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Colostrum quality in Northern Italy: The role of dry cow nutrition and colostrum feeding management

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Abstract: This study investigated the effects of dry cow feeding on colostrum quality. A survey was conducted, and samples of colostrum and feed ingredients were collected from 25 dairy farms in Northern Italy. Colostrum was analysed for quality in terms of Brix value and gamma globulins, while diets and feed ingredients were analysed for their chemical constituents. The mean colostrum quality (n = 163) was 24.3 ± 4.41% Brix and 54.2 ± 20.8 g/l gamma globulin. The refractometer method effectively assessed colostrum quality, correlating accurately with laboratory gamma globulin measurements (R = 0.729). Factor analysis indicated that key nutrients, such as protein and fat daily intakes in dry cow diets, influenced colostrum immunoglobulin G. Furthermore, supplementation of selenium, vitamin A, vitamin B12, and vitamin E also improved colostrum quality. Colostrum feeding occurred, on average, 5.44 ± 2.63 h post-calving, with a quantity of 2.74 ± 0.71 l per meal, which is below the recommended 10% of the calf body weight. However, the maximum feeding time was 12 h, and the minimum colostrum quantity was 1.25 l, highlighting considerable room for improvement.

Keywords: Brix; calf management; dairy calves; gamma globulins

The efficient rearing of replacement animals is fundamental to the sustainability and overall economic performance of dairy production. Similarly like the future of the farm, the youngstock require optimal management (Makau et al. 2018), with colostrum administration and quality being key factors influencing their performance and welfare. After birth, an immediate and sufficient supply of high-quality colostrum is a prerequisite for successful calf rearing (Hammon et al. 2020), as correct colostrum feeding plays an important role in protection against infectious diseases (Godden et al. 2019), improves feed efficiency, reduces the age at first calving, and may affect milk yield in the first lactation (Jones et al. 2004; Faber et al. 2005). Furthermore, colostrum contains immunoglobulins, particularly IgG, which provide successful passive immunity (Lopez and Heinrichs 2022). The quality of colostrum is defined according to its IgG content: a value higher than 50 g/l of IgG is used as the threshold

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to define high-quality colostrum (McGuirk and Collins 2004). Colostrogenesis is a process during the prepartum dry period in which bovine colostrum, a mixture of lacteal secretion and constituent blood serum, is formed (Godden et al. 2019). Consequently, it is important not only to manage calves at birth but also to manage cows during the dry period to optimise the production of high-quality colostrum. However, a wide variability in colostrum quality may be observed; for example, Cooneely et al. (2013) reported IgG content ranging from 13 g/l to 256 g/l for colostrum samples collected in Ireland. Esposito et al. (2024), in our country, highlighted an average IgG content of 88.0 g/l in first milking colostrum and they found that colostrum yield is closely associated with DMI. Again, in Italy, Turini et al. (2020) in their study found the mean Brix percentage of colostrum administered to the calves about 24.8 ± 0.03% Brix, ranging from 18% to 31%. Colostrum quality is affected by several factors, such as the number of parities, the volume of colostrum produced, the season of calving, and the health status of the cow. Numerous studies have focused exclusively on the effects of environmental and management factors on IgG concentrations in colostrum (Gulliksen et al. 2008), while only a few studies (e.g. Nowak et al. 2012; Dunn et al. 2017; Hare et al. 2023) have examined the nutritional strategies during the dry period and their impact on colostrum characteristics. Mann et al. (2016) showed that dry cows fed a diet that meets their energy and protein requirements increased colostrum IgG content compared with cows fed 150% of energy requirements, with no differences in colostrum production. In previous research, the influence of energy and protein content in the diet during the dry period did not significantly affect the immunological quality of colostrum (Hough et al. 1990; Nowak et al. 2012). On the other hand, Pavlata et al. (2004), in a herd with selenium deficiency, showed that supplementing selenium and vitamin E to dry cow diets improves colostrum quality, including higher immunoglobulin concentrations. This study investigates the impact of the diet composition fed to dry cows, encompassing both nutritional quality and specific feed additives, on colostrum quality (immunoglobulin content and Brix) within the intensive dairy farming systems of the Lombardy region in the north of Italy. The findings will provide evidence-based nutritional strategies for dry cows to optimise colostrum quality, thereby improving calf health, long-term productivity, and the overall sustainability of dairy operations.

MATERIAL AND METHODS

The study involved a sample of 25 dairy cattle farms of different size located in different areas of the Lombardy region. All farms were intensive and representative of dairy farms situated in the Po Plain area of Northern Italy. Each farm was visited once during the winter season, and only the samples that did not involve any direct handling of the animals were collected. Additionally, a detailed survey of calf and dry cow management practices was carried out to provide the comprehensive characterisation of the farm.

As part of the survey, information about the composition of diets for dry cows was collected. The supplementation of feed additives (trace elements and vitamins) through compound feed was also recorded. The diet of dry cows was sampled on each farm, and a near infrared reflectance (NIR) analysis (Aurora NIR, GrainIt, Padua, IT) was performed on diets fed to dry cows to determine the analytical components of the ration (% DM, ash, CP, EE, NDF, ADF, starch).

Individual colostrum samples (a total of 163 samples, a mean of 6.8 samples per farm) were collected by the farmers in the week before our visit, in order to have a representative number of samples for each farm and not strongly related to the time of the visit. The samples were placed into plastic vials labelled with the cows' identification numbers and collection dates, and they were immediately frozen (−20 °C).

The percentage of solids in colostrum was measured using a digital Brix refractometer (Misco, USA), with a range of 0–85% Brix (resolution and precision 0.1 Brix). The colostrum samples were defrosted in a fridge for 24 h and then heated to room temperature, with a volume of 0.2–0.5 ml being analysed. The determination of gamma globulins was performed in the colostrum serum by agarose gel electrophoresis, using the Sebia Hydrasis LC analytical system and the Hydrasis Hydragel Protein kit (Sebia, Issy Les Moulineaux, France). The total protein dosage was measured using the ILab 650 biochemistry analyser (Instrumentation Laboratory Company, Lexington, MA, USA).

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The entire dataset, including farm characteristics, colostrum management and quality, and diet composition and quality fed to dry cows, was analysed using SAS software (v9.4, 2012). Descriptive statistics were performed to describe the dataset using MEAN, CHART, and FREQ procedures. A correlation analysis (PROC CORR) was conducted to investigate the relationship between the two methods for evaluating colostrum quality.

Through a factor analysis, the relationships among nutritional variables were investigated. The focus was on colostrum quality [expressed as gamma globulin content (g/l) and Brix (%)], individual daily intakes of vitamins A, E, and B12, and selenium (feed additives), as well as individual daily intakes of ash, crude protein (CP), neutral detergent fibre (NDF), and ether extract (EE) (nutritional quality) in the diet for dry cows. Two factors with eigenvalues higher than 1 were selected; for each factor pattern, the variables that had the highest loading values (>0.48 in absolute value) were used to identify dry cow feed characteristics corresponding to each factor (Factor 1: nutritional quality; Factor 2: feed additives). The colostrum samples were classified based on the estimated factor scores (computed as a linear combination of the standardised values of the variables that are factored) for each factor pattern. A Generalised Linear Model (GLM) analysis was performed considering the upper 50^{th} percentile and the lower 50^{th} percentile of the estimated factor scores to evaluate the effect of dry cow feed characteristics (nutritional and microelement) on immunological colostrum quality.

RESULTS AND DISCUSSION

Descriptive characteristics of 25 dairy cattle farms are presented in Table 1. The farms considered in the present study had 201 dairy cows (SD 153) on average, a farm area of 129 ha (SD 115), and individual daily milk production of 33.6 kg (SD 4.92), representing the most common situation for farms in the Po Valley area of Northern Italy. On the farms involved in the study, the time spent by calves in a single pen was 51.2 days (SD 27.1), with a bedding renewal frequency of 41.4 days (SD 35.5); these data highlight high variability both in animal housing and in bedding management. Calf-mother separation, a conventional management practice in intensive systems, typically occurred within the first few hours after birth, though this period ranged up to 24 hours. While extending the period of cow-calf contact follows new recommendations (EFSA 2023), it is crucial to understand the resulting effects on colostrum administration and overall calf health outcomes. A mortality rate of 2.61% (SD 3.88), ranging from 0.00 to 18.0, was recorded from birth to 24 h, and a rate of 4.42% (SD 2.22), ranging from 0.50 to 9.46, was recorded from 24 h to weaning (Table 1). Data reported by the farmers showed the mean values below the critical threshold of 5% (Roy 1990), both for the birth-to-24-hour period and 24-hour-to-weaning period. However, there was a considerable variability among farms, highlighting some critical situations. The quality, timing and the amount of colostrum feeding is crucial for reducing mortality. Colostrum quality corresponded

Table 1. Farm characteristics

Farm characteristics	Unit	Mean	SD	Minimum	Maximum
Number of dairy cows	*n*	201	153	54.0	630
Individual daily milk production	kg	33.6	4.92	20.0	42.0
Time spent in single pen	days	51.2	27.1	7.50	120
Frequency of bedding renewal	days	41.4	35.5	4.50	120
Time birth-dam separation	hours	3.69	6.94	0.00	24.0
Mortality birth-24 h	%	2.61	3.88	0.00	18.0
Mortality 24 h-weaning	%	4.42	2.22	0.50	9.46
Time birth-1^{st} colostrum meal	hours	5.44	2.63	1.50	12.0
Individual colostrum feeding	l/meal	2.74	0.71	1.25	4.00
Colostrum feeding frequency*	*n*	6.11	4.72	1.00	16.0

*Including the transition milk

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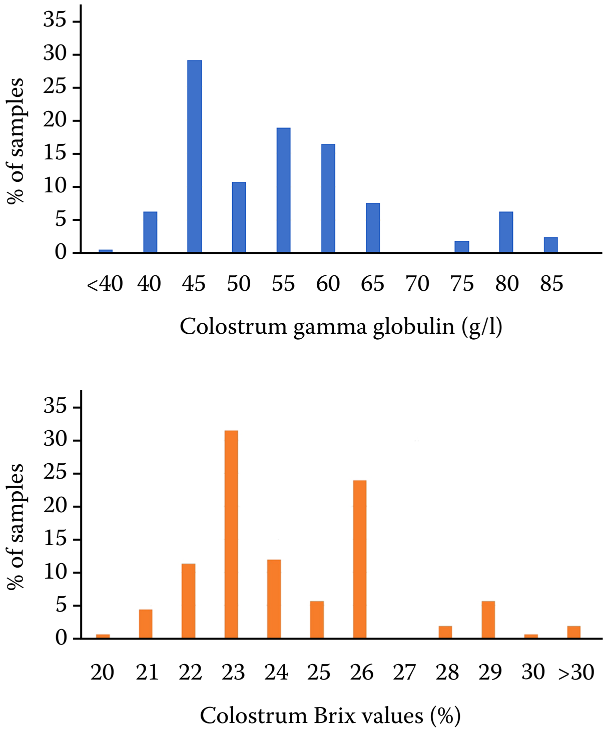

Figure 1. Frequency distribution of colostrum quality (N = 163) in terms of gamma globulin content (g/l) and Brix values (%), as collected from sample farms

to 24.3% Brix (SD 4.41) and 54.2 g/l of gamma globulin (Figure 1). According to the EU legislation (Council Directive), colostrum is considered to be of satisfactory quality when it contains at least 50 g/l of IgG. Additionally, the Brix value above 22% is commonly used as an indicator of high-quality colostrum (Bielmann et al. 2010).

As reported in Figure 2, 47% of the colostrum samples had the gamma globulin content ≤50 g/l and 16% of the samples had Brix ≤22%. Furthermore, in the present study, 54% of farms had the gamma globulin mean value in colostrum above 50 g/l, i.e. above the minimum quality level, and the Brix threshold was reached by 80% of the participating farms. The variability (the mean ranging from 12.7% to 36.3% for Brix and from 4.00 g/l to 142 g/l for gamma globulin) and the percentage of farms that do not achieve the minimum level for colostrum quality suggest that there is still a considerable potential for improvement. A strong correlation was observed between colostrum gamma globulins (g/l) and colostrum Brix (%) (R = 0.729; P < 0.001); the routine on-farm analysis for gamma globulins is not a common practice, so the refractometer is confirmed as a practical and valuable tool for the rapid on-farm assessment of colostrum quality.

In the present study, colostrum was supplied on average within 6 h from calving (5.44 h, SD 2.63), as required by the Italian legislative decree (No. 126 of 7 July 2011, implementation of EU Directive 2008/119/EC); however, 44% of the farms provided colostrum beyond the proposed legal deadlines. Moreover, the amount of supplied colostrum (2.74 l/day, SD 0.71) was lower than the recommended dose, as calves should be fed 10–12% of their body weight in colostrum at the first feeding

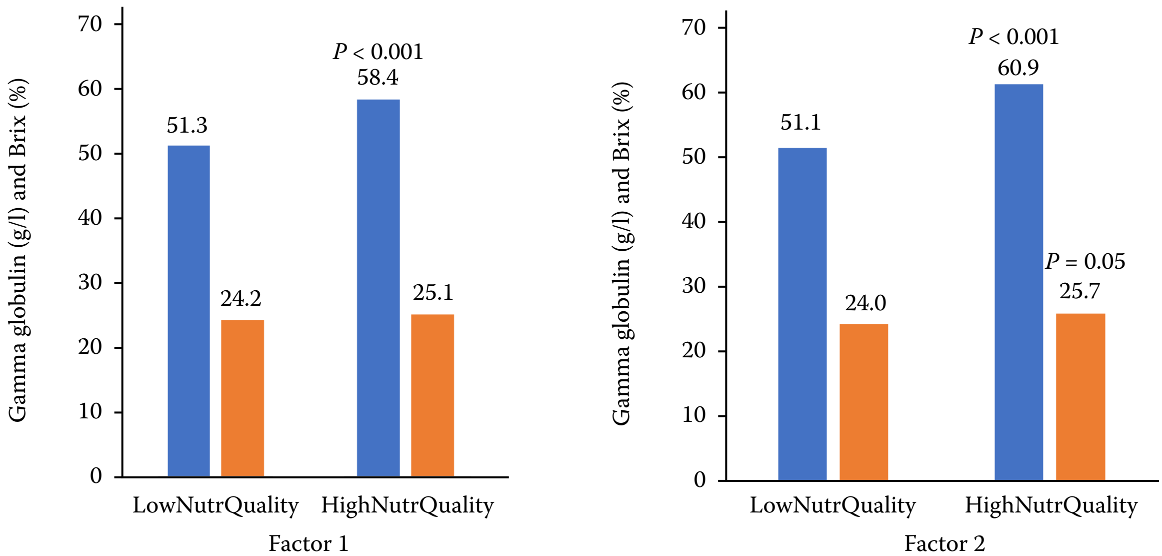

Figure 2. The least-squares means of colostrum quality (in terms of gamma globulins content, g/l, and Brix, %) from the GLM analysis comparing high and low levels of the two factors. The blue bar represents gamma globulin content (g/l) and the orange bar represents Brix (%)

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(3–4 l for a Holstein calf) (Godden et al. 2019). The number of colostrum feedings, including transition milk, before switching to whole milk or milk replacer can influence the health status of calves. Extending this feeding period may provide additional health benefits (Kargar et al. 2020) and play a key role in the effectiveness of new vaccination protocols, such as BOVILIS CRYPTIUM®. So, the variability among farms is interesting (on average 6.11 meals, SD 4.72), with a range of 1 to 16 feedings, which suggests the need of guidelines for farmers.

Table 2 reports the characteristics of the diet for dry cows; the mean dry matter intake (DMI) was 9.99 ± 1.58 kg/day. The 66% of the farms fed silage to dry cows (mainly maize silage, with an individual inclusion of 7.94 ± 3.167 kg as fed/day), and 76% of the farms fed hay to the dry cows (with an individual inclusion of 5.75 ± 2.39 kg as fed/day).

On average, the level of fodder inclusion is 83.3 ± 11.9%. Regarding nutritional feed additives, the mean intake of selenium was found to be 3.40 (SD 2.87) mg/day, vitamin A 98 298 (SD 80 026) IU/day, vitamin E 1 400 (SD 2 001) mg/day, and vitamin B12 0.25 (SD 0.43) mg/day, with significant variability among the farms. However, 32% of farmers did not use these nutritional feed additives.

Figure 2 illustrates the least-squares means (LSMs) of colostrum quality (gamma globulins in g/l and Brix in %) derived from the GLM analysis, comparing high and low levels of two key factors identified in our study

The high colostrum quality (as measured by gamma globulins) is associated with a high-quality diet fed to dry cows, in terms of intakes of both ash, CP, NDF, and EE and selenium, vitamin A, vitamin E, and vitamin B12. Specifically, the class exhibiting High Nutrient Quality (the upper end of Factor 1) showed a significantly higher daily intake of CP (0.77 vs 0.62 kg/day, respectively), NDF (2.78 vs 2.64 kg/day, respectively), and EE (0.23 vs 0.18 kg/day, respectively) compared to the Low Nutrient Quality class.

These results highlight the importance of adequate energy and protein intake during the dry period to support metabolic requirements and colostrum synthesis. For example, considering the main energy sources, the results showed that the EE content in dry cow diets affected colostrum IgG, consistently with the positive effect of prepartum dietary fat intake on colostrum quality observed by Hare et al. (2023). In contrast, starch intake did not appear to relate to the colostrum quality, differing from the results of Fatahnia et al. (2012), who found significantly higher IgG concentrations in colostrum from cows fed wheat compared to maize, probably related to the higher concentrations of plasma total protein in cows fed the wheat diet. Consequently, the observed discrepancy with our study is likely due to the fact that maize was the primary starch source in the diets fed to the dry cows.

Furthermore, our results confirm the influence of ash content in the diet of dry cows on colostrum quality, with a higher intake of minerals and vitamins, specifically selenium, vitamin A, vitamin E, and vitamin B12, being associated with increased gamma globulin content. A wide variability in the selenium content of complementary compound feed was observed (range: 0.003–40 mg/kg compound feed); the upper part of Factor 2 had significantly higher selenium daily intake (0.49 vs 5.45 mg/day for LowFeedAdditives and HighFeedAdditives). Similarly, regarding vitamin B12, the upper part of Factor 2 had significantly higher daily intake than

Table 2. Characteristics of the diet for dry cows

Diet characteristics	Unit	Mean	SD	Minimum	Maximum
Individual daily feed intake	kg as fed	17.5	3.46	10.0	22.5
DM	%	55.8	12.3	34.7	76.5
CP	% DM	13.4	1.78	9.15	16.5
Ash	% DM	8.85	1.30	6.80	12.44
EE	% DM	3.88	0.81	2.52	5.44
NDF	% DM	48.6	6.70	35.9	64.5
ADF	% DM	30.7	3.60	25.1	37.3
Starch	% DM	18.0	4.20	10.3	25.8

ADF= acid detergent fibre; CP = crude protein; DM = dry matter; EE = ether extract; NDF = neutral detergent fibre

https://doi.org/10.17221/104/2025-CJAS

the bottom part (0.05 vs 0.28 mg/day for low and high Factor 2, respectively).

This underscores the importance of not only macronutrient balance but also adequate micronutrient supplementation in the diet of dry cows for optimising the colostrum immunological quality. While the effects concerning dry cow diet and colostrum quality are well-established in the literature, our study importantly highlights the substantial gap between recommended nutritional practices and real-world management on Italian dairy farms. For example, notably, 28% of farms did not supplement any selenium at all, and among those that did, supplementation was often limited to complementary feeds without precise control over dosage or form. By supporting a healthy immune system, selenium contributes significantly to the efficient transfer of IgG into colostrum. For example, Hefnaway and Tortora-Perez (2010) reported that selenium supplementation in cows induces a high concentration of IgG in colostrum; similarly, Pavlata et al. (2004) observed that administering a product containing selenium and vitamin E twice before calving resulted in significantly higher concentrations of immunoglobulins and selenium in the colostrum. The result of the present study reveals a regional challenge to nutrient management during the dry period, when macronutrients like protein and calcium often receive more attention than crucial micronutrients. Hence, the findings of the present study have practical relevance for Italian dairy producers and consultants, emphasising the need for targeted education and intervention to improve micronutrient supplementation strategies. Similarly to the Italian case study area, previous applied studies did not explore in depth the aspects related to the management of micronutrients during the dry period and their effects on colostrum quality on commercial farms. Fujiwara et al. (2018) reported general indications on vitamin supplementation without detailed suggestion for Vit E and Se, while Gheller et al. (2024), in a survey of the US farms, only focused on macronutrient characteristics of dry cow diets.

According to NASEM (2021) guidelines, selenium intake for dry dairy cows should be around 0.3 mg/kg of dry matter intake, while vitamin E supplementation recommendations have increased substantially from earlier standards. Dry cows should receive approximately 1 000 IU of vitamin E daily, with levels rising to over 2 200 IU per day during the last three weeks before calving. These quantities are designed to mitigate oxidative stress during the transition period, support the immune function, and reduce risks of diseases such as mastitis. Integrating these evidence-based supplementation levels into feeding regimens provides a practical framework for improving colostrum quality and cow health.

CONCLUSION

This study offers a novel contribution by mapping and describing calf management practices on dairy farms in Lombardy. In particular, this study highlights the variability in calf management practices across farms in Northern Italy. In fact, the results reveal a considerable variability and a wide range of management choices made by individual farmers. While the overall immunological quality of colostrum was generally good, the percentage of farms that do not satisfy the minimal colostrum quality and calf management parameters (calf mortality, colostrum meal timing, and colostrum amount) is alarming and underscores the need for training of farmers and their staff. In fact, only 53% of farms administer the right quantity of colostrum and 54% of farms have colostrum with a sufficient amount of gamma globulin.

A further original contribution of the study is the in-depth analysis of the relationship of dry cow diet, particularly key nutrients and micronutrients such as selenium and vitamin E, to the colostrum immune quality under real on-farm conditions. The observed inconsistency in trace element supplementation suggests a critical area for improvement. Therefore, greater attention and more precise formulation of dry cow diets, with a specific focus on adequate and consistent micronutrient supplementation, are warranted to optimise colostrum quality and ultimately enhance calf health and farm sustainability in this region.

Future studies should also focus on the management of colostrum and transition milk during the first week of life, as proper handling during this phase could have a significant impact on calf health and their future growth performances.

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Conflict of interest

The authors declare no conflict of interest.

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