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ORIGINAL PAPER

Management practices and trace element-related nutritional risk factors during the transition period in dairy cows: A large-scale screening analysis*

Marcin Kocik[1], Wojciech Skupień[2], Paulina Markowska-Buńka[3], Włodzimierz Markiewicz [3], Magdalena Bryła[4], Monika Trzcińska[4], Oktay Yilmaz[5], Artur Burmańczuk[6]

[1] Private veterinary practice Marcin Kocik, Tarnów, Poland
[2] Elanco Poland sp. z o.o., Warszawa, Poland
[3] Department of Pharmacology and Toxicology
University of Warmia and Mazury, Olsztyn, Poland
[4] Department of Reproductive Biotechnology and Cryoconservation
National Research Institute of Animal Production, Kraków, Poland
[5] Department of Obstetrics and Gynaecology
Afyon Kocatepe University, ANS Campus, Afyonkarahisar, Turkey
[6] Department of Pharmacology, Toxicology and Environmental Protection
University of Life Sciences, Lublin, Poland

Abstract

The management of dairy cows during the transition period is critical for cow health, welfare, and subsequent productivity. The Vital 90™ Days, spanning approximately 60 days before calving and the first 30 days of lactation, represents a key window influencing the success of the upcoming lactation. This study aimed to evaluate transition cow management practices related to housing facilities, feeding philosophy, and cow handling using the dRisk™ screening tool. In addition, a targeted analysis of trace elements in bulk tank milk (Zn, Cu, and Se) was conducted to assess mineral-related nutritional risks. A structured screening tool comprising 65 assessment points was applied to 124 dairy farms, covering 57,211 cows. Risk factors in transition cow management were evaluated and principal components analysis was used for data exploration. The most frequent nutrition- and feeding-related risks during the far-off and close-up periods included limited access to drinking water, high body condition score, and housing cows and heifers together. Mean concentrations of trace elements in bulk tank milk from a targeted subset of farms (n = 9) were 1.68 ± 0.55 μg ml^{-1} for Zn, 0.12 ± 0.05 μg ml^{-1} for Cu, and 0.39 ± 0.08 μg ml^{-1} for Se, indicating generally adequate mineral supply, although considerable inter-farm variability was observed. In maternity and fresh pens, the most common feeding-related issues were limited access to drinking water, shared housing of cows and heifers, and insufficient bedding space. Ensuring adequate access to water, consistent body condition scoring, and separating heifers from adult cows were identified as the main opportunities for improving transition cow management on Polish dairy farms.

Keywords: dairy cow, transition period, management practices, risk assessment, trace elements

Paulina Markowska-Buńka, Department of Pharmacology and Toxicology, Faculty of Veterinary Medicine, University of Warmia and Mazury, Olsztyn, 10-719, Poland, e-mail: paulina.markowska@uwm.edu.pl
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INTRODUCTION

As dairy cows progress through late gestation and enter early lactation, they experience profound physiological, hormonal, and metabolic changes that influence energy balance, immune competence, and overall health (Aeberhard et al. 2001, Busato et al. 2002, Ceciliani et al. 2018, Schären et al. 2021). Proper management during this period is essential to support cows through these changes and prevent transition-related disorders (Melendez, Risco 2005). While the traditional transition period encompasses the three weeks before and after calving (Grummer 1995), the concept has been expanded by Elanco into the Vital 90™ Days (V90D), defined as the approximately 60 days before calving and the first 30 days of lactation (Rapnicki, Overton 2014). This broader timeframe reflects the biological reality that many metabolic and immunological shifts begin well before the final three weeks of gestation.

The physiological adjustments occurring during late gestation, particularly changes associated with declining immune function and increasing metabolic load, markedly increase susceptibility to diseases such as ketosis, metritis, mastitis, and displaced abomasum (Busato et al. 2002, Mulligan, Doherty 2008). Approximately 75% of all dairy cow diseases occur within the first 30 days postpartum, and up to 50% of high-producing cows experience at least one clinical condition (Grummer 1995, Hoeben et al. 2000). These disorders arise primarily from negative energy balance and periparturient immunosuppression (Huzzey et al. 2006, Duffield et al. 2009, LeBlanc 2010).

Given these challenges, proactive management throughout the V90D period is necessary to minimize metabolic stress and maintain immune function. Housing conditions, bedding quality, feeding philosophy, water access, grouping strategies, and cow handling practices all influence the health, welfare, and productivity of transition cows (Kimura et al. 2006, Serrenho et al. 2023). Moreover, nutritional adequacy, including the supply of key trace elements such as zinc, copper, and selenium, which play essential roles in antioxidant defence, immune function, and metabolic stability, may further affect transition outcomes (Sordillo, Streicher 2002).

Systematic assessment of these multifactorial risks is therefore valuable for identifying management weaknesses and guiding veterinary recommendations. In this context, structured risk-screening tools provide an opportunity to evaluate on-farm practices holistically and highlight the greatest opportunities for improvement.

The objective of this study was to assess management practices and nutritional risk factors during the transition period on Polish dairy farms using the dRisk™ screening tool, and to identify key areas with the highest potential to improve cow health and overall farm performance.

MATERIALS AND METHODS

Risk assessment and survey

The analysis was performed on 57,211 cows across 124 dairy farms. The Vital 90 Days™ dRisk tool (version 2.2.10, Elanco, 2013) was used to evaluate management practices during the transition period, defined as the 60 days before calving and the first 30 days after calving (Couto Serrenho et al. 2022). The tool was developed to provide an objective assessment of on-farm management and to help consultants and milk producers identify and minimize health risks associated with the transition period (Middleton, Overton 2018). Its design is based on published research on transition cow management, nutritional recommendations, and expert-based risk analysis (Horst, Jorgensen 1982, Curtis et al. 1983, Grummer 1995, Erb, Grohn 1998, Kelton et al. 1998, Loeffler et al. 1999, Bell et al. 2000, Hoeben et al. 2000, Kimura et al. 2000, 2006, Reynolds et al. 2003, Lyte 2004, Green et al. 2007, Huzzey et al. 2007, Duffield et al. 2009, LeBlanc 2010, McClary 2015).

The survey was conducted on-farm by trained auditors following a unified protocol and standardized guidelines. This ensured objective and comparable assessments across farms and enabled veterinarians, farmers, and herd managers to identify key areas affecting cow welfare, production, health, and reproductive performance.

The final report generated by the dRisk program assigns a color-coded risk level to each management area and provides an overall farm risk score. Risk levels are classified as green (optimal, low risk), yellow (moderate, suboptimal conditions), or red (high risk, poor conditions). The report also identifies the eight management areas with the highest risk and provides targeted recommendations for improvement.

The tool evaluates management practices during the far-off (>21 days prepartum), close-up (≤21 days prepartum), and fresh cow periods (≤21 days postpartum). A total of 65 closed-ended questions were included, with answer options categorized as A (optimal), B (suboptimal), or C (poor), covering facilities, feed and nutritional composition, feeding management, cow comfort, and handling practices (Table 1). Each response category was assigned a corresponding numerical value for further analysis: A = 2, B = 1, and C = 0, which were used in heatmap and principal component evaluations.

Trace element analysis (Zn, Cu – AAS; Se – AES)

Concentrations of zinc (Zn) and copper (Cu) were determined using graphite furnace atomic absorption spectrometry (GF-AAS) with a Perkin-Elmer spectrometer. Measurements were performed at wavelengths of 213.9 nm for Zn and 324.8 nm for Cu. Selenium (Se) concentration was determined by atomic emission spectrometry (AES). Milk samples were

Table 1

Screening tool for each component of the study assessment. Each answer option (A, B, or C) represents the risk level assigned to a specific transition period stage and management area. Values: A = optimal (2), B = suboptimal (1), C = poor (0)

Fresh periods – feeding			
Question	**answer: optimal A**	**answer: suboptimal B**	**Answer: poor C**
Feed quality	no evidence of altered fermentation profiles, offensive odors, or spoilage in the ration	some slight off-odors, and mild evidence of spoilage in the ration	consistent evidence of altered fermentation profiles, offensive odors, and spoilage in the ration
Ration sortability	chopped forage, well mixed, very few particles >7.6 cm but sufficient effective fiber	chopped forage, well mixed, effective fiber but long particles present; moderately sortable	poorly mixed, not chopped, lots of long sortable particles or questionable effective fiber/overly processed
Feedbunk access	≥0.76 m per cow	0.56-0.75 m per cow	< 0.56 m per cow
Bunk maintenance	bunks cleaned daily, if on pasture, feed is delivered to the clean fence line area	bunks are usually cleaned regularly but not daily; if on pasture, feed is often but not always delivered to the clean fence line area	bunks not regularly cleaned; moldy feed present; if pasture, feed is delivered to muddy location
Body condition	<10% of cows are ≥4.0	10-25% of cows are ≥4.0	>25% of cows are ≥4.0
Water access	≥10.2 cm linear access/ cow; clean water; more than 2 water sources in pen	5-10 cm linear access/ cow; moderately clean water; more than 2 water sources in pen	<5 cm linear access/cow. dirty water; only 1 water source in pen
Feeding approach	balanced, ad libitum TMR; if on pasture, active monitoring and balancing of pasture access	partial TMR or restricted access to TMR; if on pasture, inconsistent monitoring and balancing of pasture access	no TMR; cows can pick and choose what to eat; poor management of pasture and inadequate balancing
Nutritional philosophy	carefully balanced for health and productivity	deficiencies or excesses of one or more critical nutrients	grossly or excessive fermentable carbohydrates or grossly inadequate energy or excessive fiber
Protein adequacy of the ration	MP balance of 95-110%; careful consideration of AA profile	MP balance of 85-115%; no consideration of AA profile	MP balance <85% or >115%
Fresh periods – management			
Approximate time dedicated to screening	<1 h per day spent locked in stanchions	1-2 h per day spent locked in stanchions	>2 h per day spent locked in stanchions
Method of screening fresh cows for problems	rigid daily monitoring and treatment program that includes observing appetite, evaluation of front and rear cow	daily but less rigid program consisting of checking one or more cues (e.g., fever, attitude, milk). Any anomalies prompt exam and assistance	no routine use of cues for assistance: no program used to detect sick cows
How are fresh cows handled in the first few days	colostrum cows separated from sick cows	-	colostrum cows housed with sick cows

cont. Table 1

When is the newborn calf removed from the cow	removed within 2 h of delivery and colostrum is harvested immediately thereafter	removed 2-12 h of delivery and colostrum is harvested immediately thereafter	inconsistent removal from calving pen; cows often go for more than 12 h without milking or transfer to fresh pen/fresh ratio
Degree of calving trauma	little or no evidence of tearing/damage to vagina/ vulva	low occurrence of tearing/ damage to vagina/vulva	frequent occurrence of cows showing evidence of vaginal/ vulval trauma
How much time are fresh cows away from home pen	<2 h per day spent away from pen	2-3.5 h per day spent away from pen	>3.5 h per day spent away from pen
Fresh periods – cow comfort			
Bedding and comfort	loose, dry bedding with ample cushion; bed space and neck rail placement allow cows to stand squarely in stalls and rest comfortably	semi-moist bedding or moderate cushion; bed space and neck rail placement allow most cows to stand squarely in stalls and rest comfortable	very wet bedding or inadequate cushion; bed space or neck rail position does not accommodate cows adequately
Lunge access in free stalls	≥0.76 × 0.76 m of unobstructed head space for lunge	obstructed head space but side rail permits side lunging	obstructed forward and obstructed side lunge space
Dimensions of free stalls	1.27-1.32 m wide and ≥1.77 m long	1.14-1.26 m wide and 1.65-1.76 m long	<1.14 m wide and <1.65 m long
Free stall stocking density	<80% stocking density	80-100% stocking density	>100% stocking density
Bedding and comfort and stocking density	daily grooming; >13.9 m^2 per cow	regular grooming; 9.3-13.9 m^2 per cow	insufficient grooming; <9.3 m^2 per cow
Heat abatement	properly functioning soakers and fans	soaker/misting system or fans present but not both; adequate shade over feed bunk	no/improperly functioning heat abatement
Describe access to rest areas or to free stalls	no dead-ends; cows have free access 24/7	one dead-end present; no other limited access within housing	two or more dead ends present; severely restricted access between housing and feeding area
Footing and flooring	well-maintained and properly installed rubber flooring	grooved and well-maintained flooring	inadequately grooved or slick or uneven flooring
Management of stanchion lockups	cows have prior experience with stanchions; exhibit good utilization; <1 h lock-up per day	cows have little to no prior experience with stanchions but little to no reluctance to use stanchions; cows are locked for 1-2 hours per day	cows have no prior experience with stanchions and are reluctant to use them; prolonged locked up (>2 hours per day)
Distance walked/d	cows walk <914 m to and from parlor (total distance per day)	cows walk 914-2,286 m to and from parlor (total distance per day)	cows walk >2,286 m to and from parlor (total distance per day)
Size of first lactation cows	weight of 567-635 kg; height of 1.39-1.47 m; or heifers ≥85% of mature weight	weight of 476-566 kg; 1.32-1.37 m; or heifers 70-85% of mature weight	weight of <476 kg); height of ≤1.32 m; or heifers <70% of mature weight

cont. Table 1

Far-off – feeding			
Feed quality	no evidence of altered fermentation profiles, offensive odors or spoilage in the ration	some slight off-odors, mild evidence of spoilage in the ration	consistent evidence of altered fermentation profiles, offensive odors and spoilage in the ration
Ration sortability	chopped forage, well mixed, very few particles >7.6 cm but sufficient effective fiber	chopped forage, well mixed, effective fiber but long particles present; moderately sortable	poorly mixed, not chopped, lots of long sortable particles or questionable effective fiber/overly processed
Feedbunk access	≥0.76 m per cow	0.56-0.75 m per cow	< 0.56 m per cow
Bunk maintenance	bunks cleaned daily, if on pasture, feed delivered to clean fence line area	bunks usually cleaned regularly but not daily; if on pasture, feed often but not always delivered to clean fence line area	bunks not regularly cleaned; moldy feed present; if on pasture, feed is delivered to muddy location
Body condition	<10% of cows are ≥4.0	10-25% of cows are ≥4.0	>25% of cows are ≥4.0
Water access	≥10.2 cm) linear access per cow; clean water; more than 2 water sources in pen	5-10 cm linear access per cow; moderately clean water; more than 2 water sources in pen	<5 cm linear access per cow; dirty water; only 1 water source in pen
Feeding approach	balanced, ad libitum TMR; if on pasture, active monitoring and balancing of pasture access	partial TMR or restricted access to TMR; if on pasture, inconsistent monitoring and balancing of pasture access	no TMR; cows can pick and choose what to eat; poor management of pasture and inadequate balancing
Nutritional philosophy	low energy, high roughage (0.58-0.62 Mcal of NEL lb^{-1} or 15-17 Mcal of NEL per day) (5.35-5.72 MJ of ^{10}NEL kg^{-1} or 63-71 MJ of ^{8}NEL per cow)	moderate energy, high roughage (0.63-0.65 Mcal of NEL lb^{-1} or 18-19 Mcal of NEL per day) (5.81-6.00 MJ of NEL kg^{-1} or 72-76 MJ of NEL per cow)	excessively high or low energy (<0.58 or >0.66 Mcal of NEL lb^{-1} or <15 or >19 Mcal of NEL per day) (<5.35 or >6.00 MJ of NEL kg^{-1} or <63 or>76 MJ of NEL per cow)
Energy level	>1,000 g of ME	850-1,000 g of ME	<850 g of Mem
Far-off – cow comfort			
Bedding and comfort	loose, dry bedding with ample cushion; bed space and neck rail placement allow cows to stand squarely in stalls and rest comfortably	semi-moist bedding or moderate cushion; bed space and neck rail placement allow most cows to stand squarely in stalls and rest comfortable	very wet bedding or inadequate cushion; bed space or neck rail position does not accommodate cows adequately
Lunge access in free stalls	≥30 × 30 in. (≥0.76 × 0.76 m) unobstructed head space for lunge	obstructed head space but side rail permits side lunging	obstructed forward and obstructed side lunge space
Dimensions of free stalls	1.27-1.32 m wide and 1.77 m long	1.14-1.26 m wide and 1.65-1.76 m long	<1.14 m wide and <1.65 m long
Free stall stocking density	<100% stocking density	100-120% stocking density	>120% stocking density
Bedding and comfort and stocking density	daily grooming; 9.3 m^2 per cow	regular grooming; 7-9.3 m^2 per cow	insufficient grooming; <7 m^2 per cow

cont. Table 1

Heat abatement	properly functioning soakers and fans	soaker/misting system or fans present but not both; adequate shade over feedbunk	no/improperly functioning heat abatement
Describe access to rest areas or to free stalls	no dead-ends; cows have free access 24 hours per day	one dead-end present; no other limited access within housing	two or more dead ends present; severely restricted access between housing and feeding area
Far-off – management			
Group movement patterns of cows	cows are moved into pens once weekly in groups of 10 or more	cows are moved twice weekly; or weekly in groups <10 cows	cows are moved daily, are moved individually, or intervals between moves are >7 d
How often are dry cow pens observed?	pen is walked daily to detect any problems	pen is checked several times per week	no routine observation of pen other than moving cows
Management of stanchions lockups	cows have prior experience. with stanchions, exhibit good utilization; <1 hour lock-up per day	cows have little to no prior experience with stanchions but little to no reluctance to use stanchions; cows are locked for 1-2 hours per day	cows have no prior experience with stanchions and are reluctant to use them; prolonged locked up >2 hours per day
Cows and heifers grouping	separately	-	together
Close-up – feeding			
Feed quality	no evidence of altered fermentation profiles, offensive odors or spoilage in the ration	some slight off-odors, mild evidence of spoilage in the ration	consistent evidence of altered fermentation profiles, offensive odors and spoilage in the ration
Ration sortability	chopped forage, well mixed, very few particles > 3 in. (7.6 cm) but sufficient effective fiber	chopped forage, well mixed, effective fiber but long particles present; moderately sortable	poorly mixed, not chopped, lots of long sortable particles or questionable effective fiber/overly processed
Feedbunk access	≥ 0.76 m per cow	0.56-0.75 m per cow	< 0.56 m per cow
Bunk maintenance	bunks cleaned daily, if on pasture, feed delivered to clean fence line area	bunks usually cleaned regularly, but not daily; if on pasture, feed often but not always delivered to clean fence line area	bunks not regularly cleaned; moldy feed present; if on pasture, feed is delivered to muddy location
Body condition	<10% of cows are ≥4.0	10-25% of cows are ≥4.0	>25% of cows are ≥4.0
Water access	≥10.2 cm linear access/ cow; clean water; more than 2 water sources in pen	5-10 cm linear access/ cow; moderately clean water; more than 2 water sources in pen	<5 cm linear access/cow. Dirty water; only 1 water source in pen
Feeding approach	balanced, ad libitum TMR; if on pasture, active monitoring and balancing of pasture access	partial TMR or restricted access to TMR; if on pasture, inconsistent monitoring and balancing of pasture access	no TMR; cows can pick and choose what to eat; poor management of pasture and inadequate balancing

cont. Table 1

Calcium mobilization management	DCAD, urine pH monitored weekly	DCAD-urine pH inconsistently monitored; or no DCAD supplements, but major minerals balanced	no monitoring urine pH but no DCAD; or no DCAD supplements and major minerals not balanced
Nutritional philosophy	low energy, high roughage (0.60-0.63 Mcal of NEL lb^{-1} or 15-17 Mcal of NEL per day) (5.5-5.8 MJ of NEL kg^{-1} or 63-71 MJ of NEL per cow)	moderate energy, high roughage (0.64-0.66 Mcal of NEL lb^{-1} or 18-19 Mcal of NEL per day) (5.9-6.1 MJ of NEL kg^{-1} or 72-76 MJ of NEL per cow)	excessively high or low energy (<0.59 or >0.66 Mcal of NEL lb^{-1} or<15 or >19 Mcal of NEL per day) (<5.5 or>6.1 MJ of NEL kg^{-1} or <63 or > 76 MJ of NEL per cow)
Close-up – cow comfort			
Bedding and comfort	loose, dry bedding with ample cushion; bed space and neck rail placement allow cows to stand squarely in stalls and rest comfortably	semi-moist bedding or moderate cushion; bed space and neck rail placement allow most cows to stand squarely in stalls and rest comfortable	very wet bedding or inadequate cushion; bed space or neck rail position does not accommodate cows adequately
Free stall stocking density	<80% stocking density	80-100% stocking density	>100% stocking density
Bedding and comfort and stocking density	daily grooming; >13.9 m^2 per cow	regular grooming; 9.3-13.9 m^2 per cow	insufficient grooming; <9.3 m^2 per cow
Heat abatement	properly functioning soakers and fans	soaker/misting system or fans present but not both; adequate shade over feedbunk	no/improperly functioning heat abatement
Describe access to rest areas or to free stalls	no dead-ends; cows have free access 24 hours per day	one dead-end present; no other limited access within housing	two or more dead ends present; severely restricted access between housing and feeding area
Footing and flooring	well-maintained and properly installed rubber flooring	grooved and well-maintained flooring	inadequately grooved or slick or uneven flooring
Close-up – pen management			
Frequency of cow observation	>90% of cows with 14-28 d	>85% of cows with 14-28 d	>15% of cows <10 d or >45 d
Distribution of days in the close-up pen	>90% of cows with 14-28 d	>85% of cows with 14-28 d	>15% of cows <10 d or >45 d

AA – amino acids, DCAD – dietary cation-anion difference, ME – metabolizable energy, Mem – metabolizable energy maintenance, MJ – megajoules, Mcal – megacalories, MP – metabolizable protein, NEL per cow – net energy for lactation per cow, NEL per day – net energy for lactation per day, NEL kg^{-1} – net energy for lactation per kg of feed, NEL lb^{-1} – net energy for lactation per lb of feed, TMR – total mixed ration;
Energy supply was expressed using the NRC net energy for lactation (NEL) system for both dry and lactating cows to ensure consistency across transition periods.

collected into metal-free polypropylene tubes, immediately frozen at −20°C, and subsequently subjected to mineralization with nitric acid in a closed microwave digestion system. Calibration curves were prepared using certified multi-element standard solutions (five-point calibration, $r^2 > 0.995$). A targeted subset of bulk tank milk samples ($n = 9$) was analyzed, with each sample representing a distinct dairy herd.

Statistical analysis

Heatmap analyses were performed in GraphPad Prism 10.0.3 to enable visual inspection of the large dataset. Screening tool responses were converted into numerical values (A = 2 = optimal, B = 1 = suboptimal, C = 0 = poor). Heatmaps were first sorted vertically (top to bottom) according to the total score for each component of analysis. In the second step, horizontal sorting (left to right) was performed based on the components with the highest total scores. The system for maternity pens and the logarithmic values of milking and dry cow numbers were excluded from the heatmap sorting procedure.

To identify the most influential management components, principal component analysis (PCA) was applied. Components with factor loadings greater than 0.30 or less than – 0.30 were considered clinically meaningful. The first two principal components (PC1 and PC2) were retained, representing the primary variation (PC1) and secondary variation (PC2) within the dataset. Analyses were conducted using covariance matrices and a centered data structure in GraphPad Prism 10.0.3.

For critical components, descriptive statistics, including arithmetic mean, standard deviation, standard error of the mean, and 95% confidence intervals, were calculated.

RESULTS AND DISCUSSION

A total of 52,251 milking cows were evaluated, with an average of 344 cows per farm (range: 24-3,500), along with 4,960 dry cows, averaging 40 per farm (range: 2-609). Among the surveyed farms, 35% (n = 44) had separate pre-calving facilities and 61.3% (n = 76) operated a separate calving pen (Table 2). Heatmap visualizations for the far-off, close-up, and fresh cow groups enabled rapid inspection of the dataset and identification of areas requiring improvement (Figures 1-3). Critical components selected through PCA are summarized in Table 3. Principal component analysis showed that the first two principal components explained a meaningful proportion of the variability in the dataset. The first principal component (PC1) accounted for 17.2% of the total variance, while the second principal component (PC2)

Table 2

Proportions of housing system and parity grouping during dry (far-off and close-up) and fresh periods of 124 dairy farms included in management descriptive study

Housing system per farm as (%) of (n)	Far-off	Close-up	Fresh and maternity
Bedded pack	50.18(63)	65(52)	27.41(34)
Free stalls	34.67(43)	28.74(23)	70.16(87)
Dry lots/pasture	14.51(18)	6.25(5)	2.41(3)

Table 3

Characteristics of key components across three analyzed groups (fresh, far-off, close-up) selected by principal component analysis

Groups and critical components	Factor loading (PC1/PC2)	M	SD	SEM	CI_L	CI_U
Fresh						
Water access	0.640	0.758	0.800	0.072	0.616	0.900
Fresh cows handling in the first few days	0.509	1.226	0.978	0.088	1.052	1.400
Cows and heifers grouping system	0.394	0.500	0.870	0.078	0.345	0.655
Feedbunk access	0.350	0.992	0.831	0.075	0.844	1.140
Free stall stocking density	-0.474	0.930	0.779	0.084	0.763	1.097
Far-off						
Cows and heifers grouping system	0.595	0.797	0.983	0.089	0.621	0.972
Water access	0.576	0.626	0.793	0.072	0.484	0.768
Sorting of the ration	0.318	1.577	0.665	0.060	1.458	1.696
Body condition (PC2)	-0.345	1.169	0.773	0.069	1.032	1.307
Group movement patterns of cows	-0.383	1.699	0.600	0.054	1.592	1.806
Feed bunk access (PC2)	-0.652	1.447	0.749	0.068	1.313	1.581
Close-up						
Heat stress abatement (PC2)	0.362	0.984	0.572	0.052	0.882	1.086
Feed bunk access	0.345	0.936	0.647	0.058	0.821	1.050
Protein adequacy of the ration (PC2)	-0.341	1.085	0.405	0.037	1.011	1.159
Water access (PC2)	-0.404	0.790	0.768	0.069	0.654	0.927
Body condition (PC2)	-0.411	1.137	0.642	0.058	1.023	1.251
Bunk maintenance	-0.450	1.565	0.545	0.049	1.468	1.661
Sorting of the ration	-0.486	1.427	0.528	0.047	1.333	1.521
Feed quality	-0.528	1.911	0.286	0.026	1.861	1.962
Free stall stocking density (PC2))	-0.726	0.725	0.816	0.129	0.464	0.986
Nutrition within close-up dry cows	-0.764	1.642	0.619	0.069	1.505	1.779
Calcium mobilization managed	-0.844	1.282	0.802	0.072	1.140	1.425

Component	**Eigenvalue**	**Variance explained (%)**	**Cumulative variance (%)**
PC1	1.55	17.2	17.2
PC2	0.87	9.7	26.9

PC1 – principal component representing the largest proportion of variance, PC2 – principal component representing the second largest proportion of variance, M – arithmetic mean, SD – standard deviation, SEM – standard error of the mean, CI_L – lower confidence interval (95%), CI_U – upper confidence interval (95%)

explained an additional 9.7%, resulting in a cumulative explained variance of 26.9%.

Risk assessments revealed that the dry period, particularly the far-off and close-up stages, offered the greatest opportunities for improvement. Among farms evaluated during the dry period, 73% demonstrated poor

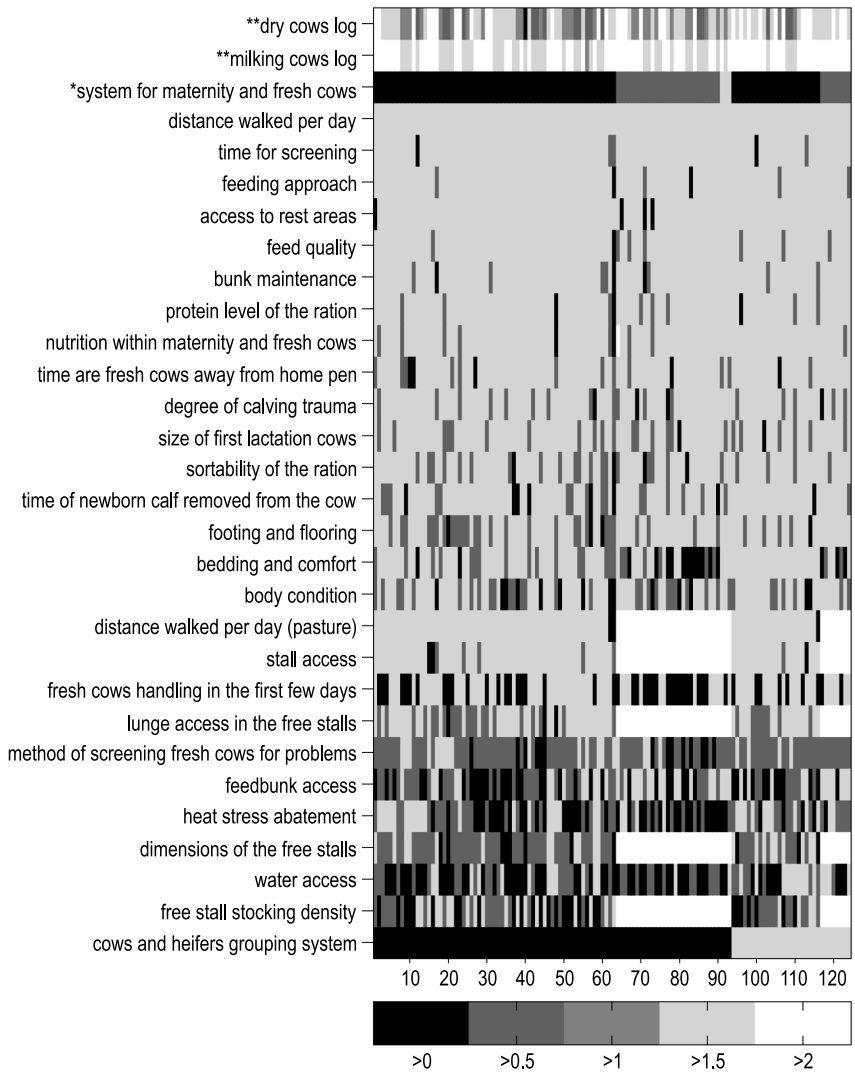

Fig. 1. A fresh group of cows. Heatmap representing key management components assessed in the fresh cow group during the transition period. For each component, possible answer options were assigned to the designated risk level: A – optimal (value of 2 in the heatmap), B – suboptimal (value of 1 in the heatmap), and C – poor (value of 0 in the heatmap); 0 – free stalls, 1 – bedded pack, 2 – dry lots/pasture, * log of the number of milking or dry cows

(n = 21) or mediocre (n = 70) housing conditions and facilities, while only 27% (n = 33) met optimal standards. Similarly, 78% of farms were categorized as high (n = 76) or medium (n = 21) risk for dry cow management. In contrast, post-calving management conditions were optimal in 74% (n = 92) of the visited farms, with only three classified as high-risk. Post-calving facilities and nutrition conditions were high risk in 10% and

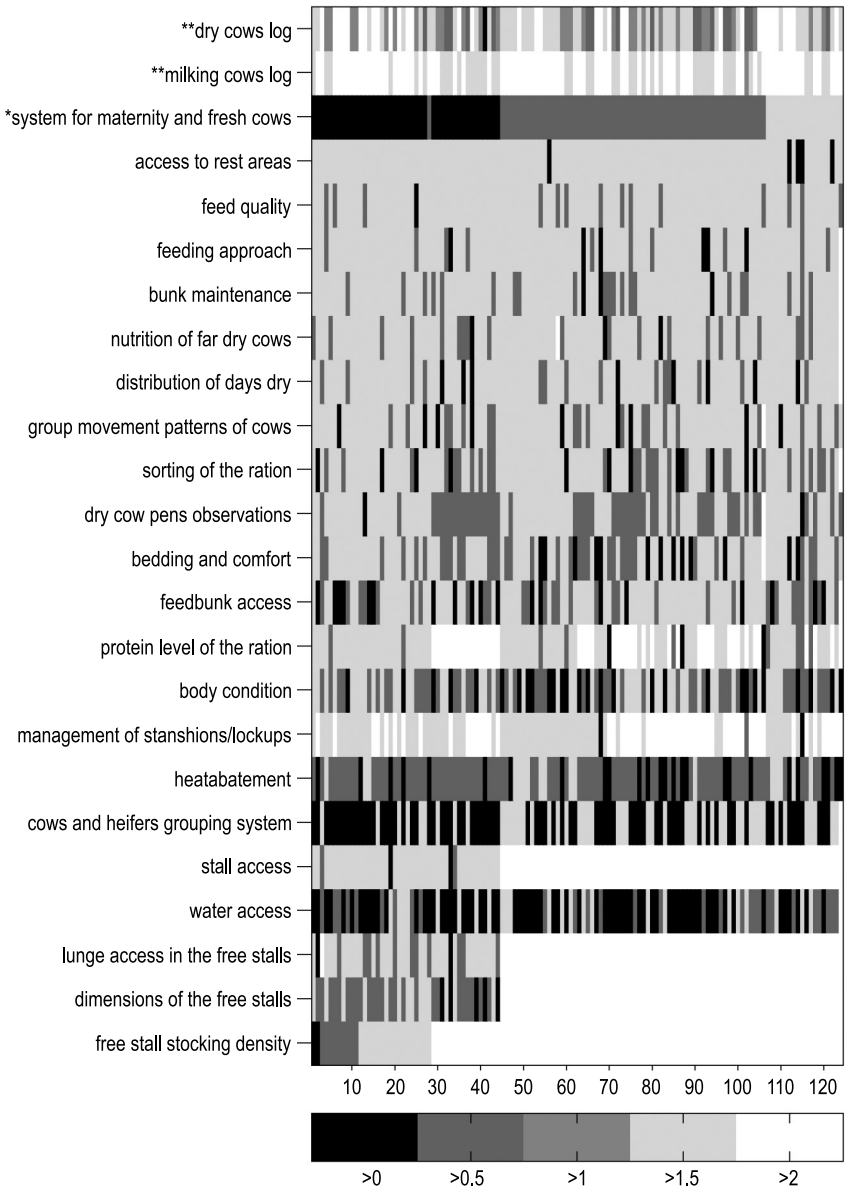

Fig. 2. Far-off group of cows. Heatmap representing key management components assessed in the far-off dry cow group. For each component, possible answer options were assigned to the designated risk level: A – optimal (value of 2 in the heatmap), B – suboptimal (value of 1 in the heatmap), and C – poor (value of 0 in the heatmap); 0 – free stalls, 1 – bedded pack, 2 – dry lots/pasture, * log of the number of milking or dry cows

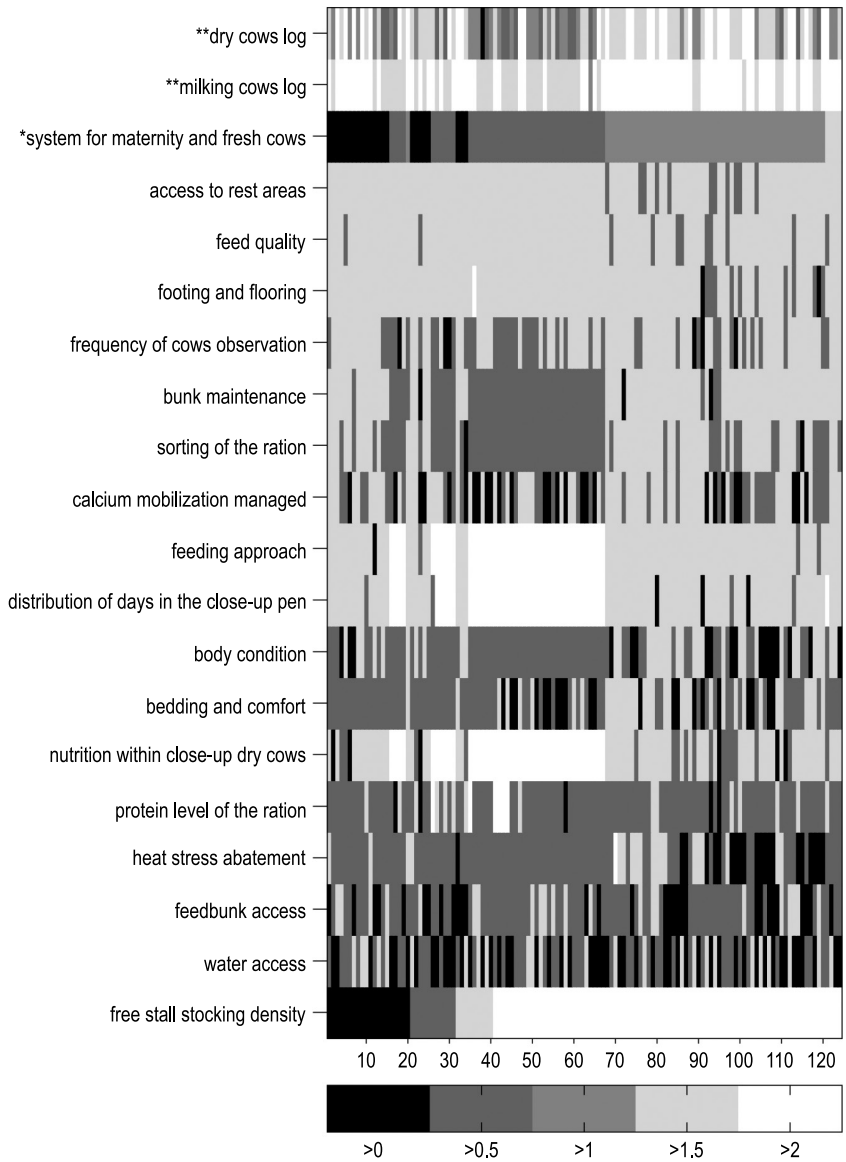

Fig. 3. Close-up group of cows. Heatmap representing key management components assessed in the close-up cow group during the transition period. For each component, possible answer options were assigned to the designated risk level: A – optimal (value of 2 in the heatmap), B – suboptimal (value of 1 in the heatmap), and C – poor (value of 0 in the heatmap). The value >0.5 denotes lack of data; 0 – free stalls, 1 – bedded pack, 2 – dry lots/pasture, * log of the number of milking or dry cows

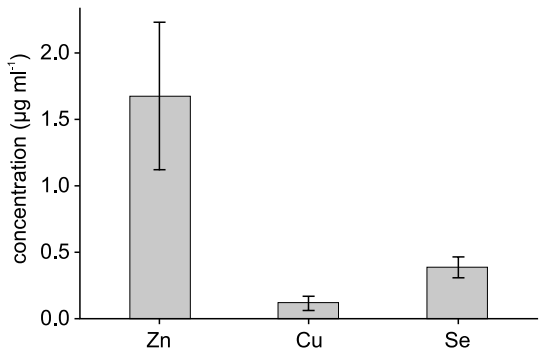

Fig. 4. Mean concentration of Zn, Cu, and Se in bulk tank milk samples (n = 9). Values expressed as µg ml^{-1}; Error bars represent standard deviation (SD)

6% of farms (n = 13 and n = 7), moderate risk in 52% and 60% (n = 65 and n = 74), and low risk in 37% and 35% (n = 46 and n = 43), respectively.

Trace element concentrations in bulk tank milk (Zn, Cu, Se) were obtained from a targeted subset of nine dairy farms. Mean concentrations (±SD) were: Zn = 1.68 ± 0.55 µg ml^{-1}, Cu = 0.12 ± 0.05 µg ml^{-1}, and Se = 0.39 ± 0.08 µg ml^{-1} (Figure 4). These values indicated generally adequate mineral supply. Selenium concentrations were within physiological ranges, consistent with its role in immune competence, while Zn and Cu levels reflected farm-dependent differences in feeding practices. Variability between farms was considerable (Zn: 0.91-2.59 µg ml^{-1}, Cu: 0.082-0.226 µg ml^{-1}, Se: 0.266-0.505 µg ml^{-1}), suggesting heterogeneity in mineral supplementation strategies. Overall, measured trace element values fell within ranges typically reported for European dairy herds.

To our knowledge, this is the first study to objectively assess management practices, nutritional conditions, and cow comfort during the transition period in Polish dairy herds using a structured risk-screening tool. The findings highlight key opportunities for improvement and may support veterinarians and farm advisors in identifying management components with the greatest impact on health, welfare, and productivity. Many of these areas remain underestimated in routine farm management, limiting the expression of cows' genetic potential.

The analysis demonstrates a persistent discrepancy between the management of dry cows and lactating cows. Many farms focus primarily on milk production, with less emphasis on the dry period, despite its critical importance. Statistical analysis confirmed that access to water, body condition scoring (BCS), stocking density, heat stress mitigation, and appropriate grouping of cows and heifers represent key areas for improvement.

Water access emerged as one of the most common deficiencies. Numerous farms failed to provide the recommended minimum of 10 cm of linear water space per cow. As water constitutes approximately 87% of milk and high-producing cows may consume more than 140 L daily, especially under

heat stress, ensuring at least two water sources per group and sufficient linear access is essential (Jensen, Vestergaard 2021, Smith et al. 2006).

Body condition scoring is another frequently neglected practice. When properly implemented, BCS is a simple, cost-effective monitoring tool with good interobserver reliability (Ferguson et al. 1994). High BCS (>3.5-4.0) prepartum increases the risk of dystocia, stillbirth, ketosis, and reduced subsequent milk production (Chassagne et al. 1999, Gillund et al. 2001, Contreras et al. 2004, Rollin et al. 2010). A high proportion of over-conditioned cows (>3.75) may also indicate reproductive inefficiencies or unrecognized pregnancy loss (Silke et al. 2002, Szenci et al. 2021).

In 59% of herds, dry cows and pregnant heifers were housed together, often due to limited capacity on smaller farms. While feasible in larger operations, mixed-parity housing in smaller herds poses challenges. Although protein requirements are similar for cows and heifers (NRC 2001), differences in intake necessitate slightly higher protein density for heifers. Close-up cows often receive DCAD-adjusted diets, which are not recommended for heifers. Social hierarchy also plays a major role: heifers are frequently displaced, exhibit increased stress behaviours, and are more prone to lameness (Galindo, Broom 2000, Soonberg et al. 2021). They may avoid stalls or lie down less due to social pressure (Friend, Polan 1974), with lying times dropping to as low as 5 h per day (Singh et al. 1993).

Stocking density, defined as the cow-to-feed barrier ratio, significantly influences competition, feed intake, and displacement events (DeVries et al. 2004, Huzzey et al. 2007). Adequate space is especially important in mixed-parity groups, where subordinate animals are more vulnerable (Grant, Albright 1995, 2001).

Our findings also show that many farms underestimate the effects of heat stress, despite increasing climatic variability in northern Europe. Heat stress results in substantial economic losses, estimated at USD 900 million annually in the United States (St-Pierre et al. 2003). It affects feed intake, endocrine function, behaviour, respiration, and milk production (Shearer, Beede 1990, Armstrong 1994, Becker, Stone 2020). Dry cows are especially vulnerable, and insufficient cooling during the dry period can negatively affect subsequent lactation performance (Sordillo, Streicher, 2002). Effective mitigation strategies include environmental modification, direct cooling, nutritional adjustments, and genetic selection (De Rensis, Scaramuzzi 2003, Urdaz et al. 2006, do Amaral et al. 2009).

Taken together, these findings emphasize five key management priorities for the transition period (Nordlund 2009):

– ensuring adequate feed and water access before and after calving,
– minimizing cow movements and social stress during late gestation,
– improving cow comfort through appropriate bedding and resting area design.

CONCLUSIONS

This large-scale evaluation of 124 Polish dairy farms (57,211 cows) demonstrates substantial opportunities for improving housing, management, and nutritional practices during the transition period, particularly within dry cow groups (n = 4,960). Systematic assessment of these conditions allows veterinarians and farm advisors to identify management deficiencies that have a direct impact on cow health, welfare, and subsequent productivity and fertility. Applying a standardized, rigorously structured screening approach facilitates comparisons between farms and supports the development of evidence-based recommendations linking management practices with health, production, and reproductive outcomes.

Complementary trace element screening (Zn, Cu, Se) confirmed adequate mineral supply in the evaluated herds, with inter-farm variability indicative of differences in feeding strategies. Integrating transition cow management assessment with targeted monitoring of nutritional and mineral adequacy provides a comprehensive basis for improving herd performance during the Vital 90™ Days.

Limitations of the study

This study has several limitations that should be considered when interpreting the findings. Farms were recruited through convenience sampling, primarily based on requests initiated by herd veterinarians. Consequently, the dataset likely includes both poorly managed farms referred for evaluation and well-managed farms that voluntarily sought external assessment. Although this sampling strategy introduces the potential for selection bias, the inclusion of farms with diverse management standards contributes to a more balanced representation.

Participation required owner consent for data usage, which may have further influenced the composition of the sample. Nevertheless, because the risk assessment tool was developed independently of the participating farms and aimed to provide an objective evaluation, substantial information bias is unlikely. Despite these limitations, the large number of farms included in the study strengthens the generalizability of the overall patterns observed.

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Author contributions

M.K. – data curation, investigation, conceptualization, methodology, writing – review and editing, W.S. –data curation, investigation, writing,

P.M.B.* – original draft preparation, writing – review and editing, M.B. – data curation, investigation, M.T. – data curation, investigation, O.Y. – material development, resources, W.M. – writing – review and editing, supervision, validation, A.B.– conceptualization, supervision, methodology.

Conflicts of interest

The authors declare no conflict of interest regarding the publication of this article.

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