Evaluating the synergistic impact of season and transport distance on bovine mortality during transport to slaughter

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Abstract

Transport-related mortality is a key indicator of animal welfare. This study evaluated the effects of season, transport distance, and their interaction on mortality in cows, heifers, fattening cattle, and calves transported to slaughter. The analysis was based on data collected in cooperation with the State Veterinary Administration on bovine transports to slaughterhouses in the Czech Republic from 2017 to 2023. In cows, mortality was significantly higher in spring than in summer, and increased with transport distance up to 300 km. A significant interaction between winter and long-distance transport was identified, resulting in the highest observed mortality (0.174%). In heifers, mortality exhibited no consistent seasonal or distance-related pattern, although the highest rate occurred at intermediate distances (51–100 km). Fattening cattle displayed low and stable mortality across all seasons and distances. In calves, the highest mortality occurred in summer (0.379%), with significantly lower rates in autumn and winter. No clear trend with distance or significant interaction effect was observed in this category. These findings indicate that season and transport distance significantly influence transport-related mortality, with the most pronounced effects in cows and calves. The identified risk patterns suggest a need for targeted interventions tailored to animal category, environmental conditions, and journey length to improve welfare during transport.

Cattle, cow, heifer, calf, dead-on-arrival, welfare

The welfare of animals being transported to slaughter is a critical issue in livestock production, with major implications for animal well-being, product quality, and public perception (Schwartzkopf-Genswein et al. 2012; Válková et al. 2022). Although cattle generally exhibit lower transport-related mortality than more sensitive species such as pigs and poultry (Válková et al. 2022), deaths in transit still represent important welfare failures and economic losses (Norris 2005; Cernicchiaro et al. 2012; González et al. 2012; Padalino et al. 2018).

Environmental and logistical factors are key contributors to stress during transport. Season and transport distance have been independently associated with adverse outcomes, yet their potential interaction remains underexplored, especially in cattle. Exposure to extreme temperatures during winter or summer has been linked to increased physiological strain and mortality, particularly in vulnerable categories such as calves or debilitated animals (Malena et al. 2006; Schwartzkopf-Genswein et al. 2012). Similarly, longer transport distances are known to intensify stress through prolonged fasting, motion, and handling (Tarrant et al. 1992; Malena et al. 2006; Cernicchiaro et al. 2012; González et al. 2012), although some evidence suggests that short journeys may also result in mortality, possibly due to abrupt environmental transitions or inadequate management (Šímová et al. 2017).

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Few studies have systematically evaluated the combined or synergistic impact of these two factors. Research in poultry has indicated that season and transport distance can interact in a non-additive manner, significantly affecting mortality outcomes depending on species and category (Justová et al. 2025a). Whether similar synergistic effects occur in bovine species remains unclear.

Moreover, different categories of cattle – cows, heifers, fattening cattle, and calves – may differ in their physiological responses to transport stress. Cows and heifers may exhibit varying levels of adaptation based on reproductive status and previous handling experience, while fattening cattle and calves often have distinct sensitivities related to age, body condition, or immunity (Knowles et al. 1995; Večerek et al. 2006a,b; Malena et al. 2007; González et al. 2012; Šímová et al. 2016; Padalino et al. 2018; Válková et al. 2022).

This study aimed to investigate the potential synergistic effects of season and transport distance on mortality in cattle during transport to slaughterhouses in the Czech Republic over a seven-year period (2017–2023).

Materials and Methods

For the purposes of this study, data on the transport of bovine animals to slaughterhouses in the Czech Republic between 2017 and 2023 were obtained in cooperation with the State Veterinary Administration. The State Veterinary Administration is the competent authority responsible for overseeing compliance with animal welfare legislation in the Czech Republic (Švestková et al. 2024a,b).

The transport of cattle was evaluated and categorized into four groups: cows (763,062 animals), heifers (197,018), fattening cattle (679,556), and calves (59,200). The number of animals transported by category, season, and transport distance is given in Table 1.

The same dataset was previously analysed by Justová et al. (2025b), who reported descriptive statistics on cattle transport and mortality rates in the Czech Republic between 2017 and 2023. Their study focused on overall trends across animal categories, without considering explanatory factors. In contrast, the present analysis examines the potential synergistic effects of season and transport distance on transport-related mortality, thus providing novel insights.

For the purposes of the analysis, the year was divided into the following seasons: spring (March, April, and May), summer (June, July, and August), autumn (September, October, and November), and winter (December,

Table 1. Number of bovine animals transported by category, season, and transport distance.

		Transport distance				
Animal category	Season	≤ 50 km	51–100 km	101–200 km	201–300 km	> 300 km
Cows	Spring	89,517	61,198	23,720	7,194	3,361
	Summer	89,763	60,899	22,508	6,696	3,187
	Autumn	95,300	66,774	27,762	9,077	3,730
	Winter	90,913	63,870	25,983	7,596	4,014
Heifers	Spring	28,259	13,271	6,931	2,058	763
	Summer	21,077	12,293	5,883	1,691	663
	Autumn	30,817	14,461	7,062	2,122	707
	Winter	27,523	12,741	5,976	1,905	815
Fattening cattle	Spring	87,077	45,617	30,479	8,909	2,433
	Summer	74,816	42,217	29,857	8,841	2,316
	Autumn	92,128	46,899	32,382	9,452	2,377
	Winter	80,643	42,058	30,144	8,647	2,264
Calves	Spring	8,392	4,679	595	149	144
	Summer	8,810	4,951	684	209	111
	Autumn	9,770	5,317	847	224	94
	Winter	8,706	4,462	733	214	109

January, and February). The average seasonal temperatures recorded by the Czech Hydrometeorological Institute during the monitored period were 8.2 °C in spring, 18.6 °C in summer, 9.2 °C in autumn, and 0.5 °C in winter.

Transport distances were categorized based on the size of the monitored area (the Czech Republic covers 78,886 km², with a maximum length of 493 km from west to east and 278 km from north to south) into the following groups: very short distance (up to 50 km), short distance (51–100 km), medium distance (101–200 km), long distance (201–300 km), and very long distance (301 km and more).

The mortality rate was assessed for each cattle category transported to slaughterhouses. Relative mortality rates were compared across the entire monitored period between different seasons to determine the influence of the season on cattle mortality during transport to slaughter. Likewise, relative mortality rates were compared across different transport distances to assess the influence of distance on transport-related mortality. Furthermore, relative mortality rates were compared across all combinations of seasons and transport distances to identify which combinations of these two factors resulted in the highest mortality rates for individual types and categories of cattle transported to slaughterhouses.

Statistical assessment was based on the comparison of relative frequencies using the χ^2 (chi-squared) test, with statistical significance set at $P < 0.05$. Calculations were performed using Microsoft Excel Office Professional Plus 2019 (Microsoft Corporation, Redmond, WA, USA).

Results

Figure 1 presents transport-related mortality rates of cows, heifers, fattening cattle, and calves across different seasons, regardless of transport distance.

In cows, no significant effect of season (i.e., variations in ambient temperature) on transport-related mortality was observed ($P > 0.05$), with the exception of a higher ($P < 0.05$) mortality rate in spring (0.069%) compared to summer (0.052%). In heifers, no significant seasonal differences ($P > 0.05$) were found, with mortality rates of 0.022% in spring and summer, and 0.024% in autumn. No transport-related deaths were recorded in winter. In fattening cattle, mortality ranged from 0.009% to 0.013% without any significant seasonal variation ($P > 0.05$). In calves, the highest mortality was observed

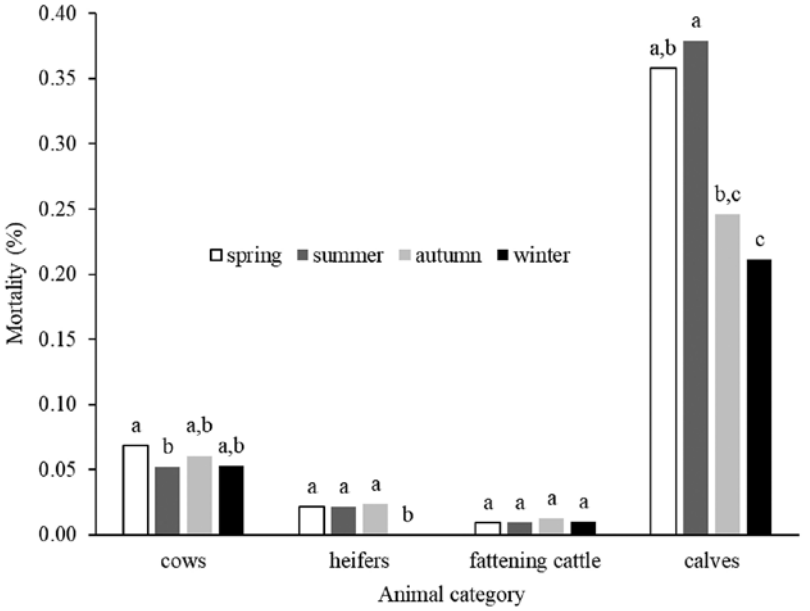

Fig. 1. Transport-related mortality of different categories of cattle as affected by season

[a–c] Different letters above columns within the same animal category indicate significant differences in mortality rates ($P < 0.05$)

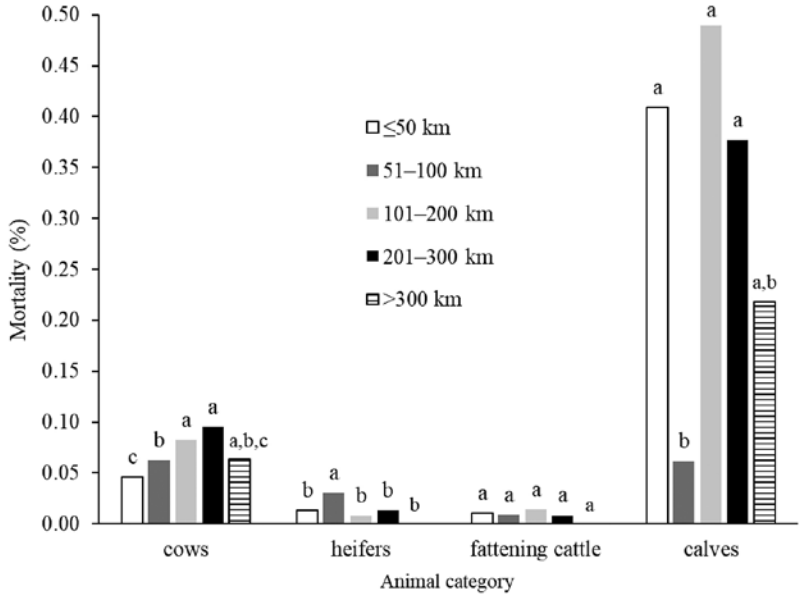

Fig. 2. Transport-related mortality of different categories of cattle as affected by transport distance

[a–c] Different letters above columns within the same animal category indicate significant differences in mortality rates ($P < 0.05$)

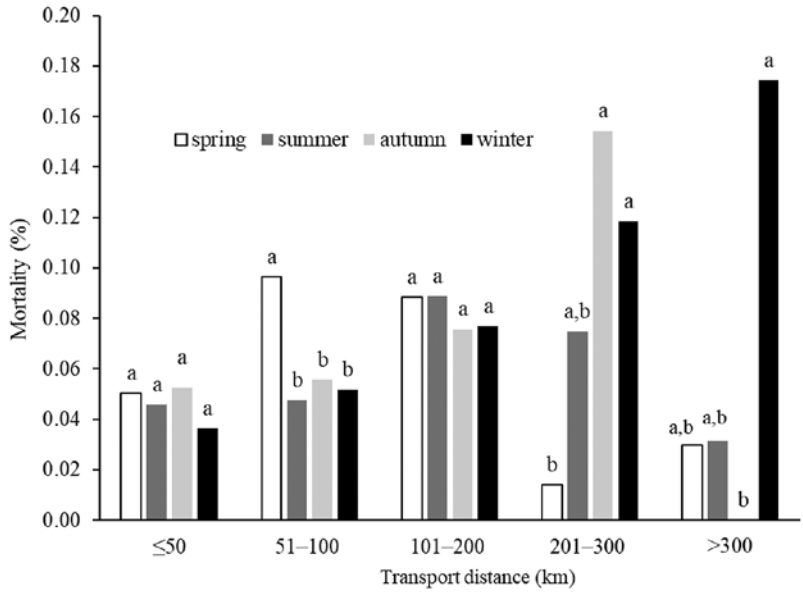

Fig. 3. Comparison of transport-related cow mortality between seasons for the monitored transport distances

[a–b] Different letters above columns within the same transport distance indicate significant differences in mortality rates ($P < 0.05$)

in summer (0.379%), with significantly ($P < 0.05$) lower mortality in autumn (0.246%) and winter (0.211%).

Figure 2 presents transport-related mortality rates of cows, heifers, fattening cattle, and calves in relation to transport distance, irrespective of season.

In cows, transport distance (and by extension, transport duration) had a significant effect on mortality. Mortality increased significantly ($P < 0.05$) with longer transport distances up to 300 km, ranging from 0.046% to 0.095%. For distances exceeding 300 km, no further significant increase in mortality was observed ($P > 0.05$). In heifers, no consistent or significant relationship between transport distance and mortality was established. Interestingly, the highest mortality rate (0.030%) was observed at transport distances of 51–100 km, but no clear increasing or decreasing trend with distance was found. In fattening cattle, mortality rates did not differ significantly ($P > 0.05$) across transport distances. Similarly, in calves, no clear relationship between distance and mortality was identified. The lowest mortality (0.062%) was recorded at distances of 51–100 km, which was significantly lower ($P < 0.05$) compared to distances of up to 50 km and 101–300 km, but not significantly different from distances over 300 km.

Figure 3 illustrates the synergistic effect of season and transport distance on mortality rates in cows during transport to slaughter. The highest mortality (0.174%) was observed in the combination of winter season and the longest transport distance, indicating this as the most detrimental condition. In heifers, no synergistic interaction between season and transport distance on mortality was identified (Fig. 4). Similarly, no clear synergistic effect of season and transport distance on transport-related mortality was observed in fattening cattle (Fig. 5). In calves, no significant interaction between season and transport distance influencing mortality rates during transport was found (Fig. 6).

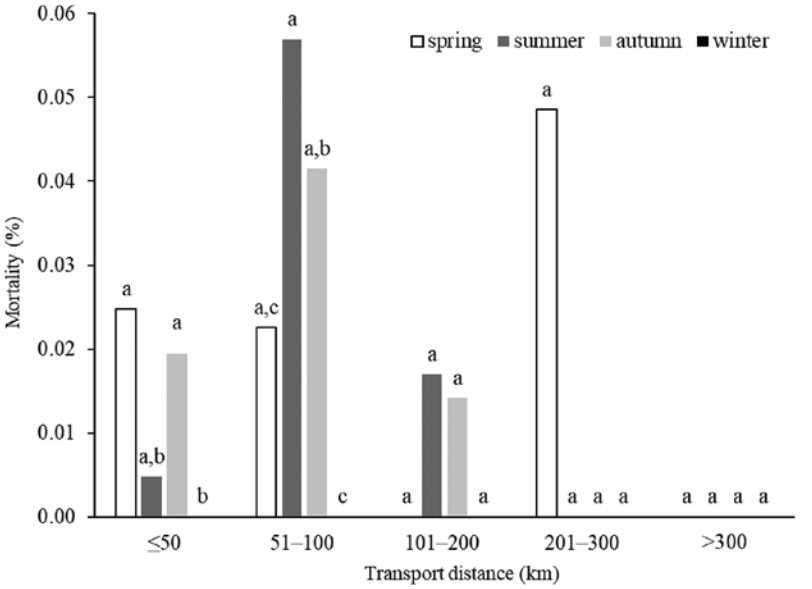

Fig. 4. Comparison of transport-related heifer mortality between seasons for the monitored transport distances

[a–c] Different letters above columns within the same transport distance indicate significant differences in mortality rates ($P < 0.05$)

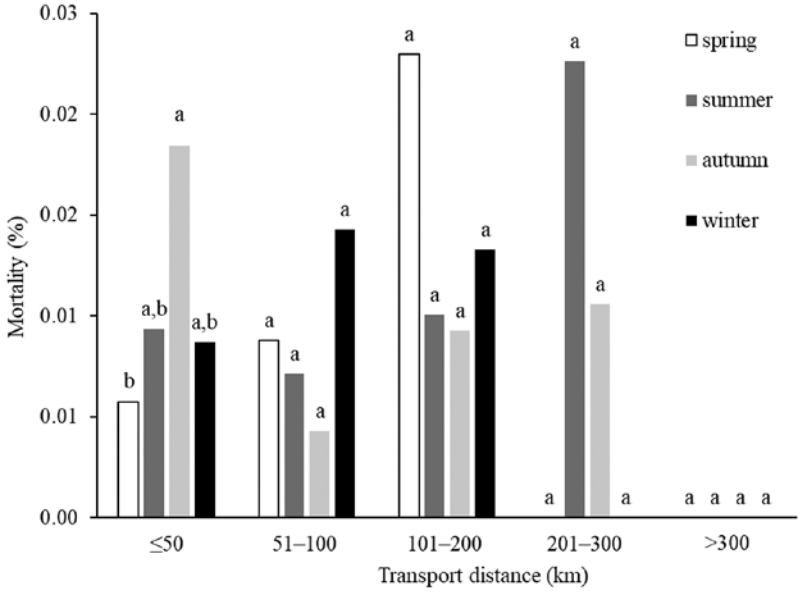

Fig. 5. Comparison of transport-related mortality of fattening cattle between seasons for the monitored transport distances

[a–b] Different letters above columns within the same transport distance indicate significant differences in mortality rates ($P < 0.05$)

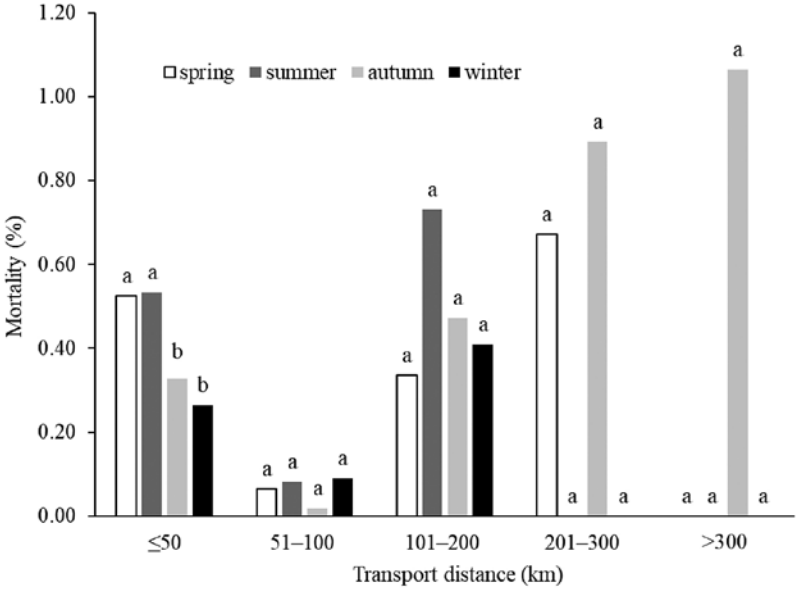

Fig. 6. Comparison of transport-related calf mortality between seasons for the monitored transport distances

[a–b] Different letters above columns within the same transport distance indicate significant differences in mortality rates ($P < 0.05$)

Discussion

This study investigated the influence of season and transport distance—as well as their possible interaction—on transport-related mortality in different categories of cattle (cows, heifers, fattening cattle, and calves) transported to slaughter. The results demonstrate that vulnerability during transport is not uniform across animal categories and is influenced by both environmental conditions and logistical factors.

A significant seasonal effect was observed in cows and calves, but not in heifers or fattening cattle. Mortality in cows was significantly higher in spring compared to summer, while calves had the highest mortality in summer, with significantly lower values in autumn and winter. These findings partially align with previous studies. Šímová et al. (2017) reported the highest transport-related mortality across all cattle categories during the spring, followed by summer for fattening cattle, heifers, and calves, and winter for cows. They suggested that reduced feed quality, weakened immunity after winter, and increased respiratory infections in spring could explain the higher mortality. The elevated mortality in cows during spring may also reflect delayed effects of poor winter housing, nutritional deficits, or immunosuppression during early lactation. Cull cows with pre-existing conditions are more likely to die during transport, become non-ambulatory, or require euthanasia upon arrival compared to healthy animals (Cockram 2019). In calves, the increased summer mortality may reflect an underestimation of heat stress risk and insufficient protective measures during transport. Although calves are generally more heat-tolerant than adult cattle – producing less metabolic heat and having more efficient heat dissipation – they are still susceptible to heat stress to some extent (Wang et al. 2020).

Transport distance significantly influenced mortality in cows and calves, but not consistently in heifers or fattening cattle. In cows, mortality increased with distance up to 300 km, after which it plateaued. This pattern may reflect cumulative transport stress up to a certain point, beyond which additional mitigation strategies (e.g., better equipment, improved ventilation, or stricter compliance with welfare regulations) may be in place for longer hauls. Better planning and compliance with welfare regulations during long-distance transport may be a response to earlier studies reporting increased mortality associated with long-haul journeys (e.g., Malena et al. 2006, 2007; Večerek et al. 2006a,b). In contrast, shorter transports may receive less logistical attention than longer journeys, as suggested by Šímová et al. (2017) and supported by the results of our study. In heifers, the highest mortality was observed at medium transport distances (51–100 km), with no clear linear trend. Likewise, calves transported over intermediate distances experienced significantly lower mortality, pointing to possible deficiencies in management of very short and long hauls. This may also indicate that very short transports involve animals in poorer condition (e.g., unsuitable for longer journeys), whereas longer transports may still expose calves to cumulative thermal and handling stress. Generally, it is not the duration of transport itself, but the associated negative factors that give rise to specific welfare issues (Miranda-de la Lama 2013).

A significant interaction between season and transport distance was detected only in cows, with the combination of winter and long-distance transport showing the highest mortality. Cold stress and long exposure times may have contributed to this outcome. Many cull cows sent for slaughter are thin with a low body condition score due to the energy demands of lactation (EFSA AHAW Panel 2022). While evidence linking low body condition score to poor transport outcomes is limited, thinness may reduce cold tolerance, increasing vulnerability during winter transport (Roche et al. 2009).

No synergistic effect was identified in heifers, fattening cattle, or calves. The absence of a clear synergistic interaction suggests that other factors, such as handling procedures or pre-transport health status, may play a more decisive role. Fattening cattle exhibited

consistently low mortality across both seasons and transport distances, with no significant trends observed. This relative resilience could be attributed to their younger age and better body condition (González et al. 2012; Schwartzkopf-Genswein et al. 2012). The lack of a seasonal or distance-related effect may also reflect more standardized transport practices in this category. Calves showed the highest overall transport-related mortality. The absence of a synergistic effect of season and distance may be due to variability in calf age, origin, or pre-transport care. In the Czech Republic, most calves sent to slaughter originate from the dairy industry and are often excluded from farms due to poor health or lack of fitness for further production. Impaired health in slaughtered calves was also documented by the prevalence of liver (Válková et al. 2023a), kidney (Válková et al. 2023b), lung (Válková et al. 2024a), and heart lesions (Válková et al. 2024b), recorded during postmortem inspection at the slaughterhouse. Compromised animals are more vulnerable to stress, improper handling, and suboptimal transport conditions, which may contribute to their higher mortality rates (Válková et al. 2022).

In conclusion, a synergistic effect of season and transport distance on cattle mortality during transport to slaughterhouses was demonstrated in the category of cows, with the combination of winter and the longest transport distance showing the highest mortality. In other categories, no synergistic effect of these two factors was observed. The findings provide important insights into species- and condition-specific vulnerabilities that can inform both transport practices and animal welfare regulations. Targeted interventions tailored to species, environmental conditions, and journey length are essential to improve animal welfare during transport.

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