to cool and heat colostrum, including utilization of a single-use O-shaped colostrum bag. The unique O-shape of these "dairy tech perfect udder colostrum bags" provide greater surface area to allow faster heating and cooling of colostrum, minimizing bacterial growth, and potentially increasing health for dairy and beef calves (Leedstone, accessed 2023). However, this practice is still relatively new and further research is essential to understanding the benefits of these single-use colostrum bags in comparison to previously successful methods.

To better understand the relationship between colostrum quality and calf health and development, as well as the direct relationship between Brix scores, laboratory IgG, and total protein counts, data was collected and analyzed through a seven-month study. This study was conducted at Donnan Farms in York, New York, where data was collected from 258 Holstein dairy calves to determine Brix percentages from colostrum and its effects on calf health and development. Blood samples were taken from each calf between two and three days of age to identify Brix percentages, before being sent out to AgSource laboratories in Wisconsin to identify IgG and total protein levels. Health events were tracked for each calf along the duration of the study, including frequencies of recorded scours (calf diarrhea, Cho & Yoo, 2014), pneumonia contracted before 90 days of age, pneumonia contracted after 90 days of age, and calf deaths to investigate specific relationships between initial Brix percentages and overall calf health. This research also includes a comparison of Brix scores obtained through use of two different methods of colostrum administration to determine if there is a significant advantage in using "dairy tech perfect udder colostrum bags" (Leadstone, accessed 2023) over the traditional reusable pitcher method.

This research aims to investigate the effect of colostrum quality determined by Brix refractometry on dairy calves' health and development from birth through weaning. We also evaluate the differences between using single-use bagged colostrum and reusable pitchers on overall passive immunity transfer. In this research, we tested three hypotheses: (1) higher Brix scores will positively correlate with elevated total blood protein counts and blood immunoglobulin levels, (2) higher levels of blood protein from colostrum will lead to better development in dairy calves, including lower frequency of fluid therapy events, treatment events, and deaths and (3) Brix scores will increase after colostrum equipment was switched over to the single-use bags. Together these results provide an increased understanding of the relationship between colostrum quality and blood protein and IgG content in pre-weaned dairy calves, as well as the importance of these factors in long-term health and development.

Materials and Methods

Colostrum procedure switched from our traditional method of reusable pitchers to our reusable O-shaped bags six months into our seven-month study. Colostrum was collected from donor

cows at their first milking hours after calving and administered to new calves born within the next day. To determine the effect of colostrum quality on calf health and development, we first collected blood samples from calves between two and three days of age. To obtain total blood protein counts, blood samples were spun in a centrifuge and then sampled through use of a Brix refractometer. Blood was taken into 10 mL red top blood collection tubes stored in 10x10 blood tube holding racks, with 20g x 1" blood collection needles connected to plastic needle holders used for cutaneous penetration. A pipette, distilled water, and paper towel were used to dispense serum from the samples run through the centrifuge for 10 minutes with a relative centrifugal force of 1506 (g) onto the Brix refractometer within the maternity office at Donnan Farms. The software DairyComp305 (VAS 2023) was utilized to enter data points and track the health events of dairy calves involved in the research project.

Blood Collection

Blood samples were taken three times per week from all calves between 48–72 hours after birth on each given day. A list of every calf between two and three days of age was generated from the command "Show ID AGEDA for AGEDA=2-3 TPRO=0" typed into DairyComp305 (VAS, 2023), and equipment was prepared. Red top blood tubes, blood collection needles, a needle holder, and a permanent marker were brought to the calf housing sector of the farm holding over 750 individual hutches for animals to grow and develop before the blood draw procedure began. A new sterile needle was used for each calf, with the needle being connected to the needle holder. Each calf was manually restrained by straddling the animal's neck while holding the head to one side, administering pressure on the newly exposed jugular vein. The needle was inserted into the jugular vein followed by blood tube attachment. Approximately 10mL of blood was collected from each calf, then blood tubes were labeled with each calf's individual identification number before being placed in a holding rack. This process was repeated for each calf between 2–3 days of age. Data was collected on a total of 258 calves from June 17th, 2022, to January 28th, 2023. Blood was taken from between one and twelve calves per day over the course of one hour. As soon as sampling was completed, materials were safely transported back to the testing office at room temperature to be analyzed minutes later.

Blood Analysis

Samples were processed using a centrifuge and Brix refractometer. The centrifuge was first loaded with blood tubes and set with a time of 10 minutes at 3500 RPM. After the centrifuge was started, the tube holding the rack, pipettes, distilled water, paper towels, and the refractometer were prepared. After completion of the centrifuge cycle, the blood displayed separation between the red erythrocytes at the bottom of the tubes and the yellow-tinged serum layered above it. The tubes were carefully removed from the centrifuge and placed vertically in the holding rack. The red tops were then removed from each tube and drops of the top layer of yellow-tinged serum were drawn into a pipette and placed on the refractometer lens. The optical Brix refractometer was read by holding the lens up to the light and reading the Brix% value between the blue and white gradients of the Brix column. These percentages were entered into DairyComp305 under "total protein" with the calf ID, the date blood was drawn, and the technician who fed the colostrum to each calf within the first hour after birth. Used pipettes were flushed with distilled water and the refractometer lens was cleaned with distilled water and paper towels before the next sample was analyzed.

Once all values were inputted into the software, the remaining serum from each blood tube was carefully removed via pipette and placed in a sterile empty blood tube, where it was then labeled with the calf ID, specific age in days of the calf, and date the blood sample was taken. This process was repeated for each original blood tube. Original blood tubes were then disposed of alongside used pipettes and paper towels. Serum tubes were placed in blood tube racks in the freezer to be stored before being sent off for further testing at AgSource labs in Wisconsin for specific blood total protein and immunoglobulin content that were compared with measured Brix percentages.

Data Analysis and Statistics

Data was analyzed through the computer programing software RStudio on an RMarkdown file (R Core Team, 2021) as well as Microsoft Excel (Microsoft Coorporation, 2018). Each calf was

followed from the day it was born until the end of the study. The first CSV file included data from the farm, including calf ID, Brix scores, frequency of scours, respiratory infections on pneumonia contracted before 90 days of age, and pneumonia contracted after 90 days of age for calves that were old enough, as well as calf deaths. The second CSV file included AgSource lab data of calf ID, Brix scores, total protein, and total immunoglobulin counts. Histogram graphs, as well as Shapiro tests, were run on all values to determine how each dataset was distributed before scatterplots were created to illustrate relationships between Brix scores and the various health events as well as lab total protein and immunoglobulin values. The Spearman Rank Correlation test was utilized to determine the significance of correlation in these graphs. Brix ranges were also analyzed between the categories of "excellent," "fair," "good," and "poor" to illustrate the frequency of high-quality Brix scores from Donnan farms. All figures are created using ggplot2 (Wickham, 2016).

Results

There was significant evidence found to support a positive correlation between frequency of pneumonia contracted after 90 days of age (S = 3513875, p-value = 0.0002261, rho = -0.2276793), (Figure 3). We also found significant evidence to suggest that higher Brix scores resulted in lower frequency of calf morbidity (df = 1, sum sq = 22.2, mean sq = 22.243, F value = 29.97, pr(>F) = 4.87e-08), (Figure 4). We did not find significant evidence to suggest that higher Brix scores led to lower frequency of scours (S=3010886, p=0.406, rho=-0.0519447), (figure 1), or pneumonia contracted before 90 days of age (S = 3054804, p-value = 0.2816, rho = -0.06728897), (Figure 2).

We found significant evidence to suggest that there is a positive correlation between farm-tested Brix scores and lab-tested total protein values of our blood samples (S = 15866, p-value = 6.31e-08, rho = 0.619203), (Figure 5). We also found significant evidence to suggest that there is also a positive correlation between farm-tested Brix scores and lab-tested immunoglobulin levels of our blood samples (S = 21742, p-value = 7.386e-05), (Figure 6).

When Brix scores of calves fed colostrum with our traditional method of single-use pitchers were compared to a new method utilizing single-use O-shaped bags, we were able to conclude that calves fed with single-use O-shaped bags had significantly higher Brix scores than the prior method (t = -2.2947, df = 256, p-value = 0.02256, 95 percent confidence interval: -0.95, -0.07), (Figure 7).

Further data analysis was conducted to determine the distribution of colostrum quality categories found during this study. Our samples were found to be 17% "poor" quality, 22% "fair" quality, 18% "good" quality, and 43% "excellent" quality.

Effect of Brix Scores on Calf Health

To determine the relationship between Brix scores and calf health, Brix scores of 258 calves between two and three days old were recorded and plotted against the frequency of scours, frequency of pneumonia contracted before 90 days of age, frequency of pneumonia after 90 days of age, and calf death.

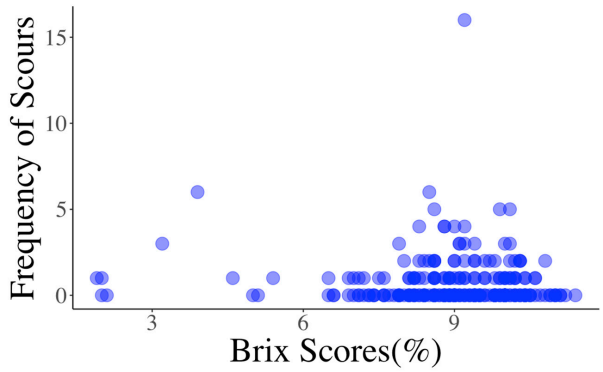

Figure 1. Scatterplot depicting the relationship between Brix score (%) and frequency of scours. Each point on the scatterplot represents one calf in the study. A Spearman Rank Correlation was run after determining normality, resulting in our conclusion that frequency of scours did not significantly correlate with Brix score (S=3010886, p=0.406, rho=-0.0519447).

Datasets for farm-tested Brix scores were visualized on a histogram to test for normality. Data appeared left skewed and were deemed nonparametric. Shapiro-Wilk tests were run on both Brix score data (W=0.83312, p=5.706e-16) and scour frequency data (W=0.49786, p<2.2e-16), both of which demonstrate that the data were nonparametric.

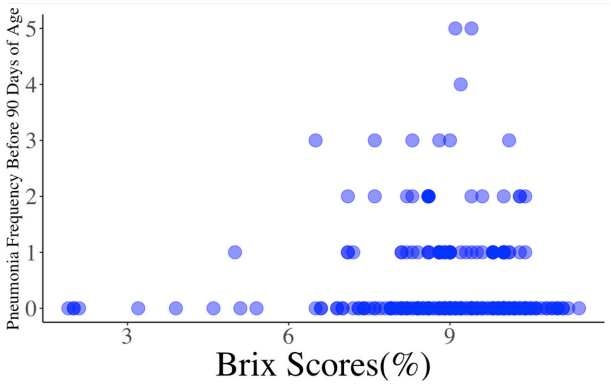

Figure 2. Scatterplot depicting the relationship between Brix score and the frequency of pneumonia contraction before 90 days of age (termed respiratory disease in pre-weaned calves, Stokka, 2010). A Spearman Rank Correlation was run after determining normality, resulting in our conclusion that frequency of pneumonia contracted before 90 days of age did not significantly correlate with Brix score (S = 3054804, p-value = 0.2816, rho = -0.06728897).

A Shapiro-Wilk test was run to determine normality for the frequency of respiratory disease (W=0.57094, p=2.2e-16), deeming the data nonparametric.

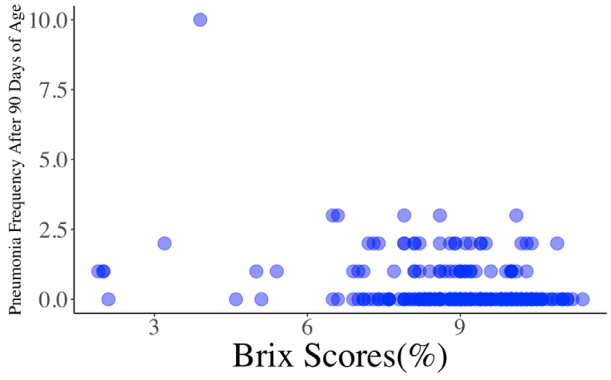

Figure 3. Scatterplot depicting the relationship between Brix score and frequency of pneumonia contracted after 90 days of age. A Spearman Rank Correlation was run after determining normality, resulting in our conclusion that frequency of pneumonia contracted after 90 days of age significantly correlated with Brix score (S = 3513875, p-value = 0.0002261, rho = -0.2276793).

The use of a Shapiro-Wilk test on frequency of pneumonia contracted after 90 days of age portrayed a nonparametric dataset with values of (W = 0.46034, p-value = 2.2e-16).

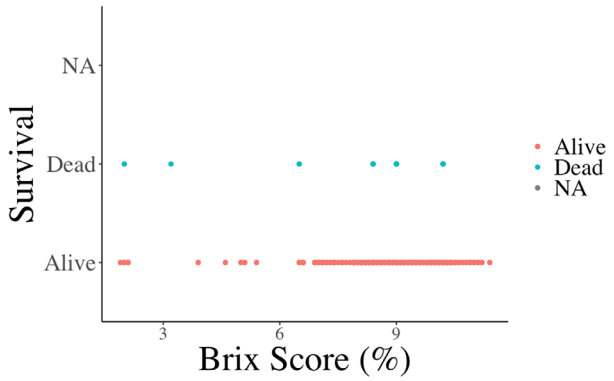

Figure 4. Scatterplot depicting the relationship between Brix score and survival rates of dairy calves through the study. A one-way ANOVA test was conducted to determine the effect of Brix scores on calf survival rates (df = 1, sum sq = 22.2, mean sq = 22.243, F value = 29.97, pr(>F) = 4.87e-08), giving us significant support that higher Brix scores correlate with lower frequency of death in dairy calves.

Comparison of Brix Scores and Immunoglobulin and Protein Levels

Blood samples from 63 calves were sent to AgSource labs to be further analyzed for blood total protein (g/dL) and blood immunoglobulin levels (g/L).

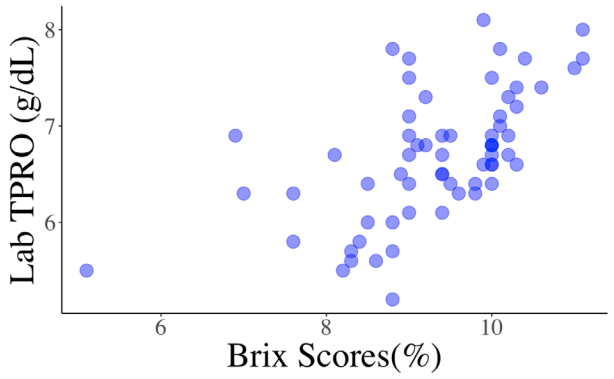

Figure 5. Scatterplot depicting the relationship between farm-measured Brix scores and lab-measured blood total protein (TPRO, g/dL). A Spearman Rank Correlation was chosen to account for conserved computation in determining normality (S = 15866, p-value = 6.31e-08, rho = 0.619203), allowing us to conclude there is a significant correlation between Brix scores and total protein values in calf blood serum.

Datasets for both farm-tested Brix scores and lab-tested blood total protein values were visualized on a histogram to test for normality. Data for Brix scores appeared left skewed and were deemed nonparametric. Data for lab-tested total protein values appeared uniform and displayed a normal distribution. Shapiro-Wilk tests were run on both Brix score data (W=0.91693, p=0.0004142) and total protein data (W=0.98258, p=0.5135).

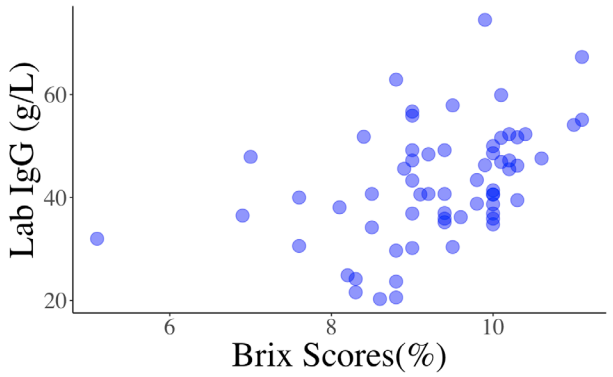

Figure 6. Scatterplot depicting the relationship between farm-measured Brix scores and Lab-measured immunoglobulin concentrations (IgG, g/L). A Spearman Rank Correlation was chosen again to account for conserved computation in determining normality (S = 21742, p-value = 7.386e-05). We are able to conclude that there is significant evidence to suggest a positive correlation between Brix score and immunoglobulin levels in dairy calves.

Lab-measured blood immunoglobulin levels were visualized on a histogram to test for normality. A bimodal distribution was observed, indicating there is not a normal distribution in the dataset. Brix score values were consistent for both laboratory data tests. A Shapiro-Wilk test was conducted for the normality of the lab-measured blood immunoglobulin levels (W = 0.98556, p-value = 0.6696).

The Effect of Colostrum Administration Procedure on Brix Scores

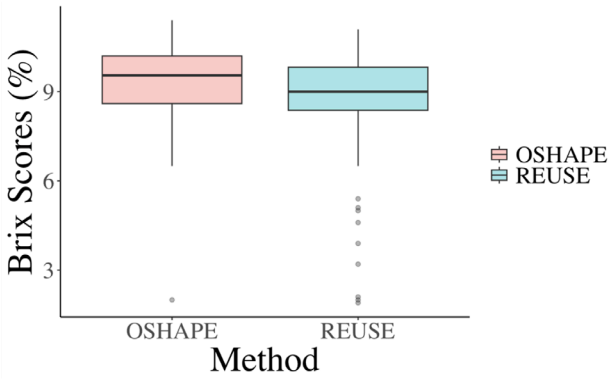

Figure 7. Boxplot depicting the distributions of Brix scores for calves fed with the O-shaped single-use bags compared with Brix scores of calves being fed with reusable pitchers. Brix scores taken before the switch to the new bags on January 1st, 2023, had an average of 8.81 with a standard deviation of 1.50, while Brix scores taken after the farm procedure change to O-shaped colostrum bags was 9.32 with a standard deviation of 1.43. A T-test was run on RStudio (t = -2.2947, df = 256, p-value = 0.02256, 95 percent confidence interval: -0.95, -0.07), allowing us to conclude that average Brix scores significantly increased after switching from reusable colostrum pitchers to single-use O-shaped colostrum bags.

Further Analysis of Farm Brix Scores

Brix data were also compiled into the four blood serum quality categories of "poor," "fair," "good," and "excellent" to determine the success of Donnan Farms colostrum program.

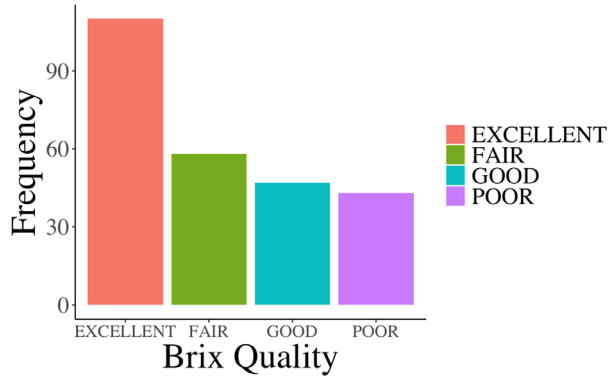

Figure 8. Bar graph depicting the frequency of Brix scores in "Excellent," "Fair," "Good," and "Poor" categories across all measurements. Percent frequencies were calculated using Microsoft Excel, with "poor" quality at 17% of the dataset, "fair" at 22%, "good" at 18%, and "excellent" at 43% of the total dataset.

Brix Score values were filtered using RStudio into the four categories of blood serum quality. Once filtered, the frequency of each category was entered into a separate Excel file and then transferred back into RStudio to create a bar graph (Figure 8, statistical results) to visualize the size of each category.

Discussion

Good colostrum management is one of the most important factors in calf health and development on dairy farms (Godden et al., 2019). This research sought to determine the effect of colostrum quality on the health of calves by investigating the relationship between Brix scores and various health events such as scours, respiratory disease, pneumonia, and death, as well as the relationship between these scores and laboratory-tested blood total protein counts and immunoglobulin levels. Determining the effect of colostrum quality on specific health events on hundreds of calves as well as further research into the relationship between Brix scores, total blood protein, and immunoglobulin levels will further the field of agricultural science by helping farms across the globe raise healthier calves. This project also demonstrates the advantages of single-use dairy tech perfect udder colostrum bags (Leadstone, accessed 2023) over other methods of colostrum management utilizing reusable pitchers. Research in this field may inform practices by both dairy and beef farms to improve hundreds of calf management systems and ensure the supply of high-quality products.

After blood samples were taken from calves and health events were recorded over a seven-month period, analyzed data significantly supported some of our hypotheses, but not others. Our first hypothesis regarding a positive relationship between farm-tested Brix scores and lab-tested blood protein counts and blood immunoglobulin levels was supported by our statistical analysis. These results provided significant evidence for our hypothesis that higher Brix scores will correlate with higher total protein counts and blood immunoglobulin levels. This agrees with prior research suggesting that Brix scores provide an accurate representation of colostrum quality, total blood protein counts, and blood immunoglobulin levels (Buranakarl et al., 2021). We can see that Brix refractometry is an accurate method of measuring colostrum quality through passive immunity transfer, and would be advantageous to be utilized by any farms that may not have this method as part of their colostrum procedure already.

The second hypothesis of this study focused on the relationship between Brix scores from colostrum quality and frequency of health events. Health events tracked for each calf included frequency of scours, respiratory disease contracted before 90 days of age, pneumonia contracted after 90 days of age, and calf deaths. There was no significant correlation between Brix scores and scours as well as frequency of respiratory disease before 90 days of age. This may be due to decreased time for the calves' immune systems to develop, and therefore higher susceptibility to disease independent of colostrum quality. However, our statistical analysis for both Brix scores' effect on pneumonia contracted after 90 days of age and calf deaths gave us significant evidence to conclude that increased colostrum quality through Brix scores leads to a lower frequency of pneumonia contracted after 90 days and death in post-weaned dairy calves. Although past studies found significant evidence supporting the positive long-term effects of colostrum quality on health and development in dairy calves (Godden et al., 2019), our study focused on health events recorded within the seven months of our study. This may account in part for the lack of significant support for our second hypothesis, as well as provide reasoning as to why our longest-running health event of pneumonia contracted after 90 days of age was the only one of two tests to agree with past research.

Our final hypothesis that average Brix scores would increase after switching colostrum administration procedure from reusable pitchers to single-use dairy tech perfect udder colostrum bags (Leadstone, accessed 2023) was also supported through our statistical analysis. Despite the averages providing support for our hypothesis, more research will have to be conducted on this sector of study, as there were under a month of blood samples taken after colostrum was fed with single-use bags versus over a six-month period of samples taken after administration of colostrum from a reusable pitcher. In conclusion, evidence has been found to suggest the utilization of single-use O-shaped colostrum bags will help to increase Brix scores in 48-72 hour-old dairy calves; however, further studies are recommended by the authors of the study to find increased significant evidence, as very few studies have taken place regarding this method prior to this research.

Brix Score Quality

The analysis of Brix score ranges placed into categories "poor," "fair," "good," and "excellent" (Godden et al., 2019), were visualized through a bar plot to show success rates of Donnan Farms colostrum program. Our goal was to have 75% or greater values in the good to excellent range. After analyzing the data, we fell short of this goal with 61% of our samples falling within the good to excellent range. This finding suggests that although strict processes remain in place to ensure high-quality colostrum administration to newborn calves, there may still be room for improvement. Improvements can be made in cleanliness procedure so that colostrum has the least contact possible with harmful bacteria introduced during the heating and cooling (Pfeiffer et al., 2010, as cited by Ahmann et al., 2021), or administration using various colostrum equipment (Ashley Silva, Personal Communication).

Limitations of Study

Although good colostrum management is a central factor in increased health and development in dairy calves (Soulfleri et al., 2021), there are other factors, such as calf nutrition (A. Lorenz et al., 2011a), temperature, and stressful events in the calf life that can also account for health issues such as pneumonia (Lorenz et al. 2011b) that may negatively impact a calf's development. Heat stress from the August weather in Western NY placed on calves when this study began as well as sub-zero temperatures recorded in December and January at the close of this study may be underlying contributing factors to decreases in calf health even if they were administered high-quality colostrum.

The freezing temperatures of late December and January during this study also may have had negative effects on the treated parlor pasteurizer at Donnan Farms, which pasteurizes milk administered to pre-weaned dairy calves (Ashley Silva, Personal Communication). During the coldest days of this study, the milk pasteurizer was not able to calibrate itself as effectively as normal, resulting in calves being fed milk that was too cold for their organs to digest effectively. This led to numerous deaths of calves from ulcers in their intestines (Dr. Alex Navarro, Personal Communication). This factor would not be accounted for in our correlation of Brix scores and calf deaths and could have skewed our results.

A final limitation of our study is the sample size of our dataset of Brix scores taken after colostrum management procedures were switched to single-use O-shaped bags. The authors believe that we may be able to find a greater significant increase in average Brix scores with a more comparable sample size to our sample size of Brix score samples taken while the reusable pitcher procedure was upheld. This would also help account for variations in temperature along a multiple-month study instead of the one-month current procedure versus the six-month record of our past procedure.

Future Directions

An extension of this study will continue to collect Brix samples from calves at Donnan Farms and enter these values into DairyComp305 (VAS, 2023). Brix scores will continue to be analyzed and compared with laboratory data from Agsource labs, as well as correlated with health events and categorized into our four categories of Brix quality percentages. This practice will continue to increase our sample size as well as allow us to continue closely monitoring our colostrum program, ensuring peak calf health and development. Average Brix scores utilizing the single-use O-ring colostrum bags will also continue to be recorded to assess the degree of advantage over prior methods.

Further follow-up studies may include research into relationships between Brix scores and calf health before and after weaning to determine if there is significant data to support the hypothesis that higher quality colostrum through increased Brix scores will positively correlate with lower health events such as scours and respiratory diseases contracted before 90 days of age. These studies can be conducted using increased sample sizes as well as a study period of over a year to account for a wider variety of weather conditions that may affect the frequency of calves contracting disease.

Conclusion

The research conducted in this study has found evidence to support that 1) higher Brix scores display a positive correlation with both total blood protein counts and blood immunoglobulin levels, 2) significant evidence was found that higher Brix scores can lead to decreased frequency of pneumonia contracted after 90 days of age as well as decreased

mortality, and 3) average Brix scores increased after colostrum equipment was switched over to single-use bags. These findings help to further the field of agricultural research by emphasizing the importance of good colostrum management for increased calf health and development rates as well as providing evidence for the advantages of using single-use O-shaped colostrum bags over reusable pitcher methods. Extended research into these topics helps support the national dairy and beef industries to ensure quality products for the consumer population.

Acknowledgments

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Animal Care

Animal care procedure at Donnan Farms follows the Animal Welfare Act to ensure all animals are treated humanely. This act also guarantees that any animal testing conducted will not cause any harm or excess stress to the subject in question (United States Department of Agriculture, 2017).

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