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LARGE HERDS - GREATER CHALLENGES: COMPARATIVE ANALYSIS OF WELFARE QUALITY OF DAIRY COWS BY FARM SIZE

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Abstract: The aim of this study was to determine the effect of dairy herd size on the health score ("Good Health") and key welfare indicators of cows, using the *Welfare Quality*® methodology. Data were collected from small (≤ 100 cows), medium (101–300 cows), and large (> 300 cows) farms. More than 30 indicators were analyzed, including the prevalence of injuries, lameness, skin lesions, metabolic and reproductive disorders, mastitis, and mortality. The results showed that smaller-capacity farms achieved significantly higher ($p < 0.05$), health scores, lower prevalence of lameness, skin lesions, and metabolic disorders, as well as lower mortality rates compared with large farms. In large herds, higher incidences of mastitis, dystocia, and downer cow syndrome, along with increased mortality, were recorded, confirming the negative impact of production pressure and high animal aggregation on welfare. Mortality above the alarm threshold was occasionally observed on small and medium farms as well, indicating the necessity for continuous monitoring across all production systems. The findings suggest that optimizing herd size, improving housing conditions, and reducing production intensity are key strategies for achieving sustainable dairy production in line with animal welfare principles.

Key words: herd size, welfare quality, dairy cows, metabolic disorders, mortality, mastitis

Introduction

Although herd size has long been recognized as a relevant factor in dairy cow welfare, scientific evidence regarding this relationship remains fragmented. Previous research has predominantly focused on resource-based indicators, such as nutrition and housing, with earlier studies demonstrating that smaller herds tend to

rank higher in these domains (Ostojić-Andrić et al., 2022). However, the impact of herd size on the health status of cows remains insufficiently elucidated, despite recent meta-analyses indicating a growing body of research on health indicators such as mastitis, laminitis, and biomarkers of metabolic stress (Linstädt et al., 2024; Wessels et al., 2025). These animal-based indicators reflect the direct response of the animal to its living conditions.

To date, most investigations have addressed this relationship through the prevalence of specific diseases and disorders (USDA, 2018; Ostojić-Andrić et al., 2022; Linstädt et al., 2024), with mixed results: certain studies report significant differences between small and large farms, while meta-analyses do not confirm a clear causal link (Wessels et al., 2025).

Among experts, there is a prevailing view that large-scale systems provide less favorable conditions for ensuring animal welfare. Increased farm capacity facilitates and accelerates pathogen spread, impedes active surveillance and timely detection of health issues, while intensive production further strains cow physiology (Lindena and Hess, 2022). Economically motivated space optimization-fewer resting places, limited feeders, and higher stocking density-often conflicts with high standards of welfare (Lindena and Hess, 2022; Popescu et al., 2007).

Globally, recent decades have seen a marked increase in herd size driven by consolidation in the dairy industry. In England, the average number of cows per farm rose by 27% between 2008 and 2018 (from 117 to 148; House of Commons Library, 2020), while in the EU-28 the increase was 69% (from 26 to 46; European Commission, 2021). Similar trends have been documented in Australia, New Zealand, and the United States, where current herd sizes are two to six times larger than in the 1990s (DairyNZ, 2014; Dairy Australia, 2015; MacDonald et al., 2007). This growth in capacity has coincided with wider adoption of modern technologies and reduced pasture access; by 2013, only about 25% of all dairy cows had access to pasture. Concurrently, selection and production pressures have intensified physiological stress and predisposition to production-related diseases (Coignard et al., 2014).

Contrary to global trends, the structure of cattle production in Serbia remains markedly small-scale. According to the 2023 Agricultural Census, 62% of cattle farms keep no more than nine cows, and the average household owns just one animal (RZS, 2024). Herds with more than 100 cows account for less than 1% of the total, yet contribute around 30% of milk sold (Ministry of Agriculture, 2025). This has resulted in a dual structure: small producers numerically dominate, while a limited number of large farms hold the leading market share. Large farms are characterized by “intensive” risks related to pathogens and metabolic stress, whereas smaller operations frequently face challenges of insufficient biosecurity and veterinary coverage (Agricultural Census, 2023).

While such changes serve to increase productivity, they also carry potential risks for dairy cow health that require timely management. Particular attention

should be paid to monitoring metabolic disorders, which are highly prevalent and economically significant (EFSA, 2023). With a view to achieving more precise understanding of the relationship between herd size and welfare, this study examines the effect of farm capacity (≤ 100, 101–300, > 300 cows) on "Good Health" scores and key clinical indicators, testing the hypotheses H_0 (herd size has no effect) and H_1 (farms with > 300 cows have lower health scores and higher mortality).

Materials and Methods

Farms

The study encompassed a total of 16 conventional dairy farms, selected to ensure the greatest possible variability in herd size and housing system. The sample included farms operating under free-stall housing (FSH) and those using tie-stall housing (TSH) systems.

Based on the number of lactating cows, farms were classified into three categories: small (≤ 100 cows), medium (101–300 cows), and large (> 300 cows). In this paper, the terms herd size, farm capacity, and farm size are used interchangeably to denote the number of lactating cows on a farm, with the classification applied according to the aforementioned criteria.

The FSH system was present on 60% of large farms, 75% of medium farms, and 15% of small farms, while the remaining farms employed the TSH system. In terms of breed composition, 80% of the total cow population consisted of domestic Simmental, and the remaining 20% of Holstein-Friesian cattle.

To preserve the anonymity of participating farms and ensure clarity in data presentation, each farm was assigned a unique code from 1 to 16.

Welfare Assessment

Cow welfare was evaluated according to the Welfare Quality® Assessment Protocol for Cattle – WQP (2009), a standardized indicator system primarily based on animal-oriented measures that directly reflect the actual welfare status of the animals. On each farm, three trained assessors—experienced in dairy cow welfare assessment—conducted the evaluation. To eliminate the effects of seasonal variation, every farm was visited twice per year (in winter and summer), and the average value for each welfare measure was calculated.

Data collected from the farms were processed using the Welfare Quality® Scoring System (2023). More than 30 indicators—covering the domains of feeding, housing, health, and behavior—were aggregated into 12 criteria and four fundamental welfare principles (good feeding, good housing, good health, and appropriate behavior). According to the overall assessment score, farms were assigned to one of four welfare categories: excellent (81–100

points), enhanced (56–80 points), or acceptable (21–55 points). Farms failing to meet minimum requirements were classified as not classified (< 20 points). Since the aim of this study was to investigate the effect of herd size on the provision of adequate health status, Table 1 presents only the parameters included in the evaluation of this principle. A detailed description of each measure is provided in WQP (2009).

Statistical Analysis

All statistical analyses were performed using the commercial software Statistica v.10 (StatSoft, Inc., USA, 2015). For the evaluated measures, as well as for the scores of criteria and principles, descriptive statistical parameters were calculated, including the mean, standard deviation, and minimum and maximum values. The effect of herd size on welfare in the studied farms was assessed using the t-test or the Mann–Whitney test, depending on the normality of the data distribution as determined by the Kolmogorov–Smirnov test. Differences were considered statistically significant at $p < 0.05$.

Table 1. Criteria and measures used in the assessment of "Good health" principle (Welfare Quality® Assessment Protocol, 2009)

Principles	Criterions	Measures
Good health	Absence of injuries	Lameness; integument alterations
	Absence of disease	Coughing; nasal discharge; ocular discharge; hampered respiration; diarrhoea; vulvar discharge; milk somatic cell count; mortality; dystocia; downer cows
	Absence of pain induced by management procedure)	Disbudding/dehorning; tail docking

Results and Discussion

The results of the present study on the effect of farm size on the provision of the *Good Health* principle (Table 2) indicate that farm size exerted a significant influence ($p \leq 0.05$) on the health of dairy cows. The average health status across the farms surveyed fell within the *acceptable* welfare quality category (21–55 points), with the lowest score recorded on large-capacity farms (36 points).

Within the criterion *absence of injuries*, medium-capacity farms achieved the highest total scores, as well as the highest proportion of healthy cows and animals free from injuries. In contrast, large farms recorded the greatest proportion

of moderately lame cows and those with skin lesions. These findings are consistent with earlier reports by Albana (1995) and Wells et al. (1999), as well as with more recent studies by Roche et al. (2024) and Patoliya et al. (2024), which indicate a four- to five-fold higher prevalence of hock lesions and a markedly greater incidence of lameness on farms with more than 300 cows compared to smaller systems. This may be attributed to increased stocking density, harder flooring, and reduced individual monitoring, which together limit lying comfort and delay the detection of early lesions (Barkema et al., 1999; Lindena and Hess, 2022).

Table 2. Comparison of welfare measures related to the "Good health"

Farm size	Large (over 300 cows)					Medium (100 - 300 cows)					Small (30 - 100 cows)					*F*	LSD test
Number of farms, n	n=5					n=4					n=7					V	V S
Principles, criterions and measures	$\bar{x}$	*SD*	S^2	*Min*	S	$\bar{x}$	*SD*	S^2	*Min*	*Max*	$\bar{x}$	*SD*	S^2	*Min*	*Max*	S	M M
Good health	35.9	7.2	52.4	23.9	43.7	43.3	7.8	60.6	35.1	56.6	43.7	7.5	56.5	32.3	55.2	*	* * ns
1. Absence of injuries, points	46.3	16.3	267.0	21.0	67.9	58.7	12.4	153.9	45.1	81.1	51.3	14.3	204.9	32.8	81.1	ns	ns ns ns
Not lame cows, %	59.7	18.9	356.8	31.0	84.7	71.2	11.8	138.6	60.3	90.0	64.2	19.3	370.8	20.6	88.6	ns	ns ns ns
Moderately lame, %	31.0	13.6	183.6	12.5	49.5	24.9	10.2	104.2	9.2	35.9	24.3	15.6	243.6	7.0	61.8	ns	ns ns ns
Severely lame, %	9.3	6.7	44.6	2.2	20.3	4.0	2.6	6.9	0.5	8.2	16.1	21.0	441.1	0.0	86.6	ns	ns ns ns
Cows with at least one hairless patch, %	26.7	23.0	528.8	9.2	73.7	11.4	4.0	16.0	5.6	16.7	15.1	13.3	176.2	0.0	41.2	ns	* ns ns
Cows with at least one lesion, %	10.4	10.7	115.4	2.3	30.0	4.8	3.9	15.1	0.0	12.5	4.7	3.2	10.2	0.0	9.1	ns	ns * ns
Cows with no lesion, %	89.6	10.7	115.4	70.0	97.7	93.3	8.9	80.0	71.9	100.0	88.8	23.8	564.9	6.9	100.0	ns	ns ns ns
2. Absence of disease, points	51.2	14.4	207.2	30.2	64.6	54.4	20.0	399.5	40.4	100.0	68.4	24.6	607.3	36.7	100.0	ns	ns ns ns
Nasal	2.2	4.7	22.3	0.0	15.2	1.0	3.0	8.7	0.0	8.3	0.0	0.0	0.0	0.0	0.0	ns	ns ns ns

Farm size	Large (over 300 cows)					Medium (100 - 300 cows)					Small (30 - 100 cows)					*F*	LSD test
Number of farms, n	n=5					n=4					n=7					V	V S
Principles, criterions and measures	$\bar{x}$	*SD*	S^2	*Min*	S	$\bar{x}$	*SD*	S^2	*Min*	*Max*	$\bar{x}$	*SD*	S^2	*Min*	*Max*	S	M M
discharge, %																	
Increased respiratory rate, %	0.2	0.4	0.2	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ns	ns * ns
Ocular discharge, %	7.1	8.1	65.2	0.0	19.8	6.3	9.5	91.0	0.0	29.2	0.4	0.6	0.4	0.0	1.4	*	ns * ns
Diarrhoea, %	2.0	2.3	5.5	0.0	7.8	2.8	3.2	10.1	0.0	8.2	1.6	2.1	4.5	0.0	6.2	ns	ns ns ns
Vulvar discharge, %	0.9	0.9	0.9	0.0	2.5	1.1	0.9	0.8	0.0	2.5	2.0	1.9	3.8	0.0	5.6	ns	ns ns ns
Frequency of coughing, per cow per 15 min	0.2	0.4	0.2	0.0	1.0	0.1	0.4	0.1	0.0	1.0	0.0	0.0	0.0	0.0	0.0	ns	ns ns ns
Mastitis, %	2.6	1.4	2.0	1.6	5.3	2.0	1.0	0.9	0.7	3.5	2.2	0.7	0.5	0.8	3.4	ns	ns ns ns
Dystocia, %	2.9	2.1	4.3	0.8	6.2	8.1	8.2	67.3	2.2	21.3	2.9	4.1	17.0	0.0	9.7	*	* ns *
Downer cows, %	1.9	1.8	3.3	0.0	5.1	1.1	1.2	1.4	0.0	2.3	0.5	0.9	0.8	0.0	2.0	*	ns ns
Mortality, %	10.7	7.1	50.5	1.3	21.3	4.4	2.3	5.2	1.1	6.3	5.2	5.2	27.1	0.0	16.7	*	* * ns
3. Absence of pain induced by management, points	28.0	0.0	0.0	28.0	28.0	46.0	33.3	1110.9	28.0	100.0	47.4	34.6	1198.4	20.0	100.0	ns	ns ns ns
Disbudding/ dehorning, %	100.0	0.0	0.0	100.0	100.0	75.0	46.3	2142.9	0.0	100.0	65.6	44.2	1953.9	0.0	100.0	ns	ns * ns

p = significance of differences between the means calculated by t-test, ns = not significant (p> 0.05), * = significant statistical differences at p< 0.05, ** = significant statistical differences at p< 0.01

The criterion *absence of disease* was rated most favorably on small farms, whereas the poorest results were documented on large farms. In the latter, a higher proportion of metabolic disorders was recorded, in line with the findings of Linstädt et al. (2024), which confirm that the prevalence of metabolic disorders and

mastitis increases proportionally with herd size. This can largely be explained by the higher production intensity and negative energy balance typical of large-capacity farms, which place additional physiological strain on high-yielding cows during early lactation and increase their susceptibility to metabolic disturbances (Egger-Danner et al., 2020; EFSA, 2023). Metabolic disorders represent key risk factors that impair health scores and prolong the service period of cows, and are often subclinical-such as subclinical hypocalcaemia (SCHC), whose prevalence on large farms reaches 35-50% (Berean et al., 2025). Higher stocking densities in such systems facilitate the spread of infectious agents and hinder timely diagnosis (Mramba and Mohamed, 2024), while greater production intensity further strains physiological functions and reduces the capacity to maintain welfare (Egger-Danner et al., 2020; EFSA, 2023). Economically driven infrastructural solutions—such as a reduced number of stalls and feeding places combined with higher stocking density—may increase efficiency but negatively affect welfare (Steeneveld et al., 2024). The association between reduced comfort and higher incidence of mastitis and laminitis has also been confirmed in earlier research (Barkema et al., 1999; Lindena and Hess, 2022).

Diseases such as coughing, downer cow syndrome, nasal and ocular discharge, tachypnoea, and mastitis were more prevalent on large farms, in accordance with the findings of Waage et al. (1998). Such patterns are likely a consequence of higher animal aggregation, which facilitates faster pathogen transmission, combined with suboptimal ventilation and delayed disease detection in large groups (Lindena and Hess, 2022; EFSA, 2023). On medium-capacity farms, a high incidence of dystocia (8.14%) was observed, notably exceeding the alarm threshold of 5.5% (Forkman and Keeling, 2009). The elevated incidence of dystocia and downer cow syndrome in medium and large herds reflects the combined effects of genetic selection for milk yield and the associated reproductive and metabolic challenges experienced by high-producing cows (EFSA, 2023; Steeneveld et al., 2024). These findings further support the EFSA (2023) conclusion that large dairy herds are a reliable predictor of increased risk of mastitis and other production-related diseases.

The highest mortality rate (10.71%) was recorded on farms with more than 300 cows; however, small (5.16%) and medium farms (4.37%) also exceeded the alarm threshold (Forkman and Keeling, 2009). A pilot study conducted on 12 pasture-based farms in Uruguay reported an average mortality rate of 4.5% (range 1.1–8.1%), with values above 8% considered a serious welfare concern (Doncel-Díaz et al., 2025).

In addition, the routine practice of dehorning, performed consistently and without anaesthesia on large farms (100% of animals), resulted in lower scores for the criterion absence of pain induced by management procedures. On smaller farms, this practice was carried out less frequently, in approximately two-thirds of cows.

Conclusion

The findings of this study confirm that herd size exerts a significant influence on the health status of dairy cows, with large-capacity farms (> 300 cows) achieving lower scores within the Good Health principle compared with smaller production systems. Higher rates of metabolic disorders, mastitis, dystocia, injuries, and mortality were recorded on larger farms, indicating a complex interaction between production intensity, biosecurity challenges, and the physiological burden placed on animals. In contrast, small and medium-sized farms generally achieved more favorable results for most indicators, although they were not entirely free from critical values for certain parameters.

These results suggest that, while increasing farm capacity may improve economic efficiency, it entails substantial risks to cow welfare and health-particularly with respect to metabolic and infectious diseases. Therefore, the expansion of production on large farms should be accompanied by systematic monitoring of animal-based indicators, enhancement of biosecurity measures, optimization of housing infrastructure, and adjustment of production intensity to align with the physiological capacities of the animals. Special emphasis should be placed on the early detection and prevention of metabolic disorders, the provision of adequate lying and feeding space, and the humane execution of routine procedures such as dehorning.

Integrating these measures into farm management practices could contribute to reducing health risks and improving overall welfare standards, thereby ensuring the sustainability of dairy production in Serbia in line with contemporary standards and consumer expectations.

Veća stada – veći izazovi: komparativna analiza kvaliteta dobrobiti mlečnih krava u zavisnosti od veličine farme

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Rezime

Cilj ovog istraživanja bio je da se utvrdi uticaj veličine mlečnog stada na zdravstveni skor (princip Dobro zdravlje) i ključne indikatore dobrobiti krava, koristeći metodologiju Welfare Quality®. Podaci su prikupljeni na malim (≤ 100 grla), srednjim (101–300) i velikim (> 300) farmama. Analizirano je više od 30 indikatora, uključujući učestalost povreda, šepavosti, kožnih lezija, metaboličkih i reproduktivnih poremećaja, mastitisa i mortaliteta. Rezultati su pokazali da farme

manjeg kapaciteta ostvaruju značajno više ($p < 0.05$) ocene zdravstvenog skora, manju prevalencu šepavosti, lezija i metaboličkih poremećaja, niži mortalitet, u poređenju sa velikim farmama. Na velikim farmama registrovana je veća učestalost mastitisa, distokija i sindroma ležanja, kao i viši mortalitet, što potvrđuje negativan uticaj proizvodnog pritiska i visoke aglomeracije životinja na njihovu dobrobit. Mortalitet iznad alarmantnog praga povremeno je registrovan i na manjim i srednjim farmama, što ukazuje na potrebu stalnog monitoringa u svim proizvodnim sistemima. Rezultati sugerišu da optimizacija veličine stada, unapređenje uslova držanja i smanjenje intenziteta proizvodnje predstavljaju ključne smernice za postizanje održive mlečne proizvodnje u skladu sa principima dobrobiti životinja.

Ključne reči: veličina stada, kvalitet dobrobiti, mlečne krave, metabolički poremećaji, mortalitet, mastitis

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Conflict of interest
The authors declare that they have no conflict of interest.

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