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RISK-BASED EVALUATION OF COLOSTRUM QUALITY AND EARLY FEEDING FOR CALF HEALTH AND SURVIVAL

Abstract. Early-life nutrition is a critical determinant of health and survival in dairy calves. However, practical quantitative thresholds linking colostrum quality and early feeding practices with neonatal health outcomes under commercial farm conditions remain insufficiently defined. Within the framework of early-life nutritional management, this study evaluated the combined effects of colostrum quality and early colostrum feeding practices on digestive health and survival of dairy calves under commercial farm conditions. Field data were collected from 250 Holstein calves reared on commercial breeding farms in western Kazakhstan. Colostrum quality was assessed using Brix refractometry and classified into quality categories, while early feeding practices were categorized according to the timing and adequacy of colostrum administration.

Calves receiving timely and adequate volumes of high-quality colostrum exhibited a significantly lower incidence of digestive disorders (5.9-23.0%) and higher survival rates (88.2-100%) compared with calves exposed to delayed or inadequate early-life management. The combined classification of colostrum quality and feeding management enabled the identification of distinct neonatal risk groups associated with substantially different health outcomes. These findings support the use of a simple, field-applicable risk stratification approach as a preventive management tool for improving neonatal calf health and survival in commercial dairy systems.

Key words. dairy calves, early-life nutrition, colostrum quality, Brix scale, digestive health.

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РИСК-ОРИЕНТИРОВАННАЯ ОЦЕНКА КАЧЕСТВА МОЛОЗИВА И РАННЕГО ВЫПАИВАНИЯ В СИСТЕМЕ ВЫРАЩИВАНИЯ МОЛОЧНЫХ ТЕЛЯТ

Аннотация. Раннее питание является одним из ключевых факторов, определяющих здоровье молочных телят. Однако пороговые значения, связывающие качество молозива с показателями здоровья новорождённых телят в условиях коммерческих хозяйств, остаются недостаточно определёнными. В рамках концепции управления питанием в ранний постнатальный период в данном исследовании была проведена оценка влияния практики раннего выпаивания на состояние пищеварительной системы молочных телят. Полевые данные были получены на 250 телятах голштинской породы, выращиваемых в племенных хозяйствах Западного региона Казахстана. Качество молозива оценивали с использованием рефрактометрии по шкале Вгіх с последующей классификацией по категориям, тогда как технику выпаивания классифицировали по времени и достаточности введения.

Телята, получавшие высококачественное молозиво в достаточном объёме и в оптимальные сроки, характеризовались значительно более низкой частотой нарушений пищеварения (5,9-23,0%) и более высокими показателями жизнеспособности (88,2-100%) по сравнению со сверстниками, подвергавшимися задержке или недостаточному уровню раннего кормления. Совместная классификация качества молозива и практик выпаивания позволила выделить различные группы неонатального риска, связанные с существенно различающимися показателями здоровья. Полученные результаты подтверждают возможность применения пригодной для практического использования системы стратификации риска в качестве профилактического инструмента управления для улучшения здоровья и сохранности телят в молочных хозяйствах.

Ключевые слова. телята молочных пород, рациональное питание в раннем возрасте, качество молозива, шкала Брикс, здоровье пищеварительной системы.

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СҮТТІ БҰЗАУЛАРДЫ ӨСІРУ ЖҮЙЕСІНДЕГІ УЫЗ САПАСЫ МЕН ЕРТЕ АЗЫҚТАНДЫРУДЫҢ ТӘУЕКЕЛГЕ НЕГІЗДЕЛГЕН БАҒАЛАУЫ

Аңдатпа. Сүтті бағыттағы ірі қара мал тұқымдарына жататын бұзауларды ерте кезеңнен бастап азықтандыру денсаулық жағдайын айқындайтын негізгі факторлардың бірі. Алайда шаруа қожалығы жағдайында уыз сапасын жаңа туылған бұзаулардың денсаулығымен байланыстыратын шекті мәндер әлі де жеткілікті деңгейде анықталмаған. Бұл зерттеуде ерте постнаталды кезеңдегі қоректенуді басқару тұжырымдамасы шеңберінде уыз ішкізу тәжірибесінің сүтті бұзаулардың ас қорыту жүйесінің жағдайына әсері бағаланды. Тәжірибе деректері Батыс Қазақстан өңіріндегі асылтұқымды шаруашылықтарда өсірілетін голштин тұқымының 250 бұзауынан жиналды. Уыз сапасы рефрактометрия әдісі арқылы Вгіх шкаласымен бағаланып, сапа санаттарына, ал оны ішкізу техникасы беру уақыты мен жеткіліктілігіне қарай жіктелді.

Жоғары сапалы уызды тиісінше көлемде және уақтылы алған бұзауларда ас қорыту бұзылыстарының жиілігі айтарлықтай төмен (5,9-23,0%) және өміршеңдік көрсеткіштері жоғары (88,2-100%) болды, бұл сүтті кеш немесе жеткіліксіз қабылдаған қатарластарымен салыстырғанда айқын байқалды. Уыз сапасы мен оны ішкізу тәжірибесінің бірлескен жіктелуі денсаулық көрсеткіштері едәуір айырмашылық көрсететін неонаталдық қауіп топтарын анықтауға мүмкіндік берді. Алынған нәтижелер сүтті шаруашылықтарда бұзаулардың денсаулығын жақсарту мақсатында тәуекелге негізделген стратификация жүйесін қарапайым және тәжірибеде оңай қолдануға болатын профилактикалық басқару құралы ретінде пайдалануға болатынын көрсетеді.

Кілт сөздер. сүтті тұқымды бұзаулар, ерте жастағы азықтандыру, уыз сапасы, Brix шкаласы, ас қорыту жүйесінің жағдайы.

Introduction. Early-life nutrition is a key determinant of health and physiological development in dairy calves. The neonatal period is characterized by rapid and coordinated maturation of the gastrointestinal tract, immune system, and metabolic functions, during which animals are particularly sensitive to nutritional and environmental influences [1,2]. Increasing evidence indicates that nutritional conditions experienced during this early window exert lasting effects on health outcomes, a concept often referred to as early-life nutritional management [3,4,5].

In dairy production systems, the first hours and days after birth represent a decisive stage for calf survival and adaptation. Calves are born agammaglobulinemic and rely entirely on colostrum intake for the acquisition of passive immunity [6]. In addition to immunoglobulins, colostrum contains a wide range of biologically active components, including growth factors, enzymes, hormones, and antimicrobial peptides, which collectively support intestinal development, immune maturation, and microbial colonization [7,8]. Thus, colostrum functions not only as a source of immunity but also as a complex nutritional signal influencing early physiological programming.

Colostrum quality is commonly evaluated based on immunoglobulin G (IgG) concentration, with Brix refractometry widely used as a practical on-farm indicator [9]. Previous studies have shown substantial variability in colostrum quality between cows and farms, and inadequate IgG intake has been associated with increased morbidity, digestive disorders, and mortality in neonatal calves. Nevertheless, much of the existing literature has examined colostrum quality as a single factor, often under controlled experimental conditions, without sufficient consideration of colostrum feeding practices [10].

Emerging research highlights that early feeding practices – including the timing of first colostrum administration, volume provided, and method of administration interact with colostrum quality to determine the efficiency of passive transfer and subsequent digestive adaptation [11]. Delayed or insufficient colostrum intake may impair intestinal permeability, alter microbial establishment, and increase susceptibility to enteric disorders, even when colostrum quality is adequate [12]. From a nutritional programming perspective, these early management decisions represent modifiable interventions capable of shaping digestive stability and immune competence during a critical developmental window.

Digestive disorders remain one of the leading causes of morbidity and mortality in dairy calves worldwide and are a major driver of antimicrobial use during the neonatal period [13]. According to the World Health Organization, global concerns regarding antimicrobial resistance and the need for sustainable livestock production emphasize the importance of preventive strategies that improve early digestive health. Optimizing colostrum management

and early feeding practices offers a practical and cost-effective approach to reducing disease incidence while supporting animal welfare and long-term productivity.

Despite extensive evidence demonstrating the importance of colostrum quality and early feeding practices, most available studies have evaluated these factors independently or under controlled experimental conditions. Consequently, practical production-scale evidence integrating colostrum quality assessment with early feeding management to define quantitative thresholds and risk-based frameworks under commercial dairy conditions remains limited [14,15]. From an applied nutritional programming perspective, such frameworks are essential for translating scientific knowledge into actionable on-farm decision-making tools.

Therefore, the objective of the present study was to evaluate the combined effects of colostrum quality and early feeding practices on digestive health and survival of dairy calves and to develop a simple, production-oriented risk stratification approach capable of identifying calves at increased risk of adverse neonatal outcomes under real-world dairy management conditions.

Research materials and methods. The study was conducted on Holstein dairy calves (n=250) reared on commercial breeding farms in the western region of the Republic of Kazakhstan, including Farm “Arystanov” and Farm “Tolengit”, using a production-scale observational design. Newborn calves were monitored from birth throughout the neonatal period to assess the association between colostrum quality, early feeding practices, digestive health, and survival. Only calves born after normal parturition and clinically healthy at birth were included, while animals with congenital abnormalities or perinatal complications were excluded.

Calves were separated from their dams immediately after birth and managed according to routine herd management practices used on the participating farms. No experimental interventions or deviations from standard husbandry protocols were introduced.

Colostrum quality was evaluated using Brix refractometry and categorized according to Brix values, with samples $\geq 22\%$ classified as high quality and lower values classified as moderate or low quality. For each calf, information on early colostrum feeding was recorded, including the timing of the first administration after birth, the volume provided, and the method of administration (bottle feeding or esophageal tubing). Feeding practices were subsequently categorized based on timing (early vs. delayed) and volume (adequate vs. insufficient).

Digestive health was monitored during the neonatal period based on the occurrence of diarrhea, identified by abnormal fecal consistency and increased frequency of defecation. Neonatal survival was also recorded, and all mortality events were documented.

Data collected for each calf included colostrum quality indicators (Brix values and infrared analysis results), timing and volume of colostrum feeding, method of administration, incidence of digestive disorders, and survival status. Colostrum quality and feeding practices were considered independent variables, while digestive disorders and survival were treated as dependent outcomes.

Statistical analyses were performed using IBM SPSS Statistics (v. 28.0; IBM Corp., Armonk, NY, USA). Descriptive statistics are presented as frequencies and percentages. Differences in the incidence of digestive disorders and survival rates between farms and feeding categories were evaluated using the chi-square (χ^2) test with statistical significance set at $p < 0.05$.

For applied interpretation, calves were stratified into risk groups based on the combined classification of colostrum quality and early feeding practices (timely and adequate vs. delayed and/or insufficient administration). This approach allowed comparison of digestive disorder incidence and survival outcomes among neonatal risk groups under field production conditions.

The study relied exclusively on observational data obtained during routine herd management and did not involve experimental interventions beyond standard animal husbandry. Therefore, ethical review and approval were waived.

Results and Discussion. A total of 250 Holstein calves were monitored during the neonatal period under commercial farm conditions. Assessment of colostrum quality indicated that the majority of colostrum samples met the criteria for high immunological quality, corresponding to Brix values $\geq 22\%$ (49.3 ± 1.8 to 52.5 ± 2.3 g/L immunoglobulin concentrations).

The incidence of digestive disorders differed markedly between farms characterized by different early-life management conditions. In Farm “Arystanov”, digestive disorders were recorded in 17 out of 132 calves (12.9%). In Farm “Tolengit”, only 4 out of 118 calves developed digestive disorders (3.4%) (Table 1).

Table 1. Incidence of digestive disorders in neonatal dairy calves

Farm	Number of calves (n)	Digestive disorders (n)	Incidence (%)
I	132	17	12.9
II	118	4	3.4

Neonatal survival differed between farms characterized by different early-life management conditions. Calves raised in Farm “Tolengit” showed a higher survival rate compared with those from Farm “Arystanov”. The survival rate reached 100% in Farm “Tolengit”, whereas in Farm “Arystanov” it was 88.2% (Figure 1).

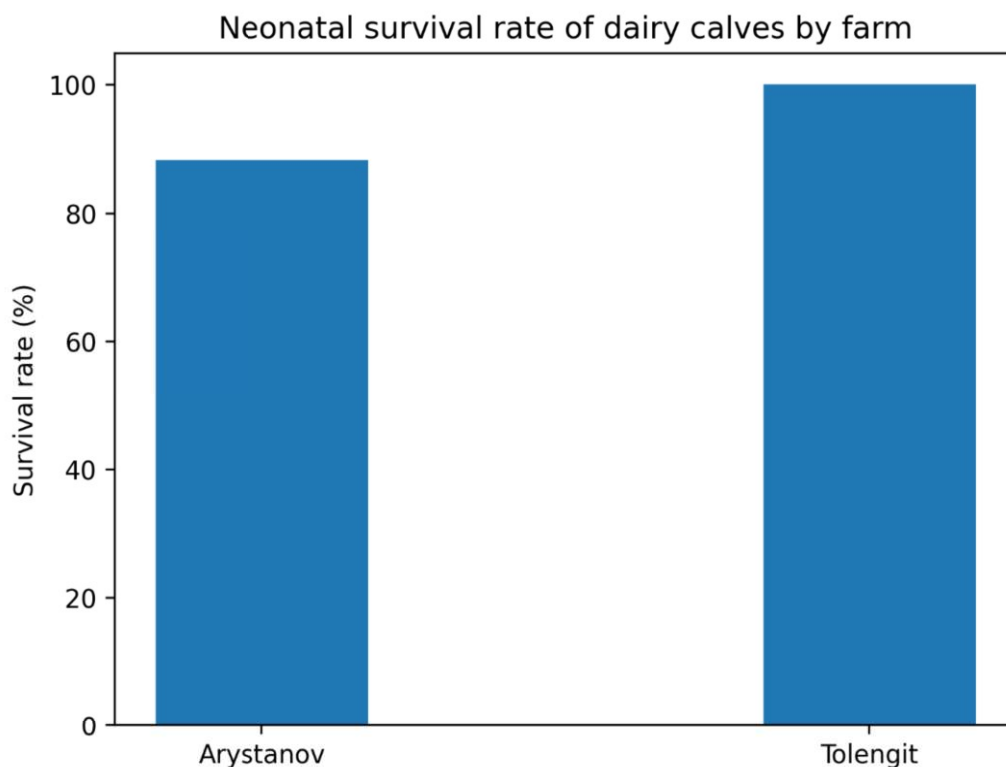


Figure 1 - Survival rate of neonatal dairy calves in 2 dairy farms

A combined analysis of colostrum quality and early feeding management demonstrated clear differences in neonatal health outcomes among management categories. Calves receiving

high-quality colostrum in a timely and adequate manner showed the lowest incidence of digestive disorders and the highest survival rate, whereas calves exposed to lower-quality colostrum combined with delayed and/or insufficient administration had the poorest outcomes (Table 2).

Table 2. Combined effects of colostrum quality and early feeding management on digestive disorders and survival in neonatal dairy calves.

Colostrum quality	Early feeding management*	Calves (n)	Digestive disorders (n)	Incidence (%)	Mortality (n)	Survival (%)
High $\geq 22\%$	Timely and adequate	98	6	6.1	1	99.0
High $\geq 22\%$	Delayed / insufficient	64	10	15.6	4	93.8
Lower quality $< 22\%$	Timely and adequate	46	9	19.6	4	91.3
Lower quality $< 22\%$	Delayed / insufficient	42	12	28.6	7	83.3
Total		250	37	14.8	16	93.6

**Timely and adequate = first colostrum administration within the recommended time after birth and in sufficient volume; delayed and/or insufficient = late administration and/or inadequate volume.*

This combined categorical classification enabled practical risk stratification under field conditions, allowing calves to be grouped into low-, moderate-, and high-risk categories based on the concurrence of colostrum quality and early feeding management.

Colostrum quality and digestive health

The observed differences in the incidence of digestive disorders between calves exposed to different colostrum quality conditions are consistent with previous reports demonstrating the protective role of adequate immunoglobulin intake during the neonatal period. Colostrum of high immunological quality, as assessed by Brix refractometry, was associated with a lower occurrence of digestive disorders, supporting its role in enhancing early immune competence and gastrointestinal stability. Importantly, the present study confirms these associations under routine farm management conditions, where variability in colostrum quality is inevitable. Unlike controlled experimental trials, production-scale observations capture real-world management heterogeneity, thereby increasing the external validity and practical relevance of the findings for dairy producers.

Role of early colostrum feeding practices

In addition to colostrum quality, early feeding practices were closely linked to neonatal health and survival outcomes. Calves receiving colostrum in a timely manner and in adequate volumes showed lower morbidity and higher survival rates compared with calves exposed to delayed or insufficient colostrum administration. These findings are in line with established physiological principles governing immunoglobulin absorption in neonatal calves, whereby intestinal permeability to macromolecules declines rapidly after birth. Delays in colostrum feeding may therefore compromise the effectiveness of passive transfer, even when colostrum quality is adequate, increasing susceptibility to enteric disorders and early mortality.

Combined effects and applied risk stratification

This approach provides a practical decision-support tool for dairy farm managers aimed at reducing neonatal morbidity and mortality. When these factors were considered jointly, distinct neonatal risk categories could be identified, characterized by substantially different health outcomes. Calves classified in the low-risk category – those receiving high-quality colostrum administered promptly and in sufficient volumes – exhibited the lowest incidence of digestive disorders and the highest survival rates.

In contrast, calves exposed to multiple suboptimal early-life conditions represented a high-risk group with markedly poorer outcomes. This pattern suggests that neonatal health outcomes are influenced by the cumulative effect of early management factors rather than by any single determinant alone. From a practical perspective, this combined categorical approach offers a simple and field-applicable method for identifying calves at increased risk of adverse neonatal outcomes, without the need for complex diagnostics or laboratory analyses. The applied nature of this framework makes it suitable for routine on-farm implementation, as it relies on readily available management information rather than complex laboratory or analytical procedures.

Implications for preventive calf health management

Digestive disorders remain a leading cause of morbidity and mortality in dairy calves and contribute substantially to antimicrobial use during the neonatal period. The results of the present study indicate that optimization of colostrum management – through routine assessment of colostrum quality and standardized early feeding practices – represents an effective preventive strategy for improving calf health and survival. By enabling early identification of high-risk calves, the proposed risk-based framework may support targeted management interventions, improved animal welfare, and reduced reliance on antimicrobial treatments. Such approaches align with current efforts to promote sustainable livestock production and responsible antimicrobial stewardship.

Study limitations and perspectives

The observational nature of the study limits causal inference, and the analysis was based primarily on categorical comparisons rather than multivariable modeling. Additionally, the focus was restricted to short-term neonatal outcomes, and long-term effects on growth performance or lifetime productivity were not assessed. Nevertheless, the study design reflects real-world production conditions and provides applied insights directly relevant to commercial dairy operations. Future studies incorporating longitudinal follow-up and multivariable analytical approaches would be valuable for further refining and validating the proposed risk-based framework. The combined stratification approach showed that neonatal outcomes were influenced not by a single factor alone, but by the interaction between colostrum quality and early feeding management. The highest morbidity and mortality were observed in calves exposed to both lower colostrum quality and suboptimal administration practices.

Conclusions. This production-scale observational study demonstrates that colostrum quality and early feeding practices are jointly associated with digestive health and survival outcomes in neonatal dairy calves under commercial farm conditions. Calves receiving high-quality colostrum in combination with timely and adequate feeding exhibited a lower incidence of digestive disorders and higher survival rates during the neonatal period.

The combined assessment of colostrum quality and early feeding management enabled the identification of distinct neonatal risk categories, providing a simple and practical framework for on-farm risk stratification. Routine Brix-based evaluation of colostrum together with standardized monitoring of feeding timing and volume may serve as an effective preventive management tool to improve calf health, enhance animal welfare, and support sustainable dairy production systems.

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